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**NSRDS—NBS 35**  
**Volume II**  
**24Cr - 41Nb**



## **ATOMIC ENERGY LEVELS**

**As Derived From the Analyses  
of Optical Spectra**

**U.S.  
DEPARTMENT  
OF  
COMMERCE**

**National  
Bureau  
of  
Standards**



**Author's Note on the Reprinting of  
Atomic Energy Levels: Volume I, 1949; Volume II,  
1952; Volume III, 1958, Circular National Bureau of Standards 467**

Although twelve years have elapsed since the publication of Volume III, there is a continuing steady demand for these Volumes. The data they contain on atomic spectra cover all elements in the Periodic Table except the two groups of rare-earths: the lanthanides ( $Z = 58-71$ ) and the actinides ( $Z = 90-?$ ). Similar data for these spectra will be handled in a forthcoming Volume IV, now in course of preparation by W. C. Martin and his colleagues.

One of the rewarding aspects of these compilations has been the stimulation they have provided to further research on the analyses of atomic spectra. Gaps in the knowledge of spectra, and needs for investigation of additional spectra are immediately apparent in this comprehensive compendium.

Many additional spectra have been studied and numerous extended analyses have been published that supersede the material contained in Circular 467. A bibliography in the National Bureau of Standards Special Publication 306, Sections 1 to 4 (1968-1969), provides later reference material on individual spectra. It will be some years, however, before the entire set of Volumes will be superseded. The existing supply of these books is low. In order to meet the steady flow of requests, it has been decided to reissue the three Volumes as part of the National Standard Reference Data System. They are reprinted here as NSRDS-NBS 35, Volumes I, II, III.

The first Volume, issued in 1952, is in great demand, and more seriously in need of extensive revision than are the others. As new analyses appear for spectra of the lighter elements, the lists of revised energy levels, together with revised Multiplet Tables, are being published by the National Bureau of Standards under the title "Selected Tables of Atomic Spectra, Atomic Energy Levels and Multiplet Tables," as Sections of NSRDS-NBS 3. Section 1 contains these data for the spectra Si II, Si III, Si IV; Section 2 for Si I; Section 3 for C I, C II, C III, C IV, C V, C VI. Similar data on the nitrogen spectra of higher ionization will be presented in Section 4. A number of other spectra are partially completed for inclusion in this Series.

Wherever the individual spectra in Volume I have been revised and reported in the NSRDS-NBS 3 Series, indication of this fact is clearly stated for each spectrum, in this reprinted issue.† Readers are urged to use the revised material for the spectra thus marked and to take note of further revisions of selected spectra as they appear in this series.

Washington, D.C.  
November 30, 1970

Charlotte E. Moore

**Abstract**

**VOLUME II.  $^{24}\text{Cr}$  to  $^{41}\text{Nb}$**

This series of three volumes is a critical compilation of atomic energy levels prepared at the National Bureau of Standards from the analyses of optical spectra. Volume I contains data on the spectra of hydrogen, deuterium, tritium, helium, lithium, beryllium, boron, carbon, nitrogen, oxygen, fluorine, neon, sodium, magnesium, aluminum, silicon, phosphorus, sulfur, chlorine, argon, potassium, calcium, scandium, titanium, and vanadium ( $^1\text{H}$  to  $^{23}\text{V}$ ). Volume II covers the spectra of chromium, manganese, iron, cobalt, nickel, copper, zinc, gallium, germanium, arsenic, selenium, bromine, krypton, rubidium, strontium, yttrium, zirconium, and niobium ( $^{24}\text{Cr}$  to  $^{41}\text{Nb}$ ). Volume III includes the spectra of molybdenum, technetium, ruthenium, rhodium, palladium, silver, cadmium, indium, tin, antimony, tellurium, iodine, xenon, cesium, barium, lanthanum; hafnium, tantalum, tungsten, rhenium, osmium, iridium, platinum, gold, mercury, thallium, lead, bismuth, polonium, radon, radium, and actinium ( $^{42}\text{Mo}$  to  $^{57}\text{La}$ ;  $^{72}\text{Hf}$  to  $^{89}\text{Ac}$ ).

Key words: Energy levels; Cr-Nb.

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†EDITORIAL NOTE: See revision note on pages 21, 24, 26, 29, 30, 31, 144, 147, 148, and 150, Volume I.

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UNITED STATES DEPARTMENT OF COMMERCE • Maurice H. Stans, *Secretary*  
NATIONAL BUREAU OF STANDARDS • Lewis M. Branscomb, *Director*

# ATOMIC ENERGY LEVELS

As Derived From the Analyses of Optical Spectra

Volume II

The Spectra of Chromium, Manganese, Iron, Cobalt,  
Nickel, Copper, Zinc, Gallium, Germanium, Arsenic,  
Selenium, Bromine, Krypton, Rubidium, Strontium,  
Yttrium, Zirconium, and Niobium

BY CHARLOTTE E. MOORE



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## Preface

The present volume is the second of a series being prepared at the National Bureau of Standards as part of a general program on the compilation of atomic energy levels derived from analyses of optical spectra. Since the publication in 1932 of "*Atomic Energy States as Derived from the Analyses of Optical Spectra*" by Robert F. Bacher and Samuel Goudsmit, the data on atomic spectra have accumulated in sufficient quantity to fill several volumes.

The first volume appeared in print June 15, 1949. That work contains the energy levels of 206 spectra of the first 23 elements, Hydrogen through Vanadium. The present volume includes similar data for 152 spectra of the elements having atomic numbers 24 through 41, Chromium through Niobium. The date of completion of the manuscript for each spectrum is entered at the end of the separate tables of energy levels. At present, structure is recognized in more than 500 spectra of 85 elements, so the program is still far from completion.

The general arrangement of Volumes I and II is identical. The adopted form of presentation is that recommended by the majority of interested workers who received a questionnaire proposed by the National Research Council Committee on Line Spectra of the Elements.

The manuscript has been prepared by Charlotte E. Moore under the direction of William F. Meggers, Chief of the Spectroscopy Section of the Atomic and Radiation Physics Division. A number of important gaps among the spectra of elements 24 to 41 have been filled, owing to the efforts of many spectroscopists to furnish data in advance of publication. The cordial cooperation of these individuals as well as that of National Research Council Committee as a whole, is greatly appreciated. This program was initiated while E. U. Condon was Director of the Bureau, and the present Volume was practically completed during his tenure.

A. V. ASTIN, *Director*.

WASHINGTON, D. C., June 30, 1952.

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## 1. Introduction

The present work is a continuation of a project started in 1946 at the National Bureau of Standards. Because Bacher and Goudsmit did not contemplate revising their extremely useful book on "*Atomic Energy States as Derived from the Analyses of Optical Spectra*" published in 1932, it was decided to prepare a critical compendium of Atomic

Energy Levels, in the Spectroscopy Section of this Bureau. The National Research Council Committee on Line Spectra of the Elements met at that time to discuss details, and this Committee has continued its enthusiastic support of the program.

## 2. Scope of the Present Tables

Requests to extend the scope of the tables are still being received. A critical compilation of data on X-ray spectra is needed.

No attempt has been made here to include data on hyperfine structure ascribed to atomic nuclei, except for H, D, and T. In Volume II reference is made under the individual spectra to the bibliography on this subject by Mack.<sup>1</sup> The earlier bibliography by Meggers<sup>2</sup> was mentioned in the references to relevant spectra in Volume I. In addition, selected papers are listed for a few spectra, particularly if they are not included in these two references summarizing hyperfine structure data. The present Volumes are, however, definitely not adequate for serious workers in this field.

Since the present tables include only the atomic energy levels derived from the analyses of optical spectra, the users must consult the separate references for lists of the lines observed in the various spectra, for line intensities, and for line classifications. To simplify this situation

the writer is preparing an "Ultraviolet Multiplet Table"<sup>3</sup> of selected spectra, along with the tabulation of energy levels. For each Volume of Atomic Energy Levels (called AEL for brevity) there is a corresponding Section of the Ultraviolet Multiplet Table (abbreviated as UVMT in the text that follows). For example, Volume I (AEL) contains the energy levels of spectra of elements with atomic numbers 1 to 23, i. e., Hydrogen through Vanadium. Section 1 of the UVMT contains selected multiplets from spectra of these same elements. Similarly, just as the present Volume (AEL) covers the range of elements of atomic numbers 24 through 41, so will Section 2 of the UVMT contain multiplets of spectra of these same elements.

The UVMT, together with the "Revised Multiplet Table"<sup>4</sup> (which is limited to lines of wavelength longer than 3000 Å), will to some extent fulfill the requests for tables of leading lines of selected spectra to accompany the energy levels.

## 3. Arrangement

The Introduction to Volume I (AEL) describes in detail the arrangement of the data, the notation, and the columns of the tables. Since Volume II is arranged in exactly the same style, the description need not be repeated here.† For convenience, the meaning of the letters in parentheses following the literature references is, however, repeated. These letters denote the following:

I P      Ionization potential.  
T      Terms.

C L      Classified lines.  
G D      Grotrian diagram.  
Z E      Zeeman effect.  
I S      Isotope shift.  
hfs      Hyperfine structure.

Briefly stated, these letters describe the scope and content of the paper in question. If no letters follow a reference, the paper is referred to in the remarks on the individual spectrum. For example, this is generally true of theoretical papers.

<sup>1</sup> J. E. Mack, *Rev. Mod. Phys.* **22**, No. 1, 64-76 (1950).

<sup>2</sup> W. F. Meggers, *J. Opt. Soc. Am.* **36**, 431 (1946).

† One minor change has been introduced for technical reasons. In Volume I the inner quantum number  $J=\frac{1}{2}$  is entered as " $\frac{1}{2}$ ." In successive volumes this quantity is entered as " $0\frac{1}{2}$ " throughout.

<sup>3</sup> C. E. Moore, *Circ. Nat. Bur. Std.* **488**; Section 1, H to V (1950); Section 2, Cr to Nb, in press (1952).

<sup>4</sup> C. E. Moore, *Princeton Univ. Obs. Contr. No.* **20** (1945).



## 4. Tables of Predicted and Observed Arrays of Terms

As in Volume I, arrays of observed terms follow the individual tables of energy levels for the more complex spectra in cases where the analysis is not seriously in-

complete. Similar arrays of terms predicted from theory for spectra of the different isoelectronic sequences are included in Tables 1 to 17 (pages XII to XXVII) as follows:

Table	Sequence	Table	Sequence	Table	Sequence
1	Cr I	7	Zn I	13	Kr I
2	Mn I	8	Ga I	14	Sr I
3	Fe I	9	Ge I	15	Y I
4	Co I	10	As I	16	Zr I
5	Ni I	11	Se I	17	Nb I
6	Cu I	12	Br I		

These tables follow exactly the same pattern as was used for the sequences in Volume I.

For the Kr I sequence, as for Ne I and Ar I, the table gives both predicted terms (*LS*-coupling) and predicted pairs of levels (*jl*-coupling). The spectra of the inert-gas type have an interesting history. Meissner in 1919<sup>5</sup> pointed out that well known series in Ne I converge to different limits. In the present notation, the separate limits, representing the two components of the limit term

<sup>5</sup> K. W. Meissner, Ann. der Phys. [4] 58, 356 (1919).

of the ion are clearly indicated. The pair-coupling notation in the general form suggested by Racah has been adopted<sup>6</sup> on the recommendation of Edlén, to take into account the departure from *LS*-coupling. Shortley has prepared an array of the theoretical arrangement of the pairs, for the writer to use as a guide in listing the energy levels of spectra of this type. This is discussed in Volume I. The Paschen notation is also retained in the table of levels of Kr I.

<sup>6</sup> G. Racah, Phys. Rev. 61, 537 (L) (1942).

## 5. The Periodic Table

### 5.1 The Chemical Elements by Atomic Number; Ionization Potentials (Table 18)

In Volume I, Table 23, the ionization potentials and ground states were recorded for the first spectra throughout the periodic table. Some revisions of these data are given at the end of Volume II. Further revisions have resulted during the course of the work on Volume II. All ionization potentials in both Volumes as revised to date are entered in Table 18. Column one gives the atomic number *Z*; column two the chemical symbol of the element. Successive columns contain the ionization potentials of the atoms or ions in successive stages of ionization, I denoting first spectra (neutral atoms); II, second spectra (singly ionized atoms); etc.

Throughout these Volumes the ionization potentials

are derived by multiplying the limit in cm<sup>-1</sup> by the factor 0.00012395, to express it in electron volts. This factor was recommended by Birge in 1941 (See Volume I, page IX.)

### 5.2 The Chemical Elements by Chemical Symbol (Table 19)

In Table 24 of Volume I the chemical elements were arranged in alphabetical order of their chemical symbols to facilitate cross reference to the book by Bacher and Goudsmit, "Atomic Energy States." This table is repeated in Volume II as Table 19, with elements 97 (Bk)<sup>7</sup> and 98 (Cf)<sup>8</sup> added, together with the changes recently adopted by the International Union of Chemistry.<sup>9</sup> The additions and corrections are as follows:

Older			Corrected		
Symbol	Element	<i>Z</i>	Symbol	Element	<i>Z</i>
-----	-----		Bk	Berkelium	97
-----	-----		Cf	Californium	98
Fa	Francium	87	Fr	Francium	87
Lu	Lutecium	71	Lu	Lutetium	71
Cb	Columbium	41	Nb	Niobium	41
Pm	Prometheum	61	Pm	Promethium	61
W	Tungsten	74	W	Wolfram	74

<sup>7</sup> S. G. Thompson, A. Ghiorso, and G. T. Seaborg, Phys. Rev. 77, 838 (L) (1950).

<sup>8</sup> S. G. Thompson, K. Street, Jr., A. Ghiorso, and G. T. Seaborg, Phys. Rev. 80, 790 (1950).

<sup>9</sup> See Report by E. Wichers, J. Am. Chem. Soc. 72, No. 4, 1431 (1950).



### 5.3 The Periodic System (Table 20)

For convenience, the Periodic System as given on page XLII of Volume I is repeated here as Table 20. Three changes have been made: The chemical symbol of element 41, formerly Cb is now Nb; elements 97 (Bk), and 98 (Cf) are added. The general arrangement is similar to that given on page 333 of "*The Theory of Atomic Spectra*" by Condon and Shortley.<sup>10</sup>

### 5.4 Index—Isoelectronic Sequences (Table 21)

This table contains the index to the data in Volume II, i. e., the spectra from Cr through Nb. The arrangement is identical with that of the corresponding Index, Table 26, in Volume I.

Column 1 contains the atomic number, followed by the chemical symbol. Across the top the successive stages of ionization are indicated, I denoting first spectra (neutral atoms), II second spectra (singly ionized atoms), III third spectra, etc. The numbers indicate the page on

<sup>10</sup> E. U. Condon and G. H. Shortley, *The Theory of Atomic Spectra*, (The Macmillan Co., New York, N. Y., The University Press, Cambridge, Eng., Corrected edition, 1951).

which the data for the individual spectra may be found.

In this table, isoelectronic spectra appear on the diagonals. Alternate diagonals are printed in bold face type to emphasize the spectra of each sequence. Blanks occur for spectra in which structure has not yet been recognized.

No sequences are carried beyond Nb in this Volume, but they will be continued in later Volumes for spectra of elements with  $Z > 41$ . The sequences started but not completed in Volume II are as follows:

Sequence	Spectrum
Co I	Mo XVI, Pd XX—Sn XXIV
Cu I	Pd XVII—Sb XXIII
Br I	Mo VIII
Kr I	Mo VII
Rb I	Mo VI
Sr I	Mo V
Y I	Mo IV
Zr I	Mo III
Nb I	Mo II

## 6. Acknowledgments

It was stated in the Introduction to Volume I that "Many scientific workers and many institutions at home and abroad are represented in this work." The same comment applies emphatically to Volume II. The inspiration to carry on such a project may be attributed directly to the large number of interested workers who have been supporting this program. At the National Bureau of Standards, E. U. Condon, during his tenure as Director, took a keen personal interest in the entire project. W. F. Meggers, Chief of the Spectroscopy Section, and Chairman of the Committee on Line Spectra, has spared no effort in giving expert advice on all difficult problems. He has carefully supervised the work and provided much spectroscopic material for inclusion here. Similarly, C. C. Kiess has arranged his entire schedule of work to meet the demands of this program. His splendid analyses of the very complex spectra Cr I and Cr II are lasting tributes illustrative of his interest in the work. The infrared observations of atomic spectra by C. J. Humphreys, Chief of the Infrared Spectroscopy Section, have already added important data, and promise to yield much more in the near future.

The writer has also received most valuable assistance from Princeton. H. N. Russell has been an active and interested consultant. Reference has been made to his work on binding energies, and in addition, he has read most of the manuscript. A. G. Shenstone has not only placed on his program the spectra most urgently needed to fill serious gaps in this Volume, but has also stimulated similar programs in other laboratories. For example, the third spectra of the elements Mn to Cu would have been seriously incomplete without his collaboration.

Three other members of the Committee on Line Spectra have also responded generously. J. E. Mack has provided unpublished data on Rb I. G. R. Harrison has supplied a number of workers with plates and films of Zeeman patterns observed at the Massachusetts Institute of Technology. W. E. Albertson has discussed some of the future problems, particularly in regard to rare earth spectra.

The international cooperation has also been gratifying. Edlén has read a large part of the manuscript, contributed valuable suggestions on a number of spectra in the iron group, and furnished unpublished data on high ionization spectra of the elements from Se through Zr, as well as on Kr I. M. A. Catalán has made two visits

to the United States in the interest of this program. His extensive work on Mn I and his study of the Mn III spectrum represent only a part of his contributions. Through the cordial collaboration of Harrison, Meggers, and Shenstone, he has also secured enough material to enable him and his staff in Madrid to continue this work.

Other analyses have been carried out especially for inclusion here. At Lehigh University C. W. Curtis has made an extensive study of Mn II, and N. E. Hager Jr., is extending the analysis of Co II. At Dartmouth and Cornell, F. L. Moore, Jr., has continued work on Cr III and Cr IV and expects to start Mn IV soon—all done in collaboration with Shenstone. Miss Dorothy W. Weeks of Wilson College, has furnished  $g$ -values for a number of spectra, with the aid of films from Harrison's laboratory. Unpublished material has also been received from R. A. Fisher (Fe I), S. Glad (Fe III), C. W. Gartlein (Ge II, As II), K. W. Meissner, K. L. Andrew (Ge I, Ge II), and F. W. Paul (Kr IX). Miss Olga García-Riquelme in Madrid (Mn); and L. Wilets (Cu III) and L. E. Gibson (Zn II), in Princeton, have also assisted.

The American Philosophical Society and the American Academy of Arts and Sciences have granted funds for work in connection with this program.

The users of this book owe a debt of gratitude to every one of these individuals and institutions for the material recorded in advance of publication.

The writer could never have prepared these Volumes without the services of experts in many fields of activity. Miss Sarah A. Jones, the Librarian at the Bureau, and her staff have continued their competent assistance with the many literature references. J. L. Mathusa and his staff in the Publications Section of the Bureau, have handled the difficult problems entailed in publishing this material with skill that has attracted the attention of many users. The personnel in the Government Printing Office have been equally cooperative. Mrs. Isabel D. Murray has provided much technical assistance in the preparation of the manuscript. Mrs. Marion W. Maddox has carefully typed the text accompanying the separate spectra.

The writer enjoys a lasting pleasure in recalling and recording the generous assistance she has received from all who have so willingly contributed to this compilation of Atomic Energy Levels.

## **Tables**

Predicted Terms Cr I to Nb I

Ionization Potentials

The Periodic System

Index—Isoelectronic Sequence







$3d^2(^1P)nx$	{	$^6F$ $^3F$		$^6D^o$ $^3D^o$	$^6F^o$ $^3F^o$	$^6G^o$ $^3G^o$	$^6P$ $^3P$	$^6D$ $^3D$	$^6F$ $^3F$	$^6G$ $^3G$	$^6H$ $^3H$	.....
$3d^4 4s(^4G)nx$	{		$^6G$ $^3G$		$^6F^o$ $^3F^o$	$^6G^o$ $^3G^o$		$^6D$ $^3D$	$^6F$ $^3F$	$^6G$ $^3G$	$^6I$ $^3I$	.....
$3d^4 4s(^2H)nx$	{		$^3H$ $^1H$			$^3G^o$ $^1G^o$			$^3F$ $^1F$	$^3G$ $^1G$	$^3I$ $^1I$	.....
$3d^4 4s(^2P)nx$	{	$^3P$ $^1P$		$^3S^o$ $^1S^o$	$^3D^o$ $^1D^o$			$^3P$ $^1P$	$^3D$ $^1D$			.....
$3d^6(^2F)nx$	{				$^3D^o$ $^1D^o$	$^3F^o$ $^1F^o$		$^3P$ $^1P$	$^3D$ $^1D$	$^3F$ $^1F$	$^3H$ $^1H$	.....
$3d^6(^2H)nx$	{		$^3H$ $^1H$			$^3G^o$ $^1G^o$					$^3K$ $^1K$	.....
$3d^4 4s(^2G)nx$	{		$^3G$ $^1G$		$^3F^o$ $^1F^o$	$^3G^o$ $^1G^o$			$^3D$ $^1D$	$^3F$ $^1F$	$^3I$ $^1I$	.....
$3d^4 4s(^4D)nx$	{	$^5D$ $^3D$			$^5D^o$ $^3D^o$	$^5F^o$ $^3F^o$	$^5S$ $^3S$	$^5P$ $^3P$	$^5D$ $^3D$	$^5F$ $^3F$	$^5G$ $^3G$	.....
$3d^6(^2G)nx$	{		$^3G$ $^1G$		$^3F^o$ $^1F^o$	$^3G^o$ $^1G^o$			$^3D$ $^1D$	$^3F$ $^1F$	$^3H$ $^1H$	.....
$3d^4 4s(^2G)nx$	{		$^3G$ $^1G$		$^3F^o$ $^1F^o$	$^3G^o$ $^1G^o$			$^3D$ $^1D$	$^3F$ $^1F$	$^3H$ $^1H$	.....
$3d^4 4s(^2F)nx$	{				$^3D^o$ $^1D^o$	$^3F^o$ $^1F^o$		$^3P$ $^1P$	$^3D$ $^1D$	$^3F$ $^1F$	$^3H$ $^1H$	.....
$3d^4 4s(^2I)nx$	{		$^3I$ $^1I$			$^3H^o$ $^1H^o$				$^3G$ $^1G$	$^3K$ $^1K$	.....
$3d^6(^2S)nx$	$^3S$ $^1S$			$^3P^o$ $^1P^o$				$^3D$ $^1D$				.....
$3d^4 4s(^2D)nx$	{	$^3D$ $^1D$		$^3P^o$ $^1P^o$	$^3D^o$ $^1D^o$	$^3F^o$ $^1F^o$	$^3S$ $^1S$	$^3P$ $^1P$	$^3D$ $^1D$	$^3F$ $^1F$	$^3G$ $^1G$	.....
$3d^4 4s(^2S)nx$	$^3S$ $^1S$			$^3P^o$ $^1P^o$				$^3D$ $^1D$				.....
$3d^6(^2D)n$	{	$^3D$ $^1D$		$^3P^o$ $^1P^o$	$^3D^o$ $^1D^o$	$^3F^o$ $^1F^o$	$^3S$ $^1S$	$^3P$ $^1P$	$^3D$ $^1D$	$^3F$ $^1F$	$^3G$ $^1G$	.....
$3d^4 4s(^2D)nx$	{			$^3P^o$ $^1P^o$	$^3D^o$ $^1D^o$	$^3F^o$ $^1F^o$	$^3S$ $^1S$	$^3P$ $^1P$	$^3D$ $^1D$	$^3F$ $^1F$	$^3G$ $^1G$	.....
$3d^4 4s(^2F)nx$	{	$^3F$ $^1F$			$^3D^o$ $^1D^o$	$^3F^o$ $^1F^o$		$^3P$ $^1P$	$^3D$ $^1D$	$^3F$ $^1F$	$^3H$ $^1H$	.....
$3d^6(^2G)nx$	{		$^3G$ $^1G$		$^3F^o$ $^1F^o$	$^3G^o$ $^1G^o$			$^3D$ $^1D$	$^3F$ $^1F$	$^3H$ $^1H$	.....

TABLE 2. PREDICTED TERMS OF THE Mn I ISOELECTRONIC SEQUENCE\*

Config. $1s^2 2s^2 2p^6 3s^2 3p^6 +$	Predicted Terms			
	$ns (n \geq 4)$	$np (n \geq 4)$	$nd (n \geq 4)$	
$3d^5 4s^2$	$\left\{ \begin{array}{l} {}^6S \\ {}^2S \end{array} \right.$	$\begin{array}{l} {}^4P \\ {}^2P \end{array}$	$\begin{array}{l} {}^4D \\ {}^2D \\ {}^2D \\ {}^2D \end{array}$	$\begin{array}{l} {}^4G \\ {}^2G \\ {}^2G \\ {}^2G \end{array}$
$3d^7$	$\left\{ \begin{array}{l} {}^4P \\ {}^2P \end{array} \right.$	$\begin{array}{l} {}^4F \\ {}^2F \end{array}$	$\begin{array}{l} {}^4D \\ {}^2D \\ {}^2D \end{array}$	$\begin{array}{l} {}^4H \\ {}^2G \\ {}^2H \end{array}$
$3d^5 4p^2 \dagger$	$\left\{ \begin{array}{l} {}^6S \\ {}^6P \\ {}^4P \end{array} \right.$		$\begin{array}{l} {}^6D \end{array}$	
$3d^5 4s({}^6S)nz$	$\left\{ \begin{array}{l} {}^6S \\ {}^6S \end{array} \right.$	$\begin{array}{l} {}^8P^o \\ {}^6P^o \end{array}$		$\begin{array}{l} {}^8D \\ {}^6D \end{array}$
$3d^5 4s({}^6S)nz$	$\left\{ \begin{array}{l} {}^6S \\ {}^4S \end{array} \right.$	$\begin{array}{l} {}^6P^o \\ {}^4P^o \end{array}$		$\begin{array}{l} {}^6D \\ {}^4D \end{array}$
$3d^5 ({}^6D)nz$	$\left\{ \begin{array}{l} {}^6D \\ {}^4D \end{array} \right.$	$\begin{array}{l} {}^6D^o \\ {}^4D^o \end{array}$		$\begin{array}{l} {}^6F \\ {}^4F \end{array}$
$3d^5 4s({}^6G)nz$	$\left\{ \begin{array}{l} {}^6G \\ {}^4G \end{array} \right.$	$\begin{array}{l} {}^6F^o \\ {}^4F^o \end{array}$		$\begin{array}{l} {}^6G \\ {}^4G \end{array}$
$3d^5 4s({}^6P)nz$	$\left\{ \begin{array}{l} {}^6P \\ {}^4P \end{array} \right.$	$\begin{array}{l} {}^6D^o \\ {}^4D^o \end{array}$		$\begin{array}{l} {}^6D \\ {}^4D \end{array}$
$3d^5 4s({}^6D)nz$	$\left\{ \begin{array}{l} {}^6D \\ {}^4D \end{array} \right.$	$\begin{array}{l} {}^6D^o \\ {}^4D^o \end{array}$		$\begin{array}{l} {}^6F \\ {}^4F \end{array}$
$3d^5 4s({}^6G)nz$	$\left\{ \begin{array}{l} {}^6G \\ {}^4G \end{array} \right.$	$\begin{array}{l} {}^6F^o \\ {}^4F^o \end{array}$		$\begin{array}{l} {}^6G \\ {}^4G \end{array}$
$3d^5 4s({}^6P)nz$	$\left\{ \begin{array}{l} {}^6P \\ {}^4P \end{array} \right.$	$\begin{array}{l} {}^6D^o \\ {}^4D^o \end{array}$		$\begin{array}{l} {}^6D \\ {}^4D \end{array}$
$3d^5 4s({}^6D)nz$	$\left\{ \begin{array}{l} {}^6D \\ {}^4D \end{array} \right.$	$\begin{array}{l} {}^6D^o \\ {}^4D^o \end{array}$		$\begin{array}{l} {}^6F \\ {}^4F \end{array}$
$3d^5 4s({}^6F)nz$	$\left\{ \begin{array}{l} {}^6F \\ {}^4F \end{array} \right.$	$\begin{array}{l} {}^6D^o \\ {}^4D^o \end{array}$		$\begin{array}{l} {}^6G \\ {}^4G \end{array}$



TABLE 3. PREDICTED TERMS OF THE Fe I ISOELECTRONIC SEQUENCE

Config. 1s <sup>2</sup> 2s <sup>2</sup> 2p <sup>6</sup> 3s <sup>2</sup> 3p <sup>6</sup> +	Predicted Terms										
3d <sup>6</sup> 4s <sup>2</sup>	{ <div><div><div><div><sup>3</sup>P</div><div><sup>5</sup>D</div></div><div><div><sup>3</sup>D</div><div><sup>3</sup>F</div></div><div><div><sup>3</sup>G</div><div><sup>3</sup>H</div></div></div><div><div><sup>3</sup>P</div><div><sup>3</sup>F</div></div></div> <div><div><div><sup>1</sup>S</div><div><sup>1</sup>D</div></div><div><div><sup>1</sup>F</div><div><sup>1</sup>G</div></div><div><div><sup>1</sup>G</div><div><sup>1</sup>I</div></div></div> <div><div><sup>1</sup>S</div><div><sup>1</sup>D</div></div> <div><div><sup>1</sup>G</div></div>										
3d <sup>8</sup>	{ <div><div><div><sup>3</sup>P</div><div><sup>1</sup>D</div></div><div><div><sup>3</sup>F</div><div><sup>1</sup>G</div></div></div> <div><div><sup>1</sup>S</div></div>										
	ns (n ≥ 4)		np (n ≥ 4)				nd (n ≥ 4)				.....
3d <sup>6</sup> 4s( <sup>6</sup> D) nx	{ <div><div><sup>7</sup>D</div><div><sup>5</sup>D</div></div>		{ <div><div><div><sup>7</sup>P°</div><div><sup>7</sup>D°</div><div><sup>7</sup>F°</div></div><div><div><sup>5</sup>P°</div><div><sup>5</sup>D°</div><div><sup>5</sup>F°</div></div></div>				{ <div><div><div><sup>7</sup>S</div><div><sup>7</sup>P</div><div><sup>7</sup>D</div><div><sup>7</sup>F</div><div><sup>7</sup>G</div></div><div><div><sup>5</sup>S</div><div><sup>5</sup>P</div><div><sup>5</sup>D</div><div><sup>5</sup>F</div><div><sup>5</sup>G</div></div></div>				..... .....
3d <sup>7</sup> ( <sup>4</sup> F) nx	{ <div><div><div><sup>5</sup>F</div><div><sup>3</sup>F</div></div></div>		{ <div><div><div><sup>5</sup>D°</div><div><sup>5</sup>F°</div><div><sup>5</sup>G°</div></div><div><div><sup>3</sup>D°</div><div><sup>3</sup>F°</div><div><sup>3</sup>G°</div></div></div>				{ <div><div><div><sup>5</sup>P</div><div><sup>5</sup>D</div><div><sup>5</sup>F</div><div><sup>5</sup>G</div><div><sup>5</sup>H</div></div><div><div><sup>3</sup>P</div><div><sup>3</sup>D</div><div><sup>3</sup>F</div><div><sup>3</sup>G</div><div><sup>3</sup>H</div></div></div>				..... .....
3d <sup>6</sup> 4s( <sup>4</sup> D) nx	{ <div><div><div><sup>5</sup>D</div><div><sup>3</sup>D</div></div></div>		{ <div><div><div><sup>5</sup>P°</div><div><sup>5</sup>D°</div><div><sup>5</sup>F°</div></div><div><div><sup>3</sup>P°</div><div><sup>3</sup>D°</div><div><sup>3</sup>F°</div></div></div>				{ <div><div><div><sup>5</sup>S</div><div><sup>5</sup>P</div><div><sup>5</sup>D</div><div><sup>5</sup>F</div><div><sup>5</sup>G</div></div><div><div><sup>3</sup>S</div><div><sup>3</sup>P</div><div><sup>3</sup>D</div><div><sup>3</sup>F</div><div><sup>3</sup>G</div></div></div>				..... .....
3d <sup>7</sup> ( <sup>4</sup> P) nx	{ <div><div><div><sup>5</sup>P</div><div><sup>3</sup>P</div></div></div>		{ <div><div><div><sup>5</sup>S°</div><div><sup>5</sup>P°</div><div><sup>5</sup>D°</div></div><div><div><sup>3</sup>S°</div><div><sup>3</sup>P°</div><div><sup>3</sup>D°</div></div></div>				{ <div><div><div><sup>5</sup>P</div><div><sup>5</sup>D</div><div><sup>5</sup>F</div></div><div><div><sup>3</sup>P</div><div><sup>3</sup>D</div><div><sup>3</sup>F</div></div></div>				..... .....
3d <sup>7</sup> ( <sup>2</sup> G) nx	{ <div><div><div><sup>3</sup>G</div><div><sup>1</sup>G</div></div></div>		{ <div><div><div><sup>3</sup>F°</div><div><sup>3</sup>G°</div><div><sup>3</sup>H°</div></div><div><div><sup>1</sup>F°</div><div><sup>1</sup>G°</div><div><sup>1</sup>H°</div></div></div>				{ <div><div><div><sup>3</sup>D</div><div><sup>3</sup>F</div><div><sup>3</sup>G</div><div><sup>3</sup>H</div><div><sup>3</sup>I</div></div><div><div><sup>1</sup>D</div><div><sup>1</sup>F</div><div><sup>1</sup>G</div><div><sup>1</sup>H</div><div><sup>1</sup>I</div></div></div>				..... .....
3d <sup>7</sup> ( <sup>2</sup> P) nx	{ <div><div><div><sup>3</sup>P</div><div><sup>1</sup>P</div></div></div>		{ <div><div><div><sup>3</sup>S°</div><div><sup>3</sup>P°</div><div><sup>3</sup>D°</div></div><div><div><sup>1</sup>S°</div><div><sup>1</sup>P°</div><div><sup>1</sup>D°</div></div></div>				{ <div><div><div><sup>3</sup>P</div><div><sup>3</sup>D</div><div><sup>3</sup>F</div></div><div><div><sup>1</sup>P</div><div><sup>1</sup>D</div><div><sup>1</sup>F</div></div></div>				..... .....
3d <sup>7</sup> ( <sup>2</sup> H) nx	{ <div><div><div><sup>3</sup>H</div><div><sup>1</sup>H</div></div></div>		{ <div><div><div><sup>3</sup>G°</div><div><sup>3</sup>H°</div><div><sup>3</sup>I°</div></div><div><div><sup>1</sup>G°</div><div><sup>1</sup>H°</div><div><sup>1</sup>I°</div></div></div>				{ <div><div><div><sup>3</sup>F</div><div><sup>3</sup>G</div><div><sup>3</sup>H</div><div><sup>3</sup>I</div><div><sup>3</sup>K</div></div><div><div><sup>1</sup>F</div><div><sup>1</sup>G</div><div><sup>1</sup>H</div><div><sup>1</sup>I</div><div><sup>1</sup>K</div></div></div>				..... .....
3d <sup>7</sup> ( <sup>2</sup> D) nx	{ <div><div><div><sup>3</sup>D</div><div><sup>1</sup>D</div></div></div>		{ <div><div><div><sup>3</sup>P°</div><div><sup>3</sup>D°</div><div><sup>3</sup>F°</div></div><div><div><sup>1</sup>P°</div><div><sup>1</sup>D°</div><div><sup>1</sup>F°</div></div></div>				{ <div><div><div><sup>3</sup>S</div><div><sup>3</sup>P</div><div><sup>3</sup>D</div><div><sup>3</sup>F</div><div><sup>3</sup>G</div></div><div><div><sup>1</sup>S</div><div><sup>1</sup>P</div><div><sup>1</sup>D</div><div><sup>1</sup>F</div><div><sup>1</sup>G</div></div></div>				..... .....
3d <sup>6</sup> 4s( <sup>4</sup> P) nx	{ <div><div><div><sup>5</sup>P</div><div><sup>3</sup>P</div></div></div>		{ <div><div><div><sup>5</sup>S°</div><div><sup>5</sup>P°</div><div><sup>5</sup>D°</div></div><div><div><sup>3</sup>S°</div><div><sup>3</sup>P°</div><div><sup>3</sup>D°</div></div></div>				{ <div><div><div><sup>5</sup>P</div><div><sup>5</sup>D</div><div><sup>5</sup>F</div></div><div><div><sup>3</sup>P</div><div><sup>3</sup>D</div><div><sup>3</sup>F</div></div></div>				..... .....
3d <sup>6</sup> 4s( <sup>4</sup> H) nx	{ <div><div><div><sup>5</sup>H</div><div><sup>3</sup>H</div></div></div>		{ <div><div><div><sup>5</sup>G°</div><div><sup>5</sup>H°</div><div><sup>5</sup>I°</div></div><div><div><sup>3</sup>G°</div><div><sup>3</sup>H°</div><div><sup>3</sup>I°</div></div></div>				{ <div><div><div><sup>5</sup>F</div><div><sup>5</sup>G</div><div><sup>5</sup>H</div><div><sup>5</sup>I</div><div><sup>5</sup>K</div></div><div><div><sup>3</sup>F</div><div><sup>3</sup>G</div><div><sup>3</sup>H</div><div><sup>3</sup>I</div><div><sup>3</sup>K</div></div></div>				..... .....
3d <sup>6</sup> 4s( <sup>4</sup> F) nx	{ <div><div><div><sup>5</sup>F</div><div><sup>3</sup>F</div></div></div>		{ <div><div><div><sup>5</sup>D°</div><div><sup>5</sup>F°</div><div><sup>5</sup>G°</div></div><div><div><sup>3</sup>D°</div><div><sup>3</sup>F°</div><div><sup>3</sup>G°</div></div></div>				{ <div><div><div><sup>5</sup>P</div><div><sup>5</sup>D</div><div><sup>5</sup>F</div><div><sup>5</sup>G</div><div><sup>5</sup>H</div></div><div><div><sup>3</sup>P</div><div><sup>3</sup>D</div><div><sup>3</sup>F</div><div><sup>3</sup>G</div><div><sup>3</sup>H</div></div></div>				..... .....
3d <sup>5</sup> 4s <sup>2</sup> ( <sup>4</sup> S) nx	{ <div><div><div><sup>7</sup>S</div><div><sup>5</sup>S</div></div></div>		{ <div><div><div><sup>7</sup>P°</div><div><sup>5</sup>P°</div></div></div>				{ <div><div><div><sup>7</sup>D</div><div><sup>5</sup>D</div></div></div>				..... .....
3d <sup>6</sup> 4s( <sup>4</sup> G) nx	{ <div><div><div><sup>5</sup>G</div><div><sup>3</sup>G</div></div></div>		{ <div><div><div><sup>5</sup>F°</div><div><sup>5</sup>G°</div><div><sup>5</sup>H°</div></div><div><div><sup>3</sup>F°</div><div><sup>3</sup>G°</div><div><sup>3</sup>H°</div></div></div>				{ <div><div><div><sup>5</sup>D</div><div><sup>5</sup>F</div><div><sup>5</sup>G</div><div><sup>5</sup>H</div><div><sup>5</sup>I</div></div><div><div><sup>3</sup>D</div><div><sup>3</sup>F</div><div><sup>3</sup>G</div><div><sup>3</sup>H</div><div><sup>3</sup>I</div></div></div>				..... .....
3d <sup>6</sup> 4s( <sup>2</sup> P) nx	{ <div><div><div><sup>3</sup>P</div><div><sup>1</sup>P</div></div></div>		{ <div><div><div><sup>3</sup>S°</div><div><sup>3</sup>P°</div><div><sup>3</sup>D°</div></div><div><div><sup>1</sup>S°</div><div><sup>1</sup>P°</div><div><sup>1</sup>D°</div></div></div>				{ <div><div><div><sup>3</sup>P</div><div><sup>3</sup>D</div><div><sup>3</sup>F</div></div><div><div><sup>1</sup>P</div><div><sup>1</sup>D</div><div><sup>1</sup>F</div></div></div>				..... .....
3d <sup>6</sup> 4s( <sup>2</sup> H) nx	{ <div><div><div><sup>3</sup>H</div><div><sup>1</sup>H</div></div></div>		{ <div><div><div><sup>3</sup>G°</div><div><sup>3</sup>H°</div><div><sup>3</sup>I°</div></div><div><div><sup>1</sup>G°</div><div><sup>1</sup>H°</div><div><sup>1</sup>I°</div></div></div>				{ <div><div><div><sup>3</sup>F</div><div><sup>3</sup>G</div><div><sup>3</sup>H</div><div><sup>3</sup>I</div><div><sup>3</sup>K</div></div><div><div><sup>1</sup>F</div><div><sup>1</sup>G</div><div><sup>1</sup>H</div><div><sup>1</sup>I</div><div><sup>1</sup>K</div></div></div>				..... .....
3d <sup>6</sup> 4s( <sup>2</sup> F) nx	{ <div><div><div><sup>3</sup>F</div><div><sup>1</sup>F</div></div></div>		{ <div><div><div><sup>3</sup>D°</div><div><sup>3</sup>F°</div><div><sup>3</sup>G°</div></div><div><div><sup>1</sup>D°</div><div><sup>1</sup>F°</div><div><sup>1</sup>G°</div></div></div>				{ <div><div><div><sup>3</sup>P</div><div><sup>3</sup>D</div><div><sup>3</sup>F</div><div><sup>3</sup>G</div><div><sup>3</sup>H</div></div><div><div><sup>1</sup>P</div><div><sup>1</sup>D</div><div><sup>1</sup>F</div><div><sup>1</sup>G</div><div><sup>1</sup>H</div></div></div>				..... .....
3d <sup>6</sup> 4s( <sup>2</sup> G) nx	{ <div><div><div><sup>3</sup>G</div><div><sup>1</sup>G</div></div></div>		{ <div><div><div><sup>3</sup>F°</div><div><sup>3</sup>G°</div><div><sup>3</sup>H°</div></div><div><div><sup>1</sup>F°</div><div><sup>1</sup>G°</div><div><sup>1</sup>H°</div></div></div>				{ <div><div><div><sup>3</sup>D</div><div><sup>3</sup>F</div><div><sup>3</sup>G</div><div><sup>3</sup>H</div><div><sup>3</sup>I</div></div><div><div><sup>1</sup>D</div><div><sup>1</sup>F</div><div><sup>1</sup>G</div><div><sup>1</sup>H</div><div><sup>1</sup>I</div></div></div>				..... .....
3d <sup>6</sup> 4s( <sup>4</sup> D) nx	{ <div><div><div><sup>5</sup>D</div><div><sup>3</sup>D</div></div></div>		{ <div><div><div><sup>5</sup>P°</div><div><sup>5</sup>D°</div><div><sup>5</sup>F°</div></div><div><div><sup>3</sup>P°</div><div><sup>3</sup>D°</div><div><sup>3</sup>F°</div></div></div>				{ <div><div><div><sup>5</sup>S</div><div><sup>5</sup>P</div><div><sup>5</sup>D</div><div><sup>5</sup>F</div><div><sup>5</sup>G</div></div><div><div><sup>3</sup>S</div><div><sup>3</sup>P</div><div><sup>3</sup>D</div><div><sup>3</sup>F</div><div><sup>3</sup>G</div></div></div>				..... .....
3d <sup>7</sup> ( <sup>2</sup> F) nx	{ <div><div><div><sup>3</sup>F</div><div><sup>1</sup>F</div></div></div>		{ <div><div><div><sup>3</sup>D°</div><div><sup>3</sup>F°</div><div><sup>3</sup>G°</div></div><div><div><sup>1</sup>D°</div><div><sup>1</sup>F°</div><div><sup>1</sup>G°</div></div></div>				{ <div><div><div><sup>3</sup>P</div><div><sup>3</sup>D</div><div><sup>3</sup>F</div><div><sup>3</sup>G</div><div><sup>3</sup>H</div></div><div><div><sup>1</sup>P</div><div><sup>1</sup>D</div><div><sup>1</sup>F</div><div><sup>1</sup>G</div><div><sup>1</sup>H</div></div></div>				..... .....



TABLE 4. PREDICTED TERMS OF THE CO I ISOELECTRONIC SEQUENCE\*

Config. $1s^2 2s^2 2p^6 3s^2 3p^6 +$	Predicted Terms			
	$ns (n \geq 4)$	$np (n \geq 4)$	$nd (n \geq 4)$	.....
$3d^7 4s^2$	$\begin{Bmatrix} {}^4P \\ {}^2P \\ {}^2D \end{Bmatrix}$	$\begin{Bmatrix} {}^4F \\ {}^2F \\ {}^2D \end{Bmatrix}$	$\begin{Bmatrix} {}^4F \\ {}^2F \\ {}^2D \end{Bmatrix}$	.....
$3d^9$	${}^2D$	${}^2D$	${}^2D$	.....
$3d^8 ({}^3F) nx$	$\begin{Bmatrix} {}^4F \\ {}^2F \end{Bmatrix}$	$\begin{Bmatrix} {}^4D \\ {}^2D \end{Bmatrix}$	$\begin{Bmatrix} {}^4D \\ {}^2D \end{Bmatrix}$	.....
$3d^8 ({}^3P) nx$	$\begin{Bmatrix} {}^4P \\ {}^2P \end{Bmatrix}$	$\begin{Bmatrix} {}^4D \\ {}^2D \end{Bmatrix}$	$\begin{Bmatrix} {}^4D \\ {}^2D \end{Bmatrix}$	.....
$3d^8 ({}^1G) nx$	${}^2G$	${}^2P^\circ$	${}^2G^\circ$	.....
$3d^8 ({}^1D) nx$	${}^2D$	${}^2D^\circ$	${}^2D^\circ$	.....
$3d^7 4s ({}^5F) nx$	$\begin{Bmatrix} {}^6F \\ {}^4F \end{Bmatrix}$	$\begin{Bmatrix} {}^6D \\ {}^4D \end{Bmatrix}$	$\begin{Bmatrix} {}^6D \\ {}^4D \end{Bmatrix}$	.....
$3d^7 4s ({}^5P) nx$	$\begin{Bmatrix} {}^6P \\ {}^4P \end{Bmatrix}$	$\begin{Bmatrix} {}^6D \\ {}^4D \end{Bmatrix}$	$\begin{Bmatrix} {}^6D \\ {}^4D \end{Bmatrix}$	.....
$3d^7 4s ({}^3F) nx$	$\begin{Bmatrix} {}^4F \\ {}^2F \end{Bmatrix}$	$\begin{Bmatrix} {}^4D \\ {}^2D \end{Bmatrix}$	$\begin{Bmatrix} {}^4D \\ {}^2D \end{Bmatrix}$	.....
$3d^7 4s ({}^3P) nx$	$\begin{Bmatrix} {}^4P \\ {}^2P \end{Bmatrix}$	$\begin{Bmatrix} {}^4D \\ {}^2D \end{Bmatrix}$	$\begin{Bmatrix} {}^4D \\ {}^2D \end{Bmatrix}$	.....
$3d^7 4s ({}^3H) nx$	$\begin{Bmatrix} {}^4H \\ {}^2H \end{Bmatrix}$	$\begin{Bmatrix} {}^4D \\ {}^2D \end{Bmatrix}$	$\begin{Bmatrix} {}^4D \\ {}^2D \end{Bmatrix}$	.....
$3d^7 4s ({}^3G) nx$	$\begin{Bmatrix} {}^4G \\ {}^2G \end{Bmatrix}$	$\begin{Bmatrix} {}^4D \\ {}^2D \end{Bmatrix}$	$\begin{Bmatrix} {}^4D \\ {}^2D \end{Bmatrix}$	.....
$3d^7 4s ({}^3F) nx$	$\begin{Bmatrix} {}^4F \\ {}^2F \end{Bmatrix}$	$\begin{Bmatrix} {}^4D \\ {}^2D \end{Bmatrix}$	$\begin{Bmatrix} {}^4D \\ {}^2D \end{Bmatrix}$	.....
$3d^7 4s ({}^3D) nx$	$\begin{Bmatrix} {}^4D \\ {}^2D \end{Bmatrix}$	$\begin{Bmatrix} {}^4D \\ {}^2D \end{Bmatrix}$	$\begin{Bmatrix} {}^4D \\ {}^2D \end{Bmatrix}$	.....
$3d^7 4s ({}^3P) nx$	$\begin{Bmatrix} {}^4P \\ {}^2P \end{Bmatrix}$	$\begin{Bmatrix} {}^4D \\ {}^2D \end{Bmatrix}$	$\begin{Bmatrix} {}^4D \\ {}^2D \end{Bmatrix}$	.....

\*Within a given configuration the limit terms are listed in the general order predicted by the Hund theory.

TABLE 5. PREDICTED TERMS OF THE Ni I ISOELECTRONIC SEQUENCE

Config. $1s^2 2s^2 2p^6 3s^2 3p^6 +$	Predicted Terms			
	$ns$ ( $n \geq 4$ )	$np$ ( $n \geq 4$ )	$nd$ ( $n \geq 4$ )	
$3d^8 4s^2$	$\begin{Bmatrix} 3P \\ 1S \end{Bmatrix}$	$\begin{Bmatrix} 3F \\ 1G \end{Bmatrix}$		
$3d^{10}$	$1S$			
$3d^8(2D)nx$	$\begin{Bmatrix} 3D \\ 1D \end{Bmatrix}$	$\begin{Bmatrix} 3D^\circ \\ 1D^\circ \\ 3F^\circ \\ 1F^\circ \end{Bmatrix}$	$\begin{Bmatrix} 3S \\ 1S \end{Bmatrix}$	$\begin{Bmatrix} 3P \\ 1P \\ 3D \\ 1D \\ 3F \\ 1F \\ 3G \\ 1G \end{Bmatrix}$
$3d^8 4s(4F)nx$	$\begin{Bmatrix} 5F \\ 3F \end{Bmatrix}$	$\begin{Bmatrix} 5D^\circ \\ 3D^\circ \\ 5F^\circ \\ 3F^\circ \\ 5G^\circ \\ 3G^\circ \end{Bmatrix}$		$\begin{Bmatrix} 5P \\ 3P \\ 5D \\ 3D \\ 5F \\ 3F \\ 5G \\ 3G \end{Bmatrix}$
$3d^8 4s(2F)nx$	$\begin{Bmatrix} 3F \\ 1F \end{Bmatrix}$	$\begin{Bmatrix} 3D^\circ \\ 1D^\circ \\ 3F^\circ \\ 1F^\circ \\ 3G^\circ \\ 1G^\circ \end{Bmatrix}$		$\begin{Bmatrix} 3P \\ 1P \\ 3D \\ 1D \\ 3F \\ 1F \\ 3G \\ 1G \end{Bmatrix}$
$3d^8 4s(2D)nx$	$\begin{Bmatrix} 3D \\ 1D \end{Bmatrix}$	$\begin{Bmatrix} 3D^\circ \\ 1D^\circ \\ 3F^\circ \\ 1F^\circ \end{Bmatrix}$		$\begin{Bmatrix} 3S \\ 1S \end{Bmatrix}$
$3d^8 4s(4P)nx$	$\begin{Bmatrix} 5P \\ 3P \end{Bmatrix}$	$\begin{Bmatrix} 5D^\circ \\ 3D^\circ \end{Bmatrix}$	$\begin{Bmatrix} 5S^\circ \\ 3S^\circ \end{Bmatrix}$	$\begin{Bmatrix} 5P \\ 3P \\ 5D \\ 3D \end{Bmatrix}$
$3d^8 4s(3P)nx$	$\begin{Bmatrix} 3P \\ 1P \end{Bmatrix}$	$\begin{Bmatrix} 3D^\circ \\ 1D^\circ \end{Bmatrix}$	$\begin{Bmatrix} 3S^\circ \\ 1S^\circ \end{Bmatrix}$	$\begin{Bmatrix} 3P \\ 1P \\ 3D \\ 1D \end{Bmatrix}$
$3d^8 4s(2G)nx$	$\begin{Bmatrix} 3G \\ 1G \end{Bmatrix}$	$\begin{Bmatrix} 3F^\circ \\ 1F^\circ \\ 3G^\circ \\ 1G^\circ \\ 3H^\circ \\ 1H^\circ \end{Bmatrix}$		$\begin{Bmatrix} 3D \\ 1D \\ 3F \\ 1F \\ 3G \\ 1G \\ 3H \\ 1H \\ 3I \\ 1I \end{Bmatrix}$
$3d^8 4s(2S)nx$	$\begin{Bmatrix} 3S \\ 1S \end{Bmatrix}$	$\begin{Bmatrix} 3P^\circ \\ 1P^\circ \end{Bmatrix}$		$\begin{Bmatrix} 3D \\ 1D \end{Bmatrix}$
$3d^8(2D)nx$	$\begin{Bmatrix} 3P^\circ \\ 1P^\circ \\ 3D^\circ \\ 1D^\circ \\ 5D^\circ \\ 3D^\circ \end{Bmatrix}$	$\begin{Bmatrix} 3F^\circ \\ 1F^\circ \\ 3G^\circ \\ 1G^\circ \\ 3H^\circ \\ 1H^\circ \end{Bmatrix}$	$\begin{Bmatrix} 3S^\circ \\ 1S^\circ \end{Bmatrix}$	$\begin{Bmatrix} 3P \\ 1P \\ 3D \\ 1D \\ 3F \\ 1F \\ 3G \\ 1G \end{Bmatrix}$
$3d^8 4s(4F)nx$	$\begin{Bmatrix} 5D^\circ \\ 3D^\circ \end{Bmatrix}$	$\begin{Bmatrix} 5F^\circ \\ 3F^\circ \\ 5G^\circ \\ 3G^\circ \\ 5I^\circ \\ 3I^\circ \end{Bmatrix}$		$\begin{Bmatrix} 5P \\ 3P \\ 5D \\ 3D \\ 5F \\ 3F \\ 5G \\ 3G \end{Bmatrix}$
$3d^8 4s(2F)nx$	$\begin{Bmatrix} 3D^\circ \\ 1D^\circ \end{Bmatrix}$	$\begin{Bmatrix} 3F^\circ \\ 1F^\circ \\ 3G^\circ \\ 1G^\circ \\ 3H^\circ \\ 1H^\circ \end{Bmatrix}$		$\begin{Bmatrix} 3P \\ 1P \\ 3D \\ 1D \\ 3F \\ 1F \\ 3G \\ 1G \end{Bmatrix}$
$3d^8 4s(2D)nx$	$\begin{Bmatrix} 3P^\circ \\ 1P^\circ \end{Bmatrix}$	$\begin{Bmatrix} 3D^\circ \\ 1D^\circ \\ 3F^\circ \\ 1F^\circ \\ 3G^\circ \\ 1G^\circ \end{Bmatrix}$		$\begin{Bmatrix} 3S \\ 1S \end{Bmatrix}$
$3d^8 4s(4P)nx$	$\begin{Bmatrix} 5D^\circ \\ 3D^\circ \end{Bmatrix}$	$\begin{Bmatrix} 5F^\circ \\ 3F^\circ \\ 5G^\circ \\ 3G^\circ \end{Bmatrix}$		$\begin{Bmatrix} 5P \\ 3P \\ 5D \\ 3D \end{Bmatrix}$
$3d^8 4s(2P)nx$	$\begin{Bmatrix} 3D^\circ \\ 1D^\circ \end{Bmatrix}$	$\begin{Bmatrix} 3F^\circ \\ 1F^\circ \\ 3G^\circ \\ 1G^\circ \end{Bmatrix}$		$\begin{Bmatrix} 3P \\ 1P \\ 3D \\ 1D \end{Bmatrix}$
$3d^8 4s(2G)nx$	$\begin{Bmatrix} 3F^\circ \\ 1F^\circ \end{Bmatrix}$	$\begin{Bmatrix} 3D^\circ \\ 1D^\circ \\ 3F^\circ \\ 1F^\circ \\ 3G^\circ \\ 1G^\circ \\ 3H^\circ \\ 1H^\circ \end{Bmatrix}$		$\begin{Bmatrix} 3D \\ 1D \\ 3F \\ 1F \\ 3G \\ 1G \\ 3H \\ 1H \end{Bmatrix}$
$3d^8 4s(2S)nx$	$\begin{Bmatrix} 3P^\circ \\ 1P^\circ \end{Bmatrix}$	$\begin{Bmatrix} 3D^\circ \\ 1D^\circ \end{Bmatrix}$		$\begin{Bmatrix} 3S \\ 1S \end{Bmatrix}$

TABLE 6. PREDICTED TERMS OF THE Cu I ISOELECTRONIC SEQUENCE

Config. $1s^2 2s^2 2p^6 3s^2 3p^6 +$	Predicted Terms					
	$3d^9 4s^2$					
	$ns (n \geq 4)$	$np (n \geq 4)$	$nd (n \geq 4)$	$nf (n \geq 4)$	$ng (n \geq 5)$	.....
$3d^9 4s^2$	$2S$	$2P^\circ$	$2D$	$2F^\circ$	$2G$	.....
$3d^{10}(1S)nx$	$\begin{Bmatrix} 4D \\ 2D \end{Bmatrix}$	$\begin{Bmatrix} 4D^\circ \\ 2D^\circ \end{Bmatrix}$	$\begin{Bmatrix} 4S \\ 2S \end{Bmatrix}$	$\begin{Bmatrix} 4P^\circ \\ 2P^\circ \end{Bmatrix}$	$\begin{Bmatrix} 4F^\circ \\ 2F^\circ \end{Bmatrix}$	$\begin{Bmatrix} 4I \\ 2I \end{Bmatrix}$
$3d^9 4s(3D)nx'$	$\begin{Bmatrix} 4D \\ 2D \end{Bmatrix}$	$\begin{Bmatrix} 4D^\circ \\ 2D^\circ \end{Bmatrix}$	$\begin{Bmatrix} 4S \\ 2S \end{Bmatrix}$	$\begin{Bmatrix} 4P^\circ \\ 2P^\circ \end{Bmatrix}$	$\begin{Bmatrix} 4F^\circ \\ 2F^\circ \end{Bmatrix}$	$\begin{Bmatrix} 4I \\ 2I \end{Bmatrix}$
$3d^9 4s(1D)nx''$	$2D$	$2D^\circ$	$2S$	$2P^\circ$	$2F^\circ$	$2I$

TABLE 7. PREDICTED TERMS OF THE Zn I ISOELECTRONIC SEQUENCE

Config. $1s^2 2s^2 2p^6 3s^2 3p^6 +$	Predicted Terms					
	$3d^{10} 4s^2$					
	$ns (n \geq 4)$	$np (n \geq 4)$	$nd (n \geq 4)$	$nf (n \geq 4)$	$ng (n \geq 5)$	.....
$3d^{10} 4s^2$	$1S$	$3P^\circ$	$3D$	$3F^\circ$	$3G$	.....
$3d^{10} 4p^2$	$\begin{Bmatrix} 1S \\ 3P \end{Bmatrix}$	$\begin{Bmatrix} 3P^\circ \\ 1P^\circ \end{Bmatrix}$	$\begin{Bmatrix} 3D \\ 1D \end{Bmatrix}$	$\begin{Bmatrix} 3F^\circ \\ 1F^\circ \end{Bmatrix}$	$\begin{Bmatrix} 3G \\ 1G \end{Bmatrix}$	.....
$3d^{10} 4d^2$	$\begin{Bmatrix} 1S \\ 3P \end{Bmatrix}$	$\begin{Bmatrix} 3P^\circ \\ 1P^\circ \end{Bmatrix}$	$\begin{Bmatrix} 3D \\ 1D \end{Bmatrix}$	$\begin{Bmatrix} 3F^\circ \\ 1F^\circ \end{Bmatrix}$	$\begin{Bmatrix} 3G \\ 1G \end{Bmatrix}$	.....
$3d^{10} 4s(2S)nx$	$\begin{Bmatrix} 3S \\ 1S \end{Bmatrix}$	$\begin{Bmatrix} 3P^\circ \\ 1P^\circ \end{Bmatrix}$	$\begin{Bmatrix} 3D \\ 1D \end{Bmatrix}$	$\begin{Bmatrix} 3F^\circ \\ 1F^\circ \end{Bmatrix}$	$\begin{Bmatrix} 3G \\ 1G \end{Bmatrix}$	.....
$3d^{10} 4p(2P^\circ)nx$	$\begin{Bmatrix} 3P^\circ \\ 1P^\circ \end{Bmatrix}$	$\begin{Bmatrix} 3P^\circ \\ 1P^\circ \end{Bmatrix}$	$\begin{Bmatrix} 3D \\ 1D \end{Bmatrix}$	$\begin{Bmatrix} 3F^\circ \\ 1F^\circ \end{Bmatrix}$	$\begin{Bmatrix} 3G \\ 1G \end{Bmatrix}$	.....
$3d^9 4s(2D)nx'$	$\begin{Bmatrix} 3D \\ 1D \end{Bmatrix}$	$\begin{Bmatrix} 3D^\circ \\ 1D^\circ \end{Bmatrix}$	$\begin{Bmatrix} 3S \\ 1S \end{Bmatrix}$	$\begin{Bmatrix} 3P^\circ \\ 1P^\circ \end{Bmatrix}$	$\begin{Bmatrix} 3F^\circ \\ 1F^\circ \end{Bmatrix}$	$\begin{Bmatrix} 3I \\ 1I \end{Bmatrix}$



TABLE 8. PREDICTED TERMS OF THE Ga I ISOELECTRONIC SEQUENCE

Config. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}+$	Predicted Terms															
$4s^2(^1S)4f$	$^2P^\circ$															
$4s\ 4p^2$	$\left\{ \begin{array}{l} ^4P \\ ^2S\ ^2P\ ^2D \end{array} \right.$															
$4p^3$	$\left\{ \begin{array}{l} ^4S^\circ \\ ^2P^\circ\ ^2D^\circ \end{array} \right.$															
	$ns\ (n \geq 5)$			$np\ (n \geq 5)$			$nd\ (n \geq 4)$			$nf\ (n \geq 4)$			$ng\ (n \geq 5)$		.....	
$4s^2(^1S)nx$	$^2S$			$^2P^\circ$			$^2D$			$^2F^\circ$			$^2G$		.....	
$4s\ 4p(^3P^\circ)nx$	$\left\{ \begin{array}{l} ^4P^\circ \\ ^2P^\circ \end{array} \right.$			$^4S$	$^4P$	$^4D$	$^4P^\circ$	$^4D^\circ$	$^4F^\circ$	$^4D$	$^4F$	$^4G$	$^4F^\circ$	$^4G^\circ$	$^4H^\circ$	.....
				$^2S$	$^2P$	$^2D$	$^2P^\circ$	$^2D^\circ$	$^2F^\circ$	$^2D$	$^2F$	$^2G$	$^2F^\circ$	$^2G^\circ$	$^2H^\circ$	.....
$4s\ 4p(^1P^\circ)nx'$	$^2P^\circ$			$^2S$	$^2P$	$^2D$	$^2P^\circ$	$^2D^\circ$	$^2F^\circ$	$^2D$	$^2F$	$^2G$	$^2F^\circ$	$^2G^\circ$	$^2H^\circ$	.....

TABLE 9. PREDICTED TERMS OF THE Ge I ISOELECTRONIC SEQUENCE

Config. $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} +$	Predicted Terms													
$4s^2 4p^2$	$\left\{ \begin{array}{ccc} 3P & & \\ 1S & & 1D \end{array} \right.$													
$4s 4p^3$	$\left\{ \begin{array}{ccc} 5S^\circ & & \\ 3S^\circ & 3P^\circ & 3D^\circ \\ & 1P^\circ & 1D^\circ \end{array} \right.$													
	$ns (n \geq 5)$	$np (n \geq 5)$			$nd (n \geq 4)$			$nf (n \geq 4)$			.....			
$4s^2 4p(2P^\circ)nx$	$\left\{ \begin{array}{c} 3P^\circ \\ 1P^\circ \end{array} \right.$	$3S$	$3P$	$3D$	$3P^\circ$	$3D^\circ$	$3F^\circ$	$3D$	$3F$	$3G$	.....			
		$1S$	$1P$	$1D$	$1P^\circ$	$1D^\circ$	$1F^\circ$	$1D$	$1F$	$1G$	.....			
$4s 4p^2(4P)nx$	$\left\{ \begin{array}{c} 5P \\ 3P \end{array} \right.$	$5S^\circ$	$5P^\circ$	$5D^\circ$	$5P$	$5D$	$5F$	$5D^\circ$	$5F^\circ$	$5G^\circ$	.....			
		$3S^\circ$	$3P^\circ$	$3D^\circ$	$3P$	$3D$	$3F$	$3D^\circ$	$3F^\circ$	$3G^\circ$	.....			

TABLE 10. PREDICTED TERMS OF THE As I ISOELECTRONIC SEQUENCE

Config. 1s <sup>2</sup> 2s <sup>2</sup> 2p <sup>6</sup> 3s <sup>2</sup> 3p <sup>6</sup> 3d <sup>10</sup> +	Predicted Terms																
4s <sup>2</sup> 4p <sup>3</sup>	{ <sup>4</sup> S <sup>o</sup> <sup>2</sup> P <sup>o</sup> <sup>2</sup> D <sup>o</sup>																
4s 4p <sup>4</sup>	{ <sup>2</sup> S <sup>4</sup> P <sup>2</sup> D <sup>2</sup> P																
4p <sup>5</sup>	<sup>2</sup> P <sup>o</sup>																
	ns (n ≥ 5)		np (n ≥ 5)			nd (n ≥ 4)			nf (n ≥ 4)			. . . .					
4s <sup>2</sup> 4p <sup>2</sup> ( <sup>3</sup> P)nx	{ <sup>4</sup> P <sup>2</sup> P		<sup>4</sup> S <sup>o</sup>	<sup>4</sup> P <sup>o</sup>	<sup>4</sup> D <sup>o</sup>	<sup>4</sup> P	<sup>4</sup> D	<sup>4</sup> F	<sup>4</sup> D <sup>o</sup>	<sup>4</sup> F <sup>o</sup>	<sup>4</sup> G <sup>o</sup>	. . . .					
			<sup>2</sup> S <sup>o</sup>	<sup>2</sup> P <sup>o</sup>	<sup>2</sup> D <sup>o</sup>	<sup>2</sup> P	<sup>2</sup> D	<sup>2</sup> F	<sup>2</sup> D <sup>o</sup>	<sup>2</sup> F <sup>o</sup>	<sup>2</sup> G <sup>o</sup>	. . . .					
4s <sup>2</sup> 4p <sup>2</sup> ( <sup>1</sup> D)nx'				<sup>2</sup> P <sup>o</sup>	<sup>2</sup> D <sup>o</sup>	<sup>2</sup> F <sup>o</sup>	<sup>2</sup> S	<sup>2</sup> P	<sup>2</sup> D	<sup>2</sup> F	<sup>2</sup> G	<sup>2</sup> P <sup>o</sup>	<sup>2</sup> D <sup>o</sup>	<sup>2</sup> F <sup>o</sup>	<sup>2</sup> G <sup>o</sup>	<sup>2</sup> H <sup>o</sup>	. . . .
4s <sup>2</sup> 4p <sup>2</sup> ( <sup>1</sup> S)nx''	<sup>2</sup> S		<sup>2</sup> P <sup>o</sup>			<sup>2</sup> D			<sup>2</sup> F <sup>o</sup>			. . . .					

TABLE 11. PREDICTED TERMS OF THE Se I ISOELECTRONIC SEQUENCE

Config. $1s^2 2s^2 2p^6 3s^2 3p^4 3d^{10} +$	Predicted Terms				
$4s^2 4p^4$	$\{^1S$	$^1D$			
$4s 4p^5$	$\{$	$^3P^o$ $^1P^o$			
	$ns (n \geq 5)$	$np (n \geq 5)$	$nd (n \geq 4)$	$nf (n \geq 4)$	.....
$4s^2 4p^3(^1S^o)nx$	$\{^1S^o$ $^3S^o$	$^5P$ $^3P$	$^5D^o$ $^3D^o$	$^6F$ $^3F$	.....
$4s^2 4p^3(^3D^o)nx'$	$\{$	$^3P$ $^3D$ $^3F$ $^1P$ $^1D$ $^1F$	$^3S^o$ $^3D^o$ $^3F^o$ $^1S^o$ $^1D^o$ $^1F^o$	$^3P$ $^3D$ $^3F$ $^3H$ $^1P$ $^1D$ $^1F$ $^1H$	.....
$4s^2 4p^3(^2P^o)nx''$	$\{$	$^3S$ $^3P$ $^3D$ $^1S$ $^1P$ $^1D$	$^3D^o$ $^3F^o$ $^1D^o$ $^1F^o$	$^3D$ $^3F$ $^3G$ $^1D$ $^1F$ $^1G$	.....

TABLE 12. PREDICTED TERMS OF THE Br I ISOELECTRONIC SEQUENCE

Config. $1s^2 2s^2 2p^6 3s^2 3p^4 3d^{10} +$	Predicted Terms				
$4s^2 4p^5$	$^2P^o$				
$4s 4p^6$	$^2S$				
	$ns (n \geq 5)$	$np (n \geq 5)$	$nd (n \geq 4)$	$nf (n \geq 4)$	$ng (n \geq 5)$
$4s^2 4p^4(^3P)nx$	$\{$	$^4S^o$ $^4P^o$ $^4D^o$ $^2S^o$ $^2P^o$ $^2D^o$	$^4P$ $^4D$ $^4F$ $^2P$ $^2D$ $^2F$	$^4D^o$ $^4F^o$ $^4F^o$ $^2D^o$ $^2F^o$ $^2G^o$	$^4F$ $^4G$ $^4H$ $^2F$ $^2G$ $^2H$
$4s^2 4p^4(^1D)nx'$	$^2D$	$^2P^o$ $^2D^o$ $^2F^o$ $^2P^o$	$^2S$ $^2P$ $^2D$ $^2F$ $^2G$ $^2D$	$^2P^o$ $^2D^o$ $^2F^o$ $^2H^o$ $^2F^o$	$^2D$ $^2F$ $^2G$ $^2H$ $^2I$
$4s^2 4p^4(^1S)nx''$	$^2S$	$^4S$ $^4P$ $^4D$ $^2S$ $^2P$ $^2D$	$^4P^o$ $^4D^o$ $^4F^o$ $^2P^o$ $^2D^o$ $^2F^o$	$^4D$ $^4F$ $^4G$ $^2D$ $^2F$ $^2G$	$^4F^o$ $^4G^o$ $^4H^o$ $^2F^o$ $^2G$ $^2H^o$
$4s 4p^5(^3P^o)nx'''$	$\{$	$^4P^o$ $^4P^o$ $^2P^o$			.....

TABLE 13. PREDICTED LEVELS OF THE Kr I ISOELECTRONIC SEQUENCE

Config. $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} +$	Predicted Terms				
$4s^2 4p^6$	$^1S$				
	$ns (n \geq 5)$	$np (n \geq 5)$	$nd (n \geq 4)$	$nf (n \geq 4)$	-----
$4s^2 4p^5(^2P^\circ)nx$	$\begin{Bmatrix} ^3P^\circ \\ ^1P^\circ \end{Bmatrix}$	$\begin{matrix} ^3S & ^3P & ^3D \\ ^1S & ^1P & ^1D \end{matrix}$	$\begin{matrix} ^3P^\circ & ^3D^\circ & ^3F^\circ \\ ^1P^\circ & ^1D^\circ & ^1F^\circ \end{matrix}$	$\begin{matrix} ^3D & ^3F & ^3G \\ ^1D & ^1F & ^1G \end{matrix}$	----- ----- -----
$4s 4p^6(^2S)nx'$	$\begin{Bmatrix} ^3S \\ ^1S \end{Bmatrix}$	$\begin{matrix} ^3P^\circ \\ ^1P^\circ \end{matrix}$	$\begin{matrix} ^3D \\ ^1D \end{matrix}$	$\begin{matrix} ^3F^\circ \\ ^1F^\circ \end{matrix}$	----- ----- -----
<i>jl</i> -Coupling Notation					
Config. $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 +$	Predicted Pairs				
	$ns (n \geq 5)$	$np (n \geq 5)$	$nd (n \geq 4)$	$nf (n \geq 4)$	-----
$4p^5(^2P^{\frac{1}{2}}_1)nx$	$[1\frac{1}{2}]^\circ$	$\begin{matrix} [0\frac{1}{2}] \\ [2\frac{1}{2}] \\ [1\frac{1}{2}] \end{matrix}$	$\begin{matrix} [0\frac{1}{2}]^\circ \\ [3\frac{1}{2}]^\circ \\ [1\frac{1}{2}]^\circ \\ [2\frac{1}{2}]^\circ \end{matrix}$	$\begin{matrix} [1\frac{1}{2}] \\ [4\frac{1}{2}] \\ [2\frac{1}{2}] \\ [3\frac{1}{2}] \end{matrix}$	----- ----- ----- -----
$4p^5(^2P^{\frac{3}{2}}_3)nx'$	$[0\frac{1}{2}]^\circ$	$\begin{matrix} [1\frac{1}{2}] \\ [0\frac{1}{2}] \end{matrix}$	$\begin{matrix} [2\frac{1}{2}]^\circ \\ [1\frac{1}{2}]^\circ \end{matrix}$	$\begin{matrix} [3\frac{1}{2}] \\ [2\frac{1}{2}] \end{matrix}$	----- -----



TABLE 14. PREDICTED TERMS OF THE SII ISOELECTRONIC SEQUENCE

Config. $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 +$	Predicted Terms			
$5s^2$	$^1S$			
$4d^2$	$\begin{Bmatrix} ^1S & ^3P & ^1D & ^3F & ^1G \end{Bmatrix}$			
$5p^2$	$\begin{Bmatrix} ^1S & ^3P & ^1D \end{Bmatrix}$			
	$ns (n \geq 5)$	$np (n \geq 5)$	$nd (n \geq 4)$	
$5s(^2S)nx$	$\begin{Bmatrix} ^3S \\ ^1S \end{Bmatrix}$	$\begin{Bmatrix} ^3P^\circ \\ ^1P^\circ \end{Bmatrix}$	$\begin{Bmatrix} ^3D \\ ^1D \end{Bmatrix}$	
$4d(^2D)nx'$	$\begin{Bmatrix} ^3D \\ ^1D \end{Bmatrix}$	$\begin{Bmatrix} ^3P^\circ & ^3D^\circ & ^3F^\circ \\ ^1P^\circ & ^1D^\circ & ^1F^\circ \end{Bmatrix}$	$\begin{Bmatrix} ^3S & ^3P & ^3D & ^3F & ^3G \\ ^1S & ^1P & ^1D & ^1F & ^1G \end{Bmatrix}$	
$5p(^2P^\circ)nx''$	$\begin{Bmatrix} ^3P^\circ \\ ^1P^\circ \end{Bmatrix}$	$\begin{Bmatrix} ^3S & ^3P & ^3D \\ ^1S & ^1P & ^1D \end{Bmatrix}$	$\begin{Bmatrix} ^3P^\circ & ^3D^\circ & ^3F^\circ \\ ^1P^\circ & ^1D^\circ & ^1F^\circ \end{Bmatrix}$	
	$nf (n \geq 4)$	$ng (n \geq 5)$	-----	
$5s(^2S)nx$	$\begin{Bmatrix} ^3F^\circ \\ ^1F^\circ \end{Bmatrix}$	$\begin{Bmatrix} ^3G \\ ^1G \end{Bmatrix}$	-----	
$4d(^2D)nx'$	$\begin{Bmatrix} ^3P^\circ & ^3D^\circ & ^3F^\circ & ^3G^\circ & ^3H^\circ \\ ^1P^\circ & ^1D^\circ & ^1F^\circ & ^1G^\circ & ^1H^\circ \end{Bmatrix}$	$\begin{Bmatrix} ^3D & ^3F & ^3G & ^3H & ^3I \\ ^1D & ^1F & ^1G & ^1H & ^1I \end{Bmatrix}$	-----	
$5p(^2P^\circ)nx''$	$\begin{Bmatrix} ^3D & ^3F & ^3G \\ ^1D & ^1F & ^1G \end{Bmatrix}$	$\begin{Bmatrix} ^3F^\circ & ^3G^\circ & ^3H^\circ \\ ^1F^\circ & ^1G^\circ & ^1H^\circ \end{Bmatrix}$	-----	

TABLE 15. PREDICTED TERMS OF THE Y I ISOELECTRONIC SEQUENCE

Config. $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 +$	Predicted Terms		
	$ns (n \geq 5)$	$np (n \geq 5)$	$nd (n \geq 4)$
$4d 5s^2$	$\begin{Bmatrix} {}^4P \\ {}^2P \\ {}^2D \end{Bmatrix}$	$\begin{Bmatrix} {}^4F \\ {}^2F \\ {}^2G \end{Bmatrix}$	
$4d^2$			
$5s^2 ({}^1S) nx$	${}^2S$		${}^2D$
$4d 5s ({}^3D) nx$	$\begin{Bmatrix} {}^4D \\ {}^2D \end{Bmatrix}$	$\begin{Bmatrix} {}^4P^\circ \\ {}^2P^\circ \end{Bmatrix}$	$\begin{Bmatrix} {}^4S \\ {}^2S \end{Bmatrix}$
$4d 5s ({}^1D) nx$	${}^2D$	${}^2P^\circ$	${}^2S$
$4d^2 ({}^3F) nx$	$\begin{Bmatrix} {}^4F \\ {}^2F \end{Bmatrix}$	$\begin{Bmatrix} {}^4D^\circ \\ {}^2D^\circ \end{Bmatrix}$	$\begin{Bmatrix} {}^4P \\ {}^2P \end{Bmatrix}$
$4d^2 ({}^3P) nx$	$\begin{Bmatrix} {}^4P \\ {}^2P \end{Bmatrix}$	$\begin{Bmatrix} {}^4S^\circ \\ {}^2S^\circ \end{Bmatrix}$	$\begin{Bmatrix} {}^4P \\ {}^2P \end{Bmatrix}$
$4d^2 ({}^1G) nx$		${}^2F^\circ$	${}^2D$
$4d^2 ({}^1D) nx$	${}^2D$	${}^2D^\circ$	${}^2S$
$4d^2 ({}^1S) nx$	${}^2S$	${}^2P^\circ$	${}^2P$
$5p^2 ({}^3P) nx$	$\begin{Bmatrix} {}^4P \\ {}^2P \end{Bmatrix}$	$\begin{Bmatrix} {}^4D^\circ \\ {}^2D^\circ \end{Bmatrix}$	$\begin{Bmatrix} {}^4P \\ {}^2P \end{Bmatrix}$
$5p^2 ({}^1D) nx$	${}^2D$	${}^2P^\circ$	${}^2S$
$5p^2 ({}^1S) nx$	${}^2S$	${}^2P^\circ$	${}^2D$

TABLE 16. PREDICTED TERMS OF THE Zr I ISOELECTRONIC SEQUENCE

Config. $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 +$	Predicted Terms			
	$ns (n \geq 5)$	$np (n \geq 5)$	$nd (n \geq 5)$	-----
$4d^2 5s^2$	$\left\{ \begin{array}{l} {}^3P \\ {}^1S \end{array} \right.$	$\left\{ \begin{array}{l} {}^3F \\ {}^1D \\ {}^1G \end{array} \right.$		
$4d^4$	$\left\{ \begin{array}{l} {}^3P \\ {}^3D \\ {}^3F \\ {}^1S \\ {}^1D \\ {}^1G \\ {}^1I \end{array} \right.$	$\left\{ \begin{array}{l} {}^3F \\ {}^3G \\ {}^3H \\ {}^1F \\ {}^1G \\ {}^1I \end{array} \right.$		
$4d^2 5p^2 \dagger$	$\left\{ \begin{array}{l} {}^3P \\ {}^1D \\ {}^3D \\ {}^1S \\ {}^1D \\ {}^1G \\ {}^1I \end{array} \right.$	$\left\{ \begin{array}{l} {}^3F \\ {}^3G \\ {}^3H \\ {}^1F \\ {}^1G \\ {}^1I \end{array} \right.$		
$4d^2 5s({}^4F)nx$	$\left\{ \begin{array}{l} {}^3P \\ {}^1D \\ {}^3D \\ {}^1S \\ {}^1D \\ {}^1G \\ {}^1I \end{array} \right.$	$\left\{ \begin{array}{l} {}^3F \\ {}^3G \\ {}^3H \\ {}^1F \\ {}^1G \\ {}^1I \end{array} \right.$		
$4d^2 5s({}^4F)nx$	$\left\{ \begin{array}{l} {}^3P \\ {}^1D \\ {}^3D \\ {}^1S \\ {}^1D \\ {}^1G \\ {}^1I \end{array} \right.$	$\left\{ \begin{array}{l} {}^3F \\ {}^3G \\ {}^3H \\ {}^1F \\ {}^1G \\ {}^1I \end{array} \right.$		
$4d^2 5s({}^3D)nx$	$\left\{ \begin{array}{l} {}^3P \\ {}^1D \\ {}^3D \\ {}^1S \\ {}^1D \\ {}^1G \\ {}^1I \end{array} \right.$	$\left\{ \begin{array}{l} {}^3F \\ {}^3G \\ {}^3H \\ {}^1F \\ {}^1G \\ {}^1I \end{array} \right.$		
$4d^2 5s({}^3P)nx$	$\left\{ \begin{array}{l} {}^3P \\ {}^1D \\ {}^3D \\ {}^1S \\ {}^1D \\ {}^1G \\ {}^1I \end{array} \right.$	$\left\{ \begin{array}{l} {}^3F \\ {}^3G \\ {}^3H \\ {}^1F \\ {}^1G \\ {}^1I \end{array} \right.$		
$4d^2 5s({}^3F)nx$	$\left\{ \begin{array}{l} {}^3P \\ {}^1D \\ {}^3D \\ {}^1S \\ {}^1D \\ {}^1G \\ {}^1I \end{array} \right.$	$\left\{ \begin{array}{l} {}^3F \\ {}^3G \\ {}^3H \\ {}^1F \\ {}^1G \\ {}^1I \end{array} \right.$		
$4d^2 5s({}^4P)nx$	$\left\{ \begin{array}{l} {}^3P \\ {}^1D \\ {}^3D \\ {}^1S \\ {}^1D \\ {}^1G \\ {}^1I \end{array} \right.$	$\left\{ \begin{array}{l} {}^3F \\ {}^3G \\ {}^3H \\ {}^1F \\ {}^1G \\ {}^1I \end{array} \right.$		
$4d^2 5s({}^2G)nx$	$\left\{ \begin{array}{l} {}^3P \\ {}^1D \\ {}^3D \\ {}^1S \\ {}^1D \\ {}^1G \\ {}^1I \end{array} \right.$	$\left\{ \begin{array}{l} {}^3F \\ {}^3G \\ {}^3H \\ {}^1F \\ {}^1G \\ {}^1I \end{array} \right.$		
$4d^2 5s({}^2P)nx$	$\left\{ \begin{array}{l} {}^3P \\ {}^1D \\ {}^3D \\ {}^1S \\ {}^1D \\ {}^1G \\ {}^1I \end{array} \right.$	$\left\{ \begin{array}{l} {}^3F \\ {}^3G \\ {}^3H \\ {}^1F \\ {}^1G \\ {}^1I \end{array} \right.$		
$4d^2 5s({}^2H)nx$	$\left\{ \begin{array}{l} {}^3P \\ {}^1D \\ {}^3D \\ {}^1S \\ {}^1D \\ {}^1G \\ {}^1I \end{array} \right.$	$\left\{ \begin{array}{l} {}^3F \\ {}^3G \\ {}^3H \\ {}^1F \\ {}^1G \\ {}^1I \end{array} \right.$		
$4d^2 5s({}^2D)nx$	$\left\{ \begin{array}{l} {}^3P \\ {}^1D \\ {}^3D \\ {}^1S \\ {}^1D \\ {}^1G \\ {}^1I \end{array} \right.$	$\left\{ \begin{array}{l} {}^3F \\ {}^3G \\ {}^3H \\ {}^1F \\ {}^1G \\ {}^1I \end{array} \right.$		
$4d^2 5s({}^2G)nx$	$\left\{ \begin{array}{l} {}^3P \\ {}^1D \\ {}^3D \\ {}^1S \\ {}^1D \\ {}^1G \\ {}^1I \end{array} \right.$	$\left\{ \begin{array}{l} {}^3F \\ {}^3G \\ {}^3H \\ {}^1F \\ {}^1G \\ {}^1I \end{array} \right.$		
$4d^2 5s({}^2D)nx$	$\left\{ \begin{array}{l} {}^3P \\ {}^1D \\ {}^3D \\ {}^1S \\ {}^1D \\ {}^1G \\ {}^1I \end{array} \right.$	$\left\{ \begin{array}{l} {}^3F \\ {}^3G \\ {}^3H \\ {}^1F \\ {}^1G \\ {}^1I \end{array} \right.$		
$4d^2 5s({}^2P)nx$	$\left\{ \begin{array}{l} {}^3P \\ {}^1D \\ {}^3D \\ {}^1S \\ {}^1D \\ {}^1G \\ {}^1I \end{array} \right.$	$\left\{ \begin{array}{l} {}^3F \\ {}^3G \\ {}^3H \\ {}^1F \\ {}^1G \\ {}^1I \end{array} \right.$		
$4d^2 5s({}^2S)nx$	$\left\{ \begin{array}{l} {}^3P \\ {}^1D \\ {}^3D \\ {}^1S \\ {}^1D \\ {}^1G \\ {}^1I \end{array} \right.$	$\left\{ \begin{array}{l} {}^3F \\ {}^3G \\ {}^3H \\ {}^1F \\ {}^1G \\ {}^1I \end{array} \right.$		

† Incomplete — only high multiplicity terms from  $d^2 3F$  listed.



TABLE 17. PREDICTED TERMS OF THE Nb I ISOELECTRONIC SEQUENCE

Config. $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 +$		Predicted Terms			
$4d^5$	$\left\{ \begin{array}{l} {}^6S \\ {}^2S \end{array} \right\}$	$\left\{ \begin{array}{l} {}^4P \quad {}^4D \quad {}^4F \quad {}^4G \\ {}^2P \quad {}^2D \quad {}^2F \quad {}^2G \quad {}^2H \\ {}^2D \end{array} \right\}$	$\left\{ \begin{array}{l} {}^4P \quad {}^4F \\ {}^2P \quad {}^2D \quad {}^2F \quad {}^2G \quad {}^2H \\ {}^2D \end{array} \right\}$		
$4d^3 5s^2$					
$4d^4({}^5D)nx$	$\left\{ \begin{array}{l} {}^6D \\ {}^4D \end{array} \right\}$		$ns \ (n \geq 5)$	$np \ (n \geq 5)$	$nd \ (n \geq 5)$
$4d^3 5s({}^5F)nx$	$\left\{ \begin{array}{l} {}^6F \\ {}^4F \end{array} \right\}$			$\left\{ \begin{array}{l} {}^6P^\circ \quad {}^6D^\circ \quad {}^6F^\circ \\ {}^4P^\circ \quad {}^4D^\circ \quad {}^4F^\circ \end{array} \right\}$	$\left\{ \begin{array}{l} {}^6S \\ {}^4S \end{array} \right\}$
$4d^4({}^3P)nx$	$\left\{ \begin{array}{l} {}^4P \\ {}^2P \end{array} \right\}$		$\left\{ \begin{array}{l} {}^4S^\circ \quad {}^4P^\circ \quad {}^4D^\circ \\ {}^2S^\circ \quad {}^2P^\circ \quad {}^2D^\circ \end{array} \right\}$	$\left\{ \begin{array}{l} {}^4P^\circ \quad {}^4F^\circ \quad {}^4G^\circ \\ {}^2P^\circ \quad {}^2F^\circ \quad {}^2G^\circ \end{array} \right\}$	$\left\{ \begin{array}{l} {}^6P \\ {}^4P \end{array} \right\}$
$4d^3 5s({}^3F)nx$	$\left\{ \begin{array}{l} {}^4F \\ {}^2F \end{array} \right\}$		$\left\{ \begin{array}{l} {}^4D^\circ \quad {}^4F^\circ \quad {}^4G^\circ \\ {}^2D^\circ \quad {}^2F^\circ \quad {}^2G^\circ \end{array} \right\}$	$\left\{ \begin{array}{l} {}^4D^\circ \quad {}^4F^\circ \quad {}^4G^\circ \\ {}^2D^\circ \quad {}^2F^\circ \quad {}^2G^\circ \end{array} \right\}$	$\left\{ \begin{array}{l} {}^6P \\ {}^4P \end{array} \right\}$
$4d^4({}^3H)nx$	$\left\{ \begin{array}{l} {}^4H \\ {}^2H \end{array} \right\}$		$\left\{ \begin{array}{l} {}^4G^\circ \quad {}^4H^\circ \quad {}^4I^\circ \\ {}^2G^\circ \quad {}^2H^\circ \quad {}^2I^\circ \end{array} \right\}$	$\left\{ \begin{array}{l} {}^4G^\circ \quad {}^4H^\circ \quad {}^4I^\circ \\ {}^2G^\circ \quad {}^2H^\circ \quad {}^2I^\circ \end{array} \right\}$	$\left\{ \begin{array}{l} {}^4K \\ {}^2K \end{array} \right\}$
$4d^4({}^3G)nx$	$\left\{ \begin{array}{l} {}^4G \\ {}^2G \end{array} \right\}$		$\left\{ \begin{array}{l} {}^4F^\circ \quad {}^4G^\circ \quad {}^4H^\circ \\ {}^2F^\circ \quad {}^2G^\circ \quad {}^2H^\circ \end{array} \right\}$	$\left\{ \begin{array}{l} {}^4D^\circ \quad {}^4F^\circ \quad {}^4G^\circ \quad {}^4H^\circ \\ {}^2D^\circ \quad {}^2F^\circ \quad {}^2G^\circ \quad {}^2H^\circ \end{array} \right\}$	$\left\{ \begin{array}{l} {}^4I \\ {}^2I \end{array} \right\}$



TABLE 18. THE CHEMICAL ELEMENTS—IONIZATION POTENTIALS

Z		Ele- ment	Spectrum																		
			I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVI	XVII	XVIII	XIX
1	H	13.595																			
2	He	24.580	54.403																		
3	Li	5.390	75.619	122.419																	
4	Be	9.320	18.206	153.850	217.657																
5	B	8.296	25.149	37.920	259.298	340.127															
6	C	11.264	24.376	47.864	64.476	391.986	489.84														
7	N	14.54	29.605	47.426	77.450	97.863	551.925	666.83													
8	O	13.614	35.146	54.934	77.394	113.873	138.080	739.114	871.12												
9	F	17.418	34.98	62.646	87.23	114.214	157.117	185.139	953.60												
10	Ne	21.559	41.07	64	97.16	126.4	157.91														
11	Na	5.138	47.29	71.65	98.88	138.60	172.36	208.444	264.155	299.78											
12	Mg	7.644	15.03	80.12	109.29	141.23	186.86	225.31	265.957	327.90	367.36	1761.23									
13	Al	5.984	18.823	28.44	119.96	153.77	190.42	241.93	285.13	330.1	398.5	441.9	2085.46								
14	Si	8.149	16.34	33.46	45.13	166.73	205.11	246.41	303.87	351.83	401.3	476.0	523.2								
15	P	10.55	19.65	30.156	51.354	65.007	220.414	263.31	309.26	372.62	425.46	479.4	560.3	611.4							
16	S	10.357	23.4	35.0	47.29	72.5	88.029	280.99	328.80	378.95	448.2										
17	Cl	13.01	23.80	39.90	53.5	67.80	96.7	114.27	348.3	400.7	455.3										
18	A	15.755	27.62	40.90	59.79	75.0	91.3	124.0	143.46	421											
19	K	4.339	31.81	46	60.90	-----	99.7	118	155	175.94	503.8										
20	Ca	6.111	11.87	51.21	67	84.39	-----	128	147	188	211.29	591.8	655								
21	Sc	6.56	12.80	24.75	73.9	92	111.1	-----	159	180	226	250	687								
22	Ti	6.83	13.57	27.47	43.24	99.8	120	140.8	-----	193	-----	266	291.5	788.4							
23	V	6.74	14.65	29.31	48	65.2	128.9	151	173.7	-----	-----	-----	309	336.3	897.1						
24	Cr	6.763	16.49	30.95	49.6	73	90.6	161.1	185	209.6	-----	-----	-----	355	384.2	1013.0					
25	Mn	7.432	15.64	33.69	-----	76	-----	119.24	196	222	248	-----	-----	-----	404	435	1135.9				
26	Fe	7.90	16.18	30.64	-----	-----	-----	-----	151.	235	262	290	-----	355	390	457	489				
27	Co	7.86	17.05	33.49	-----	-----	-----	-----	-----	-----	-----	305	-----	-----	-----	-----	512	547	1403		
28	Ni	7.633	18.15	35.16	-----	-----	-----	-----	-----	-----	-----	-----	350	-----	-----	455	-----	-----	607		
29	Cu	7.724	20.29	36.83	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	671	





TABLE 20. THE PERIODIC SYSTEM\*

1	1s	H 1	He 2
2	2s	Li 3	Be 4
	2p	B 5	C N O F Ne 6 7 8 9 10
3	3s	Na 11	Mg 12
	3p	Al 13	Si P S Cl A 14 15 16 17 18
4	4s	K 19	Ca 20
	3d	Sc 21	Ti V Cr Mn Fe Co Ni Cu Zn 22 23 24 25 26 27 28 29 30
	4p	Ga 31	Ge As Se Br Kr 32 33 34 35 36
5	5s	Rb 37	Sr 38
	4d	Y 39	Zr Nb Mo Tc Ru Rh Pd Ag Cd 40 41 42 43 44 45 46 47 48
	5p	In 49	Sn Sb Te I Xe 50 51 52 53 54
6	6s	Cs 55	Ba 56
	4f	La 57	Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Tm Yb 58 59 60 61 62 63 64 65 66 67 68 69 70
	5d	Lu 71	Hf Ta W Re Os Ir Pt Au Hg 72 73 74 75 76 77 78 79 80
7	6p	Tl 81	Pb Bi Po At Rn 82 83 84 85 86
	7s	Fr 87	Ra 88
	5f	Ac 89	Th Pa U Np Pu Am Cm Bk Cf 90 91 92 93 94 95 96 97 98 99 100 101 102
	6d	103	104 105 106 107 108 109 110 111 112

\*This arrangement is by Catalán. See J. Cabrera, Física general Zaragoza, Spain (1950). The electrons indicated in column two that are connected by braces have approximately the same binding energy. Consequently, for some elements one type of electron is preferred over another in the normal configuration, as for example, Cr, Nb, Pd, La, Ac, Th.

TABLE 21. INDEX—ISOELECTRONIC SEQUENCES  
[The tabular entries are page numbers]

Z	Element	Spectrum																		
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVI	XVII	XVIII	XIX
24	Cr	1	10	14	16	18	20	21	22	22		23	24	25	25					
25	Mn	27	32	37	38	40	41	42	43	44	45		46	46	47	47				
26	Fe	49	55	60	65	66	67	69	70	70	71	72	73	74	74	75	76			
27	Co	78	83	85	88	88	89	90	92			92		93	93	94	95	96		
28	Ni	97	101	103		104	104	105	106	108		108	108			110		110		
29	Cu	111	115	121				123												123
30	Zn	124	126	128	129															
31	Ga	130	131	133	134															
32	Ge	135	137	139	140	141														
33	As	142	144	146	147	148	149													
34	Se	150	152	154	156	156	157	158												
35	Br	159	161	163	164	165	166	167	167	168										
36	Kr	169	173	176	178					179										
37	Rb	180	184	185						186	186	187	188	188	188					
38	Sr	189	191		193							194	194	195	195					
39	Y	196	199	201		202							203	204	204	204				
40	Zr	205	209	212	213		214													
41	Nb	216	221	223	224	225	226	227												





# CHROMIUM

## Cr I

24 electrons

$Z=24$

Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 4s^1 {}^6S_{5/2}$

$a {}^7S_3$   $54565 \pm 1 \text{ cm}^{-1}$

I. P. 6.763 volts

The arc spectrum of chromium has an interesting history. As early as 1907 Miller found pairs of lines having similar Zeeman patterns, which were shown by Richter in 1914 to be members of the two outstanding triplets in the blue and violet. This early work inspired a systematic search, started in 1918 at the National Bureau of Standards, for all groups of lines exhibiting recurring constant wave number differences, and additional triplets in the near infrared were reported by Kiess and Meggers in 1920.

This spectrum is unique in that the discovery of further regularities in Cr I was made independently and almost simultaneously at three places. In 1922 when Catalán announced his discovery of multiplets in the spectra of manganese, he also reported a few in Cr I. At nearly the same time Fr. Gieseler, from her study of the Zeeman effect, found similar groups of related lines in Cr I. Shortly afterwards C. C. Kiess and H. K. Kiess reported the arrangement of the strong triplets in two systems of series including both sharp and diffuse members.

The present term list has been furnished by C. C. Kiess in advance of publication, especially for inclusion here. He has revised and extended the earlier work by Catalán and others. Approximately 2800 lines are classified in the range between 1988 Å and 11610 Å, resulting from combinations among 155 terms. Four multiplicities, singlets, triplets, quintets, and septets, are known, the terms of each being connected by observed intersystem combinations. The limit is excellently determined from three series of  ${}^7S$ ,  ${}^5S$ , and  ${}^7P^\circ$  terms, two of three members each, and one of four members, which are accurately represented by a Ritz formula.

In 1945 Kiess generously furnished the writer with his analysis for inclusion in her "*Revised Multiplet Table*." His later work has introduced changes in both the notation and the analysis she used. In order to avoid confusion these changes are recorded below, the first entry (R M T), denoting the data used in the "*Revised Multiplet Table*", the second, (A E L), the present revision of that material:

Changes in Notation			
R M T	A E L	R M T	A E L
$f {}^5P$	$e {}^5P$	$s {}^1G^\circ$	$r {}^1G^\circ$
$z {}^1H^\circ$	$y {}^1H^\circ$	$q {}^1H^\circ$	$p {}^1H^\circ$
$z {}^1I^\circ$	$y {}^1I^\circ$	$w {}^1I^\circ$	$x {}^1H^\circ$
$y {}^1I^\circ$	$x {}^1I^\circ$	$u' {}^5F^\circ$	$t {}^5F^\circ$
$w {}^5F^\circ$	$v {}^5F^\circ$	$t {}^5F^\circ$	$s {}^5F^\circ$
$v {}^5F^\circ$	$u {}^5F^\circ$	$s {}^5F^\circ$	$r {}^5F^\circ$
$u {}^5F^\circ$	$s {}^5F^\circ$	$r {}^5F^\circ$	$q {}^5F^\circ$
$t {}^5F^\circ$	$r {}^5F^\circ$	$1^\circ$	$2^\circ$

## Cr I—Continued

Changes in Analysis		
Desig.	R M T	A E L
$g\ ^3D_1$	47699. 18	47700. 18
$v\ ^3P_2^\circ$	Missing	56802. 50
$t\ ^3P_{2,1}^\circ$	-----	Rejected
$x\ ^3D_1^\circ$	48681. 53:	48839. 90
$u\ ^3H_4^\circ$	Missing	55915. 50
$w\ ^3I_6^\circ$	60005. 4	59806. 27
$w\ ^5D_0^\circ$	Missing	46081. 27
$t\ ^5D_0^\circ$	52000. 59	51999. 62
$s\ ^5D_2^\circ$	53540. 8	53558. 05

All three-place  $g$ -values in the table and those for the levels  $a\ ^5P_3$ ,  $z\ ^5S_2^\circ$ , and  $u\ ^5P_{2,1}^\circ$  have been calculated by Kiess from Zeeman patterns observed at the Massachusetts Institute of Technology. The rest are from the paper by Catalán and Sancho.

This detailed analysis will be published by the National Bureau of Standards in the near future. With this splendid piece of work Kiess has provided another highly complex spectrum which affords an excellent confirmation of Hund's general theory of atomic spectra.

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## Cr I

## Cr I

Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>	Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>
$3d^5(a^6S)4s$	$a^7S$	3	0.00		2.007	$3d^4 4s^2$	$b^3G$	3	27597.22		
$3d^5(a^6S)4s$	$a^5S$	2	7593.16		2.006			4	27703.84	106.62	
$3d^4 4s^2$	$a^5D$	0	7750.78		0.000			5	27816.88	113.04	
		1	7810.82	60.04	1.501	$3d^4 4s(a^6D)4p$	$y^7P^\circ$	2	27728.87		2.341
		2	7927.47	116.65	1.496			3	27820.23	91.36	1.929
		3	8095.21	167.74	1.501			4	27935.26	115.03	1.761
		4	8307.57	212.36	1.497	$3d^5(b^4D)4s$	$a^3D$	3	28637.00		
$3d^5(a^4G)4s$	$a^5G$	2	20517.40		0.37			2	28682.18	-45.18	
		3	20520.92	3.52	0.93			1	28679.43	2.75	
		4	20523.69	2.77	1.13	$3d^4 4s(a^6D)4p$	$y^5P^\circ$	1	29420.90		2.513
		5	20523.94	0.25	1.25			2	29584.62	163.72	1.836
		6	20519.60	-4.34	1.33			3	29824.75	240.13	1.669
$3d^5(a^4P)4s$	$a^5P$	3	21840.84		1.60	$3d^4 4s(a^6D)4p$	$z^5F^\circ$	1	30787.30		0.002
		2	21847.88	-7.04	1.847			2	30853.82	71.52	0.997
		1	21856.94	-9.06	2.500			3	30965.46	106.64	1.245
$3d^4 4s^2$	$a^3P$	0	23163.27					4	31106.37	140.91	1.345
		1	23512.00	348.73				5	31280.35	173.98	1.396
		2	24093.16	581.16		$3d^5(a^2D)4s$	$b^3D$	3	31009.00		
$3d^5(a^6S)4p$	$z^7P^\circ$	2	23305.01		2.334			2	31028.33	-19.33	
		3	23386.35	81.34	1.92			1	31048.85	-20.52	
		4	23498.84	112.49	1.752	$3d^5(a^2I)4s$	$a^3I$	7	31048.00		
$3d^4 4s^2$	$a^3H$	4	23933.90					6	31049.33	-1.33	
		5	24056.11	122.21				5	31055.35	-6.02	
		6	24200.23	144.12		$3d^5(b^4F)4s$	$a^5F$	1	31352.42		
$3d^5(b^4D)4s$	$b^5D$	0	24277.06		0.00			2	31355.21	2.79	
		1	24286.54	9.48	1.48			3	31364.33	9.12	
		2	24299.89	13.35	1.51			4	31377.96	13.63	
		3	24303.94	4.05	1.55			5	31393.40	15.44	
		4	24282.34	-21.60	1.51	$3d^4 4s^2$	$a^1G$	4	31987.06		
$3d^5(a^4G)4s$	$a^3G$	3	24833.86			$3d^4 4s^2$	$a^1I$	6	32097.36		
		4	24897.55	63.69		$3d^5(a^2F)4s$	$b^3F$	2	33040.10		
		5	25038.61	141.06				3	33060.74	20.64	
$3d^4 4s^2$	$a^3F$	2	24940.61					4	33113.27	52.53	
		3	25106.34	165.73		$3d^4 4s(a^6D)4p$	$z^5D^\circ$	0	33338.20		-0.003
		4	25177.39	71.05				1	33423.79	85.59	1.499
$3d^4 4s(a^6D)4p$	$z^7F^\circ$	0	24971.21					2	33542.11	118.32	1.497
		1	25010.64	39.43	1.52			3	33671.55	129.44	1.497
		2	25089.20	78.56	1.50			4	33816.06	144.51	1.499
		3	25206.02	116.82	1.49	$3d^4 4s(a^4D)4p$	$z^3P^\circ$	0	33762.56		0.00
		4	25359.62	153.60	1.51			1	33897.26	134.70	1.49
		5	25548.64	189.02	1.51			2	34190.49	293.23	1.55
		6	25771.40	222.76	1.53	$3d^5(a^2I)4s$	$b^1I$	6	33762.74		
$3d^5(a^6S)4p$	$z^5P^\circ$	3	26787.50		1.670	$3d^4 4s^2$	$c^3D$	1	33906.65		
		2	26796.28	-8.78	1.830			2	33935.65	29.00	
		1	26801.98	-5.65	2.512			3	33934.88	-0.77	
$3d^5(a^4P)4s$	$b^3P$	0	27163.20			$3d^6$	$c^5D$	4	35398.02		
		1	27176.22	13.02				3	35501.26	-103.24	
		2	27223.05	46.83				2	35572.94	-71.68	
$3d^4 4s(a^6D)4p$	$z^7D^\circ$	1	27300.19		3.01			1	35618.51	-45.57	
		2	27382.18	81.99	1.99			0	35640.69	-22.18	
		3	27500.37	118.19	1.76	$3d^5(b^4F)4s$	$c^3F$	2	35807.90		
		4	27649.71	149.34	1.66			3	35813.73	5.83	
		5	27825.45	175.74	1.61			4	35862.82	49.09	



## Cr I—Continued

## Cr I—Continued

Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>	Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>
$3d^5(b^2H)4s$	$b^3H$	4 5 6	35870.53 35884.40 35934.02	13.87 49.62		$3d^5(a^4G)4p$	$z^5G^\circ$	2 3 4 5 6	42515.35 42538.81 42564.85 42589.25 42605.81	23.46 26.04 24.40 16.56	0.35 1.23 1.32
$3d^4 4s(a^4D)4p$	$z^3F^\circ$	2 3 4	35897.87 36034.22 36212.15	136.35 177.93		$3d^4 4s(b^4P)4p$	$z^5S^\circ$	2	43124.88		1.96
$3d^5(b^2F)4s$	$d^3F$	2 3 4	36558.55 36552.13 36577.73	—6.42 25.60		$3d^5(a^6S)4d$	$e^5D$	4 3 2 1 0	44050.87 44068.72 44080.90 44088.92 44092.80	—17.85 —12.18 —8.02 —3.88	
$3d^5(a^6S)5s$	$e^7S$	3	36895.73			$3d^5(a^4P)4p$	$w^5P^\circ$	1 2 3	44125.90 44186.92 44259.36	61.02 72.44	2.74 1.79 1.68
$3d^5(b^2G)4s$	$c^3G$	3 4 5	37205.88 37244.17 37233.50	38.29 —10.67		$3d^4 4s(a^4H)4p$	$z^5I^\circ$	4 5 6 7 8	44246.70 44307.96 44393.10 44514.44 44666.55	61.26 85.14 121.34 152.11	
$3d^5(a^6S)5s$	$e^5S$	2	37883.34			$3d^4 4s(a^4H)4p$	$y^5G^\circ$	2 3 4 5 6	44299.98 44373.34 44534.46 44591.46 44746.26	73.36 161.12 57.00 154.80	0.35 0.93
$3d^5(b^2H)4s$	$a^1H$	5	38537.68			$3d^4 4s(b^4P)4p$	$v^5P^\circ$	1 2 3	44666.74 44875.19 45113.22	208.45 238.03	2.47 1.65
$3d^4 4s(a^4D)4p$	$z^3D^\circ$	1 2 3	38597.06 38730.67 38911.33	133.61 180.66		$3d^4 4s(a^4F)4p$	$x^5F^\circ$	1 2 3 4 5	45201.84 45225.20 45255.51 45286.08 45306.45	23.36 30.31 30.57 20.37	1.41
$3d^5(b^2G)4s$	$b^1G$	4	39158.63			$3d^5(a^4G)4p$	$z^3H^\circ$	6 5 4	45348.73 45354.18 45358.63	—5.45 —4.45	
$3d^4 4s(a^4D)4p$	$y^5F^\circ$	1 2 3 4 5	40906.46 40971.29 41086.26 41224.78 41393.47	64.83 114.97 138.52 168.69	0.004 1.28 1.246 1.360	$3d^5(a^4G)4p$	$y^5H^\circ$	3 4 5 6 7	45566.02 45614.88 45663.28 45707.36 45741.49	48.86 48.40 44.08 34.13	0.52 1.29
$3d^4 4s(a^4D)4p$	$x^5P^\circ$	1 2 3	40930.31 40982.97 41043.35	52.66 60.38	2.455 1.76 1.640	$3d^5(a^6S)6s$	$f^7S$	3	45643.38		2.05
$3d^4 4s(a^4D)4p$	$y^5D^\circ$	0 1 2 3 4	41224.80 41289.17 41409.03 41575.10 41782.19	64.37 119.86 166.07 207.09	—0.001 1.503 1.504 1.503 1.500	$3d^5(a^4P)4p$	$y^3P^\circ$	0 1 2	45722.59 45719.20 45734.32	—3.39 15.12	
$3d^4 4s(a^4H)4p$	$z^5H^\circ$	3 4 5 6 7	42025.60 42079.81 42153.74 42252.17 42387.32	54.21 73.93 98.43 135.15		$3d^5(a^4G)4p$	$y^3F^\circ$	2 3 4	45966.45 46000.36 46058.20	33.91 57.84	
$3d^4 4s(b^4P)4p$	$x^5D^\circ$	0 1 2 3 4	42218.37 42292.96 42438.82 42648.26 42908.57	74.59 145.86 209.44 260.31	—0.003 1.501 1.494 1.498 1.497	$3d^5(a^6S)6s$	$f^5S$	2	45967.81		
$3d^5(a^6S)5p$	$x^7P^\circ$	2 3 4	42238.04 42254.11 42275.20	16.07 21.09		$3d^5(a^4P)4p$	$y^3D^\circ$	1 2 3	46077.09 46109.26 46174.40	32.17 65.14	1.24 1.33
$3d^5(a^6S)4d$	$e^7D$	1 2 3 4 5	42253.42 42254.52 42256.26 42258.37 42261.06	1.10 1.74 2.11 2.69	1.55						



## Cr I—Continued

## Cr I—Continued

Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>	Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>
$3d^5(a^4P)4p$	$w^5D^\circ$	0	46081.27			$3d^4 4s(b^4G)4p$	$u^5F^\circ$	1	47877.55		0.00
		1	46298.32	217.05				2	47917.93	40.38	1.04
		2	46349.50	51.18				3	47974.53	56.60	1.36
		3	46368.35	18.85				4	48014.40	39.87	
		4	46422.46	54.11				5	47985.76	-28.64	1.38
$3d^4 4s(a^6D)5s$	$f^7D$	1	46448.60		2.99	$3d^4 4s(c^4D)4p$	$t^5F^\circ$	1	48210.04		
		2	46524.84	76.24	1.99			2	48217.83	7.79	
		3	46637.21	112.37	1.77			3	48251.91	34.08	
		4	46783.06	145.85	1.63			4	48042.83	-209.08	
		5	46958.98	175.92	1.61			5			
$3d^5(a^4G)4p$	$w^5F^\circ$	1	46678.35	-1.29		$3d^4 4s(b^4P)4p$	$x^3P^\circ$	0	48226.36		
		2	46677.06	11.18				1	48331.30	104.94	
		3	46688.24	32.30	1.25			2	48458.67	127.37	
		4	46720.54	-15.56		$3d^4 4s(a^4H)4p$	$y^3H^\circ$	4	48288.37		
		5	46704.98		1.37			5	48310.39	22.02	
$3d^4 4s(a^4H)4p$	$z^3G^\circ$	3	46846.77					6	48445.35	134.96	
		4	46905.03	58.26		$3d^4 4s(a^6D)5s$	$f^5D$	0	48488.23		
		5	46985.87	80.84				1	48507.56	19.33	
$3d^4 4s(c^4D)4p$	$u^5P^\circ$	3	46878.61	-89.09	1.68			2	48558.57	51.01	
		2	46967.70	-54.05	1.83			3	48661.59	103.02	
		1	47021.75		2.43			4	48824.50	162.91	1.46
$3d^4 4s(b^4G)4p$	$x^5G^\circ$	2	47047.47		0.45	$3d^4 4s(a^4F)4p$	$x^3G^\circ$	3	48515.08		
		3	47125.70	78.23	0.96			4	48562.16	47.08	
		4	47189.87	64.17				5	48786.39	224.23	
		5	47228.80	38.93	1.27						
		6	47222.27	-6.53	1.44			1°	48636.14		
$3d^5(a^4G)4p$	$y^3G^\circ$	3	47048.48			$3d^4 4s(b^4P)4p$	$x^3D^\circ$	1	48839.90		
		4	47054.91	6.43				2	49027.58	187.68	
		5	47055.31	0.40				3	49310.86	283.28	
$3d^4 4s(b^4P)4p$	$z^3S^\circ$	1	47088.40			$3d^5(a^6S)7s$	$g^7S$	3	49177.83		
$3d^4 4s(a^4H)4p$	$z^3I^\circ$	5	47586.06			$3d^4 4s(b^4G)4p$	$w^3G^\circ$	3	49370.70		
		6	47630.43	44.37				4	49453.94	83.24	
		7	47692.63	62.20				5	49538.06	84.12	
$3d^4 4s(b^4G)4p$	$x^5H^\circ$	3	47621.31			$3d^4 4s(a^4F)4p$	$w^5G^\circ$	2	49466.77		
		4	47688.51	67.20				3	49519.72	52.95	
		5	47793.82	105.31				4	49573.03	53.31	1.04
		6	47942.29	148.47		$3d^5(a^4P)4p$	$y^3S^\circ$	5	49617.61	44.58	
		7	48140.18	197.89				6	49635.16	17.55	1.35
$3d^5(b^4D)4p$	$v^5F^\circ$	1	47629.66			$3d^5(b^4D)4p$	$t^5P^\circ$	1	49477.04		
		2	47631.51	1.85				2	49588.97		
		3	47636.25	4.74				3	49593.08	9.11	2.48
		4	47639.84	3.59				4	49812.46	214.38	1.88
		5	47644.76	4.92	1.34	$3d^5(b^4D)4p$	$x^3F^\circ$	2	49620.69		
$3d^5(a^6S)6p$	$w^7P^\circ$	2	47697.44					3	49650.22	-29.53	
		3	47708.59	11.15				2	49652.76	-2.54	
		4	47719.08	10.49		$3d^5(a^4P)4p$	$y^5S^\circ$	2	49822.59		2.00
$3d^5(a^6S)5d$	$g^7D$	1	47700.18			$3d^4 4s(a^6D)5p$	$s^5F^\circ$	1	50018.80		
		2	47700.95	0.77				2	50057.61	38.81	
		3	47702.30	1.35				3	50102.04	44.43	1.27
		4	47704.66	2.36				4	50210.87	108.83	1.25
		5	47709.80	5.14				5	50253.27	42.40	1.39
$3d^5(b^4D)4p$	$v^5D^\circ$	0	47788.08		0.00						
		1	47772.30	-15.78	1.37						
		2	47786.10	13.80	1.39						
		3	47814.40	28.30	1.53						
		4	47866.48	52.08	1.50						

## Cr I—Continued

## Cr I—Continued

Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>	Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>		
$3d^5(b^4D)4p$	$w^3D^\circ$	1	50105.54			$3d^4 4s(a^4D)5p$	$q^5F^\circ$	1	54198.23				
		2	50184.10	78.56				2	54252.19	53.96			
		3	50264.48	80.38				3	54328.95	76.76			
$3d^4 4s(c^4D)4p$	$u^3D^\circ$	4	50557.56		1.54			4	54425.29	96.34			
		3	50628.11	-70.55	1.54			5	54536.53	111.24			
		2	50654.76	-26.65	1.51	$e^5F$		1	54296.76	86.60			
		1	50662.77	-8.01	1.46			2	54383.36	92.93			
		0	50661.20	1.57	0.00			3	54476.29	96.55			
$3d^4 4s(a^4F)4p$	$w^3F^\circ$	2	50890.15					4	54572.84	87.47			
		3	50950.42	60.27				5	54660.31				
		4	51059.79	109.37		$3d^5(a^2I)4p$	$z^3K^\circ$	6	54316.83				
$3d^5(b^4D)4p$	$w^3P^\circ$	0	51176.88					7	54404.94	88.11			
		1	51246.87	69.99				8	54498.27	93.33			
		2	51286.52	39.65		Cr II( $^6S_{2/2}$ )		Limit	54565				
$3d^5(a^2I)4p$	$z^3H^\circ$	5	51401.24			$3d^4 4s(a^4D)5s$	$g^5D$	0					
								1	54671.90				
$3d^4 4s(a^4F)4p$	$t^3D^\circ$	0	51999.62					2	54818.55	146.65			
		1	52003.06	3.44				3	54986.82	168.27			
		2	52012.44	9.38				4	55209.01	222.19			
		3	52031.72	19.28		$3d^4 4s(a^2H)4p$	$w^3H^\circ$	4	54736.55				
		4	52064.27	32.55				5	54799.18	62.63			
$3d^5(a^2I)4p$	$y^3I^\circ$	5	52591.94					6	54886.82	87.64			
		6	52660.61	68.67		$3d^4 4s(a^2H)4p$	$z^3I^\circ$	6	54800.26				
		7	52677.88	17.27									
		2°	52720.07			$3d^4 4s(a^4D)5s$	$e^3D$	1	54804.69				
$3d^4 4s(b^4G)4p$	$x^3H^\circ$	6	52914.94					2	54974.64	169.95			
		5	52885.39	29.55				3	55204.79	230.15			
		4	52963.44	-78.05		$3d^5(a^2I)4p$	$v^3H^\circ$	4	54810.94				
								5	54929.72	118.78			
$3d^5(b^4F)4p$	$r^3F^\circ$	1	53011.65					6	54866.57	-63.15			
		2	53037.52	25.87		$3d^5(a^2D)4p$	$v^3D^\circ$	1	54956.59				
		3	53073.90	36.38				2	55152.63	196.04			
		4	53117.54	43.64				3	55451.64	299.01			
		5	53172.33	54.79	1.42	$3d^5(a^2I)4p$	$z^3K^\circ$	7	54970.23				
$3d^4 4s(a^6D)4d$	$e^3G$	1	53148.35			$3d^4 4s(c^2F)4p$	$v^3F^\circ$	2	54992.93				
		2	53177.87	29.52				3	55101.87	108.94			
		3	53228.49	50.62				4	55207.40	105.53			
		4	53298.90	70.41		$3d^5(a^2F)4p$	$u^3F^\circ$	4	55120.77				
		5	53393.50	94.60				3	55352.72	-231.95			
		6	53517.85	124.35				2	55473.67	-120.95			
		7	53662.64	144.79		$3d^5(a^2I)4p$	$y^3I^\circ$	6	55516.69				
$3d^4 4s(a^6D)4d$	$e^3F$	0	53376.7			$3d^4 4s(a^2H)4p$	$x^3I^\circ$	5	55686.46				
		1	53414.1	37.4				6	55741.11	54.65			
		2	53467.4	53.3				7	55799.10	57.99			
		3	53563.0	95.6		$3d^5(b^2H)4p$	$u^3H^\circ$	6	55908.12				
		4	53703.9	140.9				5	55874.98	33.14			
		5	53848.1	144.2				4	55915.50	-40.52			
		6	54040.2	192.1		$3d^4 4s(a^6D)5p$	$s^3D^\circ$	0					
$3d^4 4s(a^6D)5p$	$s^3D^\circ$	1				$3d^4 4s(a^2H)4p$	$y^3H^\circ$	5	55945.08				
		2	53558.05					$3d^5(b^4F)4p$	$v^5G^\circ$	2	56155.12		
		3	53640.74	82.69						3	56209.81	54.69	
		4	53782.77	142.03						4	56279.56	69.75	
$3d^4 4s(a^2G)4p$	$v^3G^\circ$	3	53804.84							5	56361.86	82.30	
		4	53927.59	122.75						6	56449.10	87.24	
		5	54078.13	150.54									



## Cr I—Continued

## Cr I—Continued

Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>	Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>
$3d^5(a^2D)4p$	$v^3P^\circ$	2 1 0	56591.88 56722.60 56802.50	-130.72 -79.90		$3d^5(b^4F)4p$	$q^3F^\circ$	2 3 4	60253.00 60326.04 60367.38	73.04 41.34	
$3d^5(b^2H)4p$	$u^3G^\circ$	3 4 5	56985.67 57033.60 57088.25	47.93 54.65		$3d^44s(b^2I)4p$	$v^3I^\circ$	5 6 7	60427.63 60527.55 60656.97	99.92 129.42	
$3d^44s(a^2P)4p$	$u^3P^\circ$	2 1 0	57087.70 57132.59 57154.59	-44.89 -22.00		$3d^5(b^2H)4p$	$x^1I^\circ$	6	60441.42		
$3d^44s(a^2D)6p$	$p^5F^\circ$	1 2 3 4 5	57096.62 57100.66 57186.60 57237.50 57327.66	4.04 85.94 50.90 90.16			$s^3G^\circ$	5 4 3	60467.85 60503.94 60518.16	-36.09 -14.22	
$3d^5(b^2F)4p$	$t^3F^\circ$	2 3 4	57220.67 57276.42 57335.47	55.75 59.05		$3d^5(b^2F)4p$	$s^3D^\circ$	3 2 1	60615.84 60629.87 60678.12	-14.03 -48.25	
$3d^5(a^4G)5s$	$e^5G$	2 3 4 5 6	57350.65 57361.24 57372.78 57382.93 57389.32	10.59 11.54 10.15 6.39		$3d^44s(c^2G)4p$	$p^3F^\circ$	2 3 4	60819.50 60960.58	141.08	
$3d^44s(c^2G)4p$	$t^3G^\circ$	3 4 5	57557.03 57587.36 57702.36	30.33 115.00		$3d^44s(c^2G)4p$	$s^3H^\circ$	4 5 6	60870.63 61008.07 61191.64	137.44 183.57	
$3d^44s(a^4D)5p$	$r^5D^\circ$	0 1 2 3 4	57958.42 57995.04 58063.80 58147.76 58292.62	36.62 68.76 83.96 144.86		$3d^5(b^2G)4p$	$r^3G^\circ$	3 4 5	61078.28 61123.20 61161.35	44.92 38.15	
	$e^3G$	3 4 5	57984.94 57992.15 57990.23	7.21 -1.92		$3d^44s(b^4P)5s$	$e^5P$	1 2 3	61558.17 61687.56 61850.17	129.39 162.61	
$3d^5(a^2D)4p$	$s^3F^\circ$	2 3 4	58162.84 58202.65 58167.89	39.81 -34.76			$3^\circ$	2	61675.72		
$3d^44s(a^2P)4p$	$u^3D^\circ$	1 2 3	58725.28 58860.23 59122.15	134.95 261.92			$q^3G^\circ$	3 4 5	61930.05 61976.50 62037.60	46.45 61.10	
$3d^44s(a^2G)4p$	$t^3H^\circ$	4 5 6	58728.29 58754.58 58775.36	26.29 20.78		$3d^5(a^4G)4d$	$f^5G$	2 3 4 5 6	62646.60 62661.96 62671.00 62690.96 62673.92	15.36 9.04 19.96 -17.04	
$3d^5(a^2F)4p$	$t^3D^\circ$	1 2 3	58870.20 58772.03 58924.12	-98.17 152.09		$3d^44s(b^2I)4p$	$r^3H^\circ$	4 5 6	62762.06 62830.26 62903.03	68.20 72.77	
$3d^44s(a^2G)4p$	$r^3F^\circ$	2 3 4	59357.90 59417.01 59487.71	59.11 70.70		$3d^5(b^2G)4p$	$q^3H^\circ$	4 5 6	63116.80 63144.36 63182.94	27.56 38.58	
$3d^5(b^2H)4p$	$w^3I^\circ$	5 6 7	59806.27 59884.27 59957.46	78.00 73.19		$3d^5(d^2G)4p$	$p^3H^\circ$	4 5 6	63341.81 63927.27 63997.86	85.46 70.59	
$3d^5(b^2H)4p$	$x^1H^\circ$	5	60005.60			$3d^44s(a^4H)5s$	$e^5H$	3 4 5 6 7	64712.04 64751.42 64802.08 64836.30 64940.28	39.38 50.66 34.22 103.98	
$3d^44s(a^2P)4p$	$x^3S^\circ$	1	60084.09			$3d^5(d^2G)4p$	$p^3G^\circ$	3 4 5	66008.95 66094.06 66180.34	85.11 86.28	

February 1950.

Cr I OBSERVED TERMS\*

Config. $1s^2 2s^2 2p^6 3s^2 3p^5 \pm$	Observed Terms				
	$a^3P$	$a^5D$ $c^3D$	$a^3F$ $a^1G$	$a^3H$ $a^1I$	
$3d^4 4s^3$					
$3d^5$		$c^5D$			
		$ns (n \geq 4)$			$np (n \geq 4)$
$3d^5(a^6S)nx$	$\{a, e, f, g^7S$ $\{a, e, f, g^5S$				$z, x, w^7P^o$ $z^5P^o$
$3d^4 4s(a^6D)nx$	$\{f^7D$ $f^5D$				$y^7P^o$ $z^7D^o$ $z^7F^o$ $y^5P^o$ $z, s, r^5D^o$ $z, s, r^5F^o$
$3d^4 4s(a^4D)nx$	$\{g^6D$ $e^3D$				$x^6P^o$ $y, r^5D^o$ $y, q^5F^o$ $z^3P^o$ $z^3D^o$ $z^3F^o$
$3d^5(a^4G)nx$	$\{a, e^6G$ $a^3G$				$w^6F^o$ $z^5G^o$ $y^6H^o$ $y^3F^o$ $y^3G^o$ $z^3H^o$
$3d^5(a^4P)nx$	$\{a^5P$ $b^3P$				$w^5P^o$ $y^5D^o$ $y^5H^o$ $y^3P^o$ $y^3D^o$ $z^3H^o$
$3d^5(b^4D)nx$	$\{b^5D$ $a^3D$				$t^5P^o$ $v^5D^o$ $v^5F^o$ $w^3P^o$ $w^3D^o$ $x^3F^o$
$3d^4 4s(b^4P)nx$	$\{e^5P$				$v^5P^o$ $x^5D^o$ $x^5H^o$ $x^3P^o$ $x^3D^o$ $z^3H^o$
$3d^5(a^4I)nx$	$\{a^4I$ $b^4I$				$y^3I^o$ $z^3K^o$ $y^1I^o$ $z^1K^o$
$3d^4 4s(a^4H)nx$	$\{e^6H$				$v^6H^o$ $z^6H^o$ $y^6H^o$ $z^1H^o$ $z^1I^o$ $z^3I^o$
$3d^4 4s(a^4F)nx$	$\{x^6F^o$ $w^3F^o$				$y^6G^o$ $z^6G^o$ $w^6G^o$ $z^3G^o$ $x^3G^o$
$3d^5(a^3D)nx$	$\{b^3D$				$v^3P^o$ $v^3D^o$ $s^3F^o$



$3d^5(a^2F)nx$	$b^3F$	$t^3D^\circ$	$u^3F^\circ$	
$3d^5(b^4F)nx$	$a^5F$ $c^3F$		$r^5F^\circ$ $q^3F^\circ$	$v^5G^\circ$
$3d^4 4s(b^4G)nx$			$u^5F^\circ$	$x^5H^\circ$ $x^5H^\circ$
$3d^4 4s(a^2H)nx$				$w^5H^\circ$ $y^5H^\circ$ $x^5I^\circ$ $z^5I^\circ$
$3d^4 4s(a^2P)nx$		$x^3S^\circ$	$u^3P^\circ$	
$3d^5(b^2F)nx$	$d^3F$		$t^3F^\circ$	
$3d^5(b^2H)nx$	$b^3H$ $a^1H$			
$3d^4 4s(a^2G)nx$				
$3d^4 4s(c^4D)nx$			$u^3G^\circ$	$u^3H^\circ$ $x^3H^\circ$ $t^3H^\circ$
$3d^5(b^2G)nx$	$c^3G$ $b^1G$		$t^5F^\circ$	$v^3G^\circ$
$3d^4 4s(c^2G)nx$				$r^3G^\circ$
$3d^4 4s(c^2F)nx$			$p^3F^\circ$	$t^3G^\circ$
$3d^4 4s(b^2I)nx$			$v^3F^\circ$	$s^3H^\circ$
$3d^5(d^2G)nx$				$r^3H^\circ$ $p^3H^\circ$ $v^3I^\circ$
<hr/>				
	$nd (n \geq 4)$			
<hr/>				
$3d^5(a^6S)nx$	$e, g^7D$ $e^5D$			
$3d^4 4s(a^6D)nx$	$e^7F$			
$3d^5(a^4G)nx$	$e^7G$ $f^5G$			

\*For predicted terms in the spectra of the Cr I isoelectronic sequence, see Vol. II, Introduction.

## Cr II

(V I sequence; 23 electrons)

Z=24

Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 {}^6S_{5/2}$  $a {}^6S_{5/2}$  133060  $\text{cm}^{-1}$ 

I. P. 16.49 volts

The present term list is the result of an extensive and detailed analysis of this complex spectrum recently completed by C. C. Kiess especially for inclusion here. His wavelength list extends from 1700 Å to 7300 Å, based on spectrograms secured at the National Bureau of Standards and at the Mt. Wilson Observatory; also at Princeton for the region shorter than 2000 Å. Approximately 1950 classified lines and about 500 multiplets are now known.

Three series of two members each,  ${}^6D$ ,  ${}^4D$ , and  ${}^4G$ , give a limit that is known to be high. The correction derived from longer known series in related spectra has been estimated by H. N. Russell as about  $-0.37$  ev, or roughly  $-2940 \text{ cm}^{-1}$ . This adjustment has been made in the limit quoted here.

Intersystem combinations connect the terms of all multiplicities.

The low singlet terms from  $3d^4$  in Cr III have not yet been found, although terms from these limits are known in Cr II. In the array of observed terms these limit terms have been inserted in the numerical order in which they appear in the table. The prefixes "a" have been assumed for them.

## REFERENCES

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 C. C. Kiess, J. Research Nat. Bur. Std. **47**, 385, RP2266 (1951). (I P) (T) (C L) (Z E)  
 H. N. Russell, J. Opt. Soc. Am. **40**, 619 (1950). (I P)

## Cr II

## Cr II

Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>	Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>
$3d^5$	$a {}^6S$	$2\frac{1}{2}$	0. 00			$3d^4(a {}^3H)4s$	$a {}^4H$	$3\frac{1}{2}$	30156. 94		0. 667
$3d^4(a {}^5D)4s$	$a {}^5D$	$0\frac{1}{2}$	11962. 00		3. 323			$4\frac{1}{2}$	30219. 04	62. 10	0. 978
		$1\frac{1}{2}$	12032. 72	70. 72	1. 867			$5\frac{1}{2}$	30298. 77	79. 73	1. 162
		$2\frac{1}{2}$	12148. 00	115. 28	1. 669			$6\frac{1}{2}$	30391. 94	93. 17	1. 234
		$3\frac{1}{2}$	12303. 98	155. 98	1. 578	$3d^4(a {}^3F)4s$	$a {}^4F$	$1\frac{1}{2}$	31083. 11		0. 418
		$4\frac{1}{2}$	12496. 79	192. 81	1. 554			$2\frac{1}{2}$	31117. 59	34. 48	1. 032
$3d^4(a {}^5D)4s$	$a {}^4D$	$0\frac{1}{2}$	19528. 38		0. 000			$3\frac{1}{2}$	31168. 78	51. 19	1. 246
		$1\frac{1}{2}$	19631. 28	102. 90	1. 192			$4\frac{1}{2}$	31219. 49	50. 71	1. 340
		$2\frac{1}{2}$	19798. 01	166. 73	1. 370	$3d^5$	$a {}^2D$	$2\frac{1}{2}$	31351. 15		
		$3\frac{1}{2}$	20024. 18	226. 17	1. 427			$1\frac{1}{2}$	31531. 62	-180. 47	
$3d^5$	$a {}^4G$	$2\frac{1}{2}$	20512. 62		0. 599	$3d^5$	$a {}^2F$	$3\frac{1}{2}$	32355. 94		
		$3\frac{1}{2}$	20518. 33	5. 71	0. 994			$2\frac{1}{2}$	32603. 73	-247. 79	
		$4\frac{1}{2}$	20519. 85	1. 52	1. 161	$3d^5$	$b {}^4F$	$1\frac{1}{2}$	32844. 92		
		$5\frac{1}{2}$	20512. 75	-7. 10	1. 278			$2\frac{1}{2}$	32855. 09	10. 17	
$3d^5$	$a {}^4P$	$2\frac{1}{2}$	21822. 86		1. 590			$3\frac{1}{2}$	32836. 84	-18. 25	
		$1\frac{1}{2}$	21824. 82	-1. 96	1. 717			$4\frac{1}{2}$	32854. 46	17. 62	
		$0\frac{1}{2}$	21824. 25	0. 57	2. 693	$3d^4(a {}^3G)4s$	$b {}^4G$	$2\frac{1}{2}$	33418. 11		0. 588
$3d^5$	$b {}^4D$	$3\frac{1}{2}$	25033. 95		1. 432			$3\frac{1}{2}$	33521. 23	103. 12	1. 024
		$2\frac{1}{2}$	25047. 04	-13. 09	1. 381			$4\frac{1}{2}$	33619. 13	97. 90	1. 185
		$1\frac{1}{2}$	25043. 10	3. 94	1. 207			$5\frac{1}{2}$	33694. 47	75. 34	1. 276
		$0\frac{1}{2}$	25035. 64	7. 46	-0. 045	$3d^4(a {}^3H)4s$	$a {}^2H$	$4\frac{1}{2}$	34631. 14		
$3d^4(a {}^3P)4s$	$b {}^4P$	$0\frac{1}{2}$	29952. 08		2. 685			$5\frac{1}{2}$	34813. 06	181. 92	
		$1\frac{1}{2}$	30307. 60	355. 52	1. 756	$3d^4(a {}^3P)4s$	$a {}^2P$	$0\frac{1}{2}$	34659. 48		0. 670
		$2\frac{1}{2}$	30864. 61	557. 01	1. 572			$1\frac{1}{2}$	35356. 06	696. 58	1. 331
$3d^5$	$a {}^2I$	$5\frac{1}{2}$	30143. 72			$3d^4(a {}^3F)4s$	$b {}^2F$	$2\frac{1}{2}$	35569. 02		0. 867
		$6\frac{1}{2}$	30150. 16	6. 44				$3\frac{1}{2}$	35607. 60	38. 58	1. 144

## Cr II—Continued

## Cr II—Continued

Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>	Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>
$3d^5$	$b^2H$	$4\frac{1}{2}$ $5\frac{1}{2}$	35610. 50 35707. 66	97. 16		$3d^3 4s^2$	$e^2G$	$3\frac{1}{2}$ $4\frac{1}{2}$	54444. 19 54678. 95	234. 76	
$3d^5$	$a^2G$	$3\frac{1}{2}$ $4\frac{1}{2}$	36101. 82 36272. 66	170. 84		$3d^3 4s^2$	$c^4P$	$2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	55023. 30 55081. 77	—58. 4	
$3d^4(a^3D)4s$	$c^4D$	$3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	38269. 67 38315. 00 38362. 56 38396. 36	—45. 33 —47. 56 —33. 80		$3d^3 4s^2$	$b^2P$	$0\frac{1}{2}$ $1\frac{1}{2}$	59130. 51		
$3d^4(a^1G)4s$	$b^2G$	$3\frac{1}{2}$ $4\frac{1}{2}$	38509. 07 38563. 15	54. 08	0. 910 1. 100	$3d^3 4s^2$	$e^2D$	$1\frac{1}{2}$ $2\frac{1}{2}$	59527. 05 59570. 23	43. 18	
$3d^4(a^3G)4s$	$c^2G$	$3\frac{1}{2}$ $4\frac{1}{2}$	39684. 00 39824. 52	140. 52		$3d^4(a^3H)4p$	$z^4H^\circ$	$3\frac{1}{2}$ $4\frac{1}{2}$ $5\frac{1}{2}$ $6\frac{1}{2}$	63601. 20 63706. 62 63849. 11 64030. 85	105. 42 142. 49 181. 74	0. 680 1. 030 1. 138 1. 234
$3d^5$	$c^2F$	$2\frac{1}{2}$ $3\frac{1}{2}$	39742. 36 39877. 28	134. 92		$3d^4(a^3P)4p$	$y^4D^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$	63802. 41 64061. 82 64448. 84 64924. 30	259. 41 387. 02 475. 46	0. 000 1. 199 1. 380 1. 411
$3d^4(a^1I)4s$	$b^2I$	$6\frac{1}{2}$ $5\frac{1}{2}$	40202. 14 40228. 44	—26. 30		$3d^4(a^3P)4p$	$z^2S^\circ$	$0\frac{1}{2}$	65029. 67		
$3d^4(a^1S)4s$	$a^2S$	$0\frac{1}{2}$	40415. 34			$3d^4(a^3H)4p$	$z^4G^\circ$	$2\frac{1}{2}$ $3\frac{1}{2}$ $4\frac{1}{2}$ $5\frac{1}{2}$	65156. 84 65257. 03 65384. 04 65709. 53	100. 19 127. 01 325. 49	0. 593 0. 920 1. 120 1. 265
$3d^4(a^3D)4s$	$b^2D$	$2\frac{1}{2}$ $1\frac{1}{2}$	42898. 12 42986. 73	—88. 61		$3d^4(a^3H)4p$	$z^4I^\circ$	$4\frac{1}{2}$ $5\frac{1}{2}$ $6\frac{1}{2}$ $7\frac{1}{2}$	65217. 61 65419. 95 65618. 41 65812. 63	202. 34 198. 46 194. 22	
$3d^5$	$b^2S$	$0\frac{1}{2}$	44307. 44			$3d^4(a^3P)4p$	$y^4P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$	66256. 77 66355. 13 66727. 16	98. 36 372. 03	2. 545 1. 671 1. 502
$3d^4(a^1D)4s$	$c^2D$	$1\frac{1}{2}$ $2\frac{1}{2}$	45669. 54 45730. 74	61. 20		$3d^4(a^3P)4p$	$z^2D^\circ$	$1\frac{1}{2}$ $2\frac{1}{2}$	66649. 71 67012. 28	362. 57	
$3d^4(a^5D)4p$	$z^6F^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$ $4\frac{1}{2}$ $5\frac{1}{2}$	46823. 64 46905. 52 47040. 54 47227. 50 47464. 94 47751. 93	81. 88 135. 02 186. 96 237. 44 287. 04	—0. 689 1. 124 1. 314 1. 378 1. 416	$3d^4(a^3H)4p$	$z^2G^\circ$	$3\frac{1}{2}$ $4\frac{1}{2}$	65543. 06 65680. 15	137. 09	
$3d^5$	$d^2D$	$2\frac{1}{2}$ $1\frac{1}{2}$	47354. 63 47372. 75	—18. 12		$3d^4(a^3P)4p$	$y^4P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$	66256. 77 66355. 13 66727. 16	98. 36 372. 03	2. 545 1. 671 1. 502
$3d^4(a^5D)4p$	$z^6P^\circ$	$1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$	48399. 19 48491. 39 48632. 36	92. 20 140. 97	2. 382 1. 875 1. 710	$3d^4(a^3P)4p$	$z^2P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	66872. 12 67070. 48	198. 36	
$3d^4(a^5D)4p$	$z^4P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$	48749. 57 49006. 15 49351. 96	256. 58 345. 81	2. 844 1. 802 1. 628	$3d^4(a^3F)4p$	$y^4G^\circ$	$2\frac{1}{2}$ $3\frac{1}{2}$ $4\frac{1}{2}$ $5\frac{1}{2}$	67344. 42 67334. 20 67353. 60 67369. 33	—10. 22 19. 40 15. 73	
$3d^4(a^5D)4p$	$z^6D^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$ $4\frac{1}{2}$	49493. 00 49564. 80 49706. 47 49646. 25 49838. 43	71. 80 141. 67 —60. 22 192. 18	3. 155 1. 824 1. 624 1. 577 1. 570	$3d^4(a^3F)4p$	$y^4F^\circ$	$1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$ $4\frac{1}{2}$	67379. 92 67387. 30 67393. 80 67448. 82	7. 38 6. 50 55. 02	
$3d^4(a^1F)4s$	$d^2F$	$3\frac{1}{2}$ $2\frac{1}{2}$	50667. 33 50687. 63	—20. 30		$3d^4(a^3H)4p$	$z^2I^\circ$	$5\frac{1}{2}$ $6\frac{1}{2}$	67506. 34 67589. 06	82. 72	
$3d^4(a^5D)4p$	$z^4F^\circ$	$1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$ $4\frac{1}{2}$	51584. 44 51669. 75 51789. 21 51943. 04	85. 31 119. 46 153. 83	0. 406 1. 025 1. 248 1. 338	$3d^4(a^3F)4p$	$z^4D^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$	67859. 91 67870. 50 67868. 05 67875. 68	10. 59 —2. 45 7. 63	
$3d^5$	$d^2G$	$3\frac{1}{2}$ $4\frac{1}{2}$	52298. 12 52321. 30	23. 18		$3d^4(a^3P)4p$	$z^4S^\circ$	$1\frac{1}{2}$	68305. 73		1. 978
$3d^3 4s^2$	$c^4F$	$1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$ $4\frac{1}{2}$	53051. 55 53271. 07 53566. 22 53923. 57	219. 52 295. 15 357. 35		$3d^4(a^3H)4p$	$z^2H^\circ$	$4\frac{1}{2}$ $5\frac{1}{2}$	68477. 11 68737. 99	260. 88	
						$3d^4(a^3F)4p$	$z^2F^\circ$	$2\frac{1}{2}$ $3\frac{1}{2}$	68583. 44 68760. 00	176. 56	
$3d^4(a^5D)4p$	$z^4D^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$	54418. 08 54499. 70 54625. 76 54784. 67	81. 62 126. 06 158. 91	0. 007 1. 178 1. 376 1. 430	$3d^4(a^3G)4p$	$y^4H^\circ$	$3\frac{1}{2}$ $4\frac{1}{2}$ $5\frac{1}{2}$ $6\frac{1}{2}$	68843. 51 68992. 55 69170. 60 69388. 40	149. 04 178. 05 217. 80	



## Cr II—Continued

Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>
$3d^4(a^3G)4p$	$x^4F^\circ$	$1\frac{1}{2}$	69348.36		
		$2\frac{1}{2}$	69478.06	129.70	
		$3\frac{1}{2}$	69506.16	28.10	
		$4\frac{1}{2}$	69498.27	-7.89	
$3d^4(a^3F)4p$	$y^2D^\circ$	$1\frac{1}{2}$	69638.77		
		$2\frac{1}{2}$	69954.20	315.43	
$3d^4(a^3F)4p$	$y^2G^\circ$	$3\frac{1}{2}$	69903.46		
		$4\frac{1}{2}$	70107.83	204.37	
$3d^4(a^3G)4p$	$x^4G^\circ$	$2\frac{1}{2}$	70317.04		
		$3\frac{1}{2}$	70427.22	110.18	
		$4\frac{1}{2}$	70679.22	252.00	
		$5\frac{1}{2}$	70879.95	200.73	
$3d^4(a^3G)4p$	$y^2H^\circ$	$4\frac{1}{2}$	70394.46		
		$5\frac{1}{2}$	70399.04	4.58	
$3d^4(a^3G)4p$	$y^2F^\circ$	$2\frac{1}{2}$	70584.64		
		$3\frac{1}{2}$	70852.24	267.60	
$3d^4(a^3G)4p$	$x^2G^\circ$	$3\frac{1}{2}$	72648.79		
		$4\frac{1}{2}$	72716.91	68.12	
$3d^4(a^3D)4p$	$w^4D^\circ$	$0\frac{1}{2}$	73406.68		
		$1\frac{1}{2}$	73411.94	5.26	
		$2\frac{1}{2}$	73436.27	24.33	
		$3\frac{1}{2}$	73485.60	49.33	
$3d^4(a^3D)4p$	$x^2F^\circ$	$3\frac{1}{2}$	74114.48		
		$2\frac{1}{2}$	74436.14	-321.66	
$3d^4(a^3D)4p$	$w^4F^\circ$	$1\frac{1}{2}$	74273.48		
		$2\frac{1}{2}$	74318.86	45.38	
		$3\frac{1}{2}$	74423.84	104.98	
		$4\frac{1}{2}$	74504.51	80.67	
$3d^4(a^1I)4p$	$y^2I^\circ$	$5\frac{1}{2}$	74421.76		
		$6\frac{1}{2}$	74424.35	2.59	
$3d^4(a^1I)4p$	$x^2H^\circ$	$4\frac{1}{2}$	74455.90		
		$5\frac{1}{2}$	74707.42	251.52	
$3d^4(a^3D)4p$	$x^4P^\circ$	$2\frac{1}{2}$	74484.25		
		$1\frac{1}{2}$	74718.05	-233.80	
		$0\frac{1}{2}$	74920.80	-202.75	
$3d^4(a^1I)4p$	$z^2K^\circ$	$6\frac{1}{2}$	74743.33		
		$7\frac{1}{2}$	74958.80	215.47	
$3d^4(a^3D)4p$	$y^2P^\circ$	$0\frac{1}{2}$	74854.08		
		$1\frac{1}{2}$	74984.93	130.85	
$3d^4(a^1G)4p$	$w^2G^\circ$	$3\frac{1}{2}$	75716.74		
		$4\frac{1}{2}$	75810.10	93.36	
$3d^4(a^1G)4p$	$w^2F^\circ$	$3\frac{1}{2}$	76879.03		
		$2\frac{1}{2}$	76987.78	-108.75	
$3d^4(a^1G)4p$	$w^2H^\circ$	$5\frac{1}{2}$	77078.96		
		$4\frac{1}{2}$	77270.40	-191.44	
$3d^4(a^1S)4p$	$x^2P^\circ$	$1\frac{1}{2}$	77713.66		
		$0\frac{1}{2}$	77777.58	-63.92	
$3d^4(a^3D)4p$	$x^2D^\circ$	$2\frac{1}{2}$	77935.24		
		$1\frac{1}{2}$	78109.64	-174.40	
$3d^4(a^3D)4p$	$w^2D^\circ$	$1\frac{1}{2}$	80288.25		
		$2\frac{1}{2}$	80420.43	132.18	
$3d^4(a^1D)4p$	$v^2F^\circ$	$2\frac{1}{2}$	81232.91		
		$3\frac{1}{2}$	81432.36	199.45	
$3d^4(a^5D)5s$	$e^6D$	$0\frac{1}{2}$	82692.26		
		$1\frac{1}{2}$	82763.45	71.19	
		$2\frac{1}{2}$	82881.30	117.85	
		$3\frac{1}{2}$	83041.20	159.90	
		$4\frac{1}{2}$	83240.20	199.00	

## Cr II—Continued

Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>
$3d^4(a^1D)4p$	$w^2P^\circ$	$0\frac{1}{2}$	82854.00	66.03	
		$1\frac{1}{2}$	82920.03		
$3d^4(a^5D)5s$	$e^4D$	$0\frac{1}{2}$	84208.28	110.26	
		$1\frac{1}{2}$	84318.54		
		$2\frac{1}{2}$	84494.20		
		$3\frac{1}{2}$	84725.96		
$3d^4(a^1F)4p$	$u^2F^\circ$	$2\frac{1}{2}$	84604.99	72.40	
		$3\frac{1}{2}$	84677.39		
$3d^4(a^1F)4p$	$v^2G^\circ$	$3\frac{1}{2}$	85573.42	366.08	
		$4\frac{1}{2}$	85939.50		
$3d^4(a^1F)4p$	$v^2D^\circ$	$2\frac{1}{2}$	86507.38	-3.70	
		$1\frac{1}{2}$	86511.08		
$3d^4(a^5D)4d$	$e^6G$	$1\frac{1}{2}$	86594.82	59.61	
		$2\frac{1}{2}$	86654.43		
		$3\frac{1}{2}$	86738.36		
		$4\frac{1}{2}$	86847.30		
		$5\frac{1}{2}$	86980.42		
		$6\frac{1}{2}$	87137.34		
$3d^4(a^5D)4d$	$e^6P$	$1\frac{1}{2}$	86667.95	23.82	
		$2\frac{1}{2}$	86691.77		
		$3\frac{1}{2}$	86782.07		
$3d^4(a^5D)4d$	$f^6D$	$0\frac{1}{2}$	87314.0	40.1	
		$1\frac{1}{2}$	87354.62		
		$2\frac{1}{2}$	87413.27		
		$3\frac{1}{2}$	87515.10		
		$4\frac{1}{2}$	87687.66		
$3d^4(a^5D)4d$	$e^6F$	$0\frac{1}{2}$	87542.12	52.48	
		$1\frac{1}{2}$	87594.60		
		$2\frac{1}{2}$	87666.00		
		$3\frac{1}{2}$	87758.88		
		$4\frac{1}{2}$	87948.70		
		$5\frac{1}{2}$	88001.32		
$3d^4(a^5D)4d$	$e^4G$	$2\frac{1}{2}$	89056.10	118.00	
		$3\frac{1}{2}$	89174.10		
		$4\frac{1}{2}$	89325.60		
		$5\frac{1}{2}$	89508.63		
$3d^4(a^5D)4d$	$e^4P$	$0\frac{1}{2}$	88426.2	210.5	
		$1\frac{1}{2}$	88636.7		
		$2\frac{1}{2}$	88923.2		
$3d^4(a^5D)4d$	$f^4D$	$0\frac{1}{2}$	89269.88	67.82	
		$1\frac{1}{2}$	89337.70		
		$2\frac{1}{2}$	89475.08		
		$3\frac{1}{2}$	89621.25		
$3d^4(a^5D)4d$	$e^4F$	$1\frac{1}{2}$	90512.50	78.60	
		$2\frac{1}{2}$	90591.10		
		$3\frac{1}{2}$	90725.50		
		$4\frac{1}{2}$	90851.00		
$3d^4(b^3F)4p$	$u^2G^\circ$	$3\frac{1}{2}$	90986.31	117.05	
		$4\frac{1}{2}$	91103.36		
$3d^4(b^3F)4p$	$u^2D^\circ$	$2\frac{1}{2}$	91426.31	-130.23	
		$1\frac{1}{2}$	91556.54		
$3d^4(a^5D)4d$	$e^6S$	$2\frac{1}{2}$	91954.78		
$3d^4(a^3G)5s$	$f^4G$	$2\frac{1}{2}$		56.7	
		$3\frac{1}{2}$			
		$4\frac{1}{2}$	105365.2		
		$5\frac{1}{2}$	105421.9		
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Cr III ( $a^5D_0$ )	Limit	-----	133060		



## Cr II OBSERVED TERMS\*

Config. $1s^2 2s^2 2p^6 3s^2 3p^6 +$	Observed Terms	
$3d^5$	$\left\{ \begin{array}{l} b^6S \\ b^2S \end{array} \right. \begin{array}{l} a^4P \\ a^2D \\ c^2D \end{array} \begin{array}{l} b^4D \\ a^2D \\ c^2D \end{array} \begin{array}{l} b^4F \\ a^2F \\ c^2F \end{array} \begin{array}{l} a^4G \\ a^2G \\ d^2G \end{array} \begin{array}{l} b^2H \\ a^2I \end{array}$	
$3d^3 4s$	$\left\{ \begin{array}{l} c^4P \\ b^2P \end{array} \right. \begin{array}{l} e^2D \\ e^2G \end{array} \begin{array}{l} c^4F \end{array}$	
	$ns \ (n \geq 4)$	$np \ (n \geq 4)$
$3d^4(a^5D)nx$	$\left\{ \begin{array}{l} a,e^6D \\ a,e^4D \end{array} \right.$	$\begin{array}{l} z^6P^\circ \quad z^6D^\circ \quad z^6F^\circ \\ z^4P^\circ \quad z^4D^\circ \quad z^4F^\circ \end{array}$
$3d^4(a^3P)nx$	$\left\{ \begin{array}{l} b^4P \\ a^2P \end{array} \right.$	$\begin{array}{l} z^4S^\circ \quad y^4P^\circ \quad y^4D^\circ \\ z^2S^\circ \quad z^2P^\circ \quad z^2D^\circ \end{array}$
$3d^4(a^3H)nx$	$\left\{ \begin{array}{l} a^4H \\ a^2H \end{array} \right.$	$\begin{array}{l} z^4G^\circ \quad z^4H^\circ \quad z^4I^\circ \\ z^2G^\circ \quad z^2H^\circ \quad z^2I^\circ \end{array}$
$3d^4(a^3F)nx$	$\left\{ \begin{array}{l} a^4F \\ b^2F \end{array} \right.$	$\begin{array}{l} x^4D^\circ \quad y^4F^\circ \quad y^4G^\circ \\ y^2D^\circ \quad z^2F^\circ \quad y^2G^\circ \end{array}$
$3d^4(a^3G)nx$	$\left\{ \begin{array}{l} b,f^4G \\ c^2G \end{array} \right.$	$\begin{array}{l} x^4F^\circ \quad x^4G^\circ \quad y^4H^\circ \\ y^2F^\circ \quad x^2G^\circ \quad y^2H^\circ \end{array}$
$3d^4(a^3D)nx$	$\left\{ \begin{array}{l} c^4D \\ b^2D \end{array} \right.$	$\begin{array}{l} x^4P^\circ \quad w^4D^\circ \quad w^4F^\circ \\ y^2P^\circ \quad x^2D^\circ \quad x^2F^\circ \end{array}$
$3d^4(a^1G)nx$	$b^2G$	$w^2F^\circ \quad w^2G^\circ \quad w^2H^\circ$
$3d^4(a^1I)nx$	$b^2I$	$x^2H^\circ \quad y^2I^\circ \quad z^2K^\circ$
$3d^4(a^1S)nx$	$a^2S$	$x^2P^\circ$
$3d^4(a^1D)nx$	$c^2D$	$w^2P^\circ \quad w^2D^\circ \quad v^2F^\circ$
$3d^4(a^1F)nx$	$d^2F$	$v^2D^\circ \quad u^2F^\circ \quad v^2G^\circ$
$3d^4(b^3F)nx$		$u^2D^\circ \quad u^2G^\circ$
	$nd \ (n \geq 4)$	
$3d^4(a^5D)nx$	$\left\{ \begin{array}{l} e^6S \\ e^4P \end{array} \right. \begin{array}{l} e^6P \\ f^4D \\ e^4F \end{array} \begin{array}{l} f^6D \\ f^4D \\ e^4F \end{array} \begin{array}{l} e^6F \\ e^4F \\ e^4G \end{array} \begin{array}{l} e^6G \\ e^4G \end{array}$	

\*For predicted terms of the V I isoelectronic sequence, see Volume I, pp. xxxviii and xxxix.

## Cr III

(Ti I sequence; 22 electrons)

 $Z=24$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^4 {}^5D_0$  $\alpha {}^5D_0$  249700  $\text{cm}^{-1}$ 

I. P. 30.95 volts

The early work on Cr III by White and by Bowen resulted in the classification of 112 lines from 16 triplet and quintet terms. Bowen found strong intersystem combinations connecting the two systems of terms.

Recently, F. L. Moore, Jr., has extended the observations and analysis, utilizing also unpublished wavelengths by Kiess and Lang. He has observed more than 2300 lines between 712 Å and 3924 Å, of which approximately 750 Cr III lines are classified. About 60 terms are known, including eight singlets, also connected with the rest by observed intersystem combinations. The limit quoted here has been estimated by Catalán from a study of isoelectronic data. From the  $ns {}^5, {}^3F$  series ( $n=4, 5$ ) Moore derives the value 253064. White estimated the value of the limit as about 222000  $\text{cm}^{-1}$ .

This spectrum is of considerable astrophysical interest. For this reason Moore has made the present investigation and furnished his results especially for inclusion here. All of the terms in the table have been taken from his manuscript.

## REFERENCES

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 I. S. Bowen, Phys. Rev. **52**, 1153 (1937). (T) (C L)  
 F. L. Moore, Jr., unpublished material (May 1951). (I P) (T) (C L)  
 M. A. Catalán, unpublished material (April 1951). (I P)

## Cr III

## Cr III

Config.	Desig.	$J$	Level	Interval	Config.	Desig.	$J$	Level	Interval
$3d^4$	$a {}^5D$	0	0.0		$3d^3(a {}^4F)4s$	$c {}^4F$	2	56650.5	
		1	59.9	59.9			3	56992.2	341.7
		2	181.9	122.0			4	57422.1	429.9
		3	355.8	173.9					
		4	575.0	219.2	$3d^3(a {}^4P)4s$	$a {}^5P$	1	63038.6	133.6
$3d^4$	$a {}^3P$	0	16770.9				2	63172.2	
		1	17167.4	396.5			3	63420.3	248.1
		2	17850.0	682.6	$3d^3(a {}^2G)4s$	$b {}^3G$	3	65890.9	
$3d^4$	$a {}^3H$	4	17272.8				4	66027.8	136.9
		5	17395.5	122.7			5	66222.7	194.9
		6	17528.8	133.3	$3d^3(a {}^4P)4s$	$c {}^3P$	0		
$3d^4$	$a {}^3F$	2	18451.0				1	66602.2	
		3	18510.0	59.0			2	67181.7	579.5
		4	18581.6	71.6	$3d^3(a {}^2G)4s$	$c {}^1G$	4	68575.4	
$3d^4$	$a {}^3G$	3	20702.0						
		4	20851.3	149.3					
		5	20994.6	143.3	$3d^3(a {}^2P)4s$	$d {}^3P$	0	69510.6	
$3d^4$	$a {}^3D$	3	25725.8				1	69780.9	270.3
		2	25781.0	-55.2			2	70291.8	510.9
		1	25848.2	-67.2	$3d^3(a {}^2D)4s$	$b {}^3D$	1	70980.2	
$3d^4$	$a {}^1F$	3	41052.8				2	71166.1	185.9
							3	71321.8	155.7
$3d^4$	$b {}^3F$	4	43286.4		$3d^3(a {}^2H)4s$	$a {}^1H$	5	71408.2	
		3	43321.7	-35.3					
		2	43304.1	17.6	$3d^3(a {}^2H)4s$	$b {}^3H$	4	71676.2	
$3d^4$	$b {}^3P$	0	48759.7				5	71736.0	59.8
		1	48923.3	163.6			6	71868.5	132.5
		2	49467.5	544.2	$3d^3(a {}^2F)4s$	$d {}^3F$	2		
$3d^3(a {}^4F)4s$	$a {}^5F$	1	49491.0				3	81664.5	
		2	49626.8	135.8			4	82255.9	591.4
		3	49827.7	200.9	$3d^3(a {}^4F)4p$	$z {}^5G^\circ$	2	93765.6	
		4	50089.2	261.5			3	94029.2	263.6
		5	50408.2	319.0			4	94374.7	345.5
$3d^4$	$b {}^1G$						5	94799.6	424.9
		4	51093.1				6	95304.1	504.5

## Cr III—Continued

## Cr III—Continued

Config.	Desig.	<i>J</i>	Level	Interval	Config.	Desig.	<i>J</i>	Level	Interval
$3d^3(a^4F)4p$	$z^5D^\circ$	0 1 2 3 4	95778.6 96148.5 96385.9 96713.1 97097.1	369.9 237.4 327.2 384.0	$3d^3(a^2H)4p$	$x^3G^\circ$	5 4 3	120699.7 120747.8 120765.3	—48.1 —17.5
$3d^3(a^4F)4p$	$z^5F^\circ$	1 2 3 4 5	96773.5 96921.4 97120.3 97358.7 97618.3	147.9 198.9 238.4 259.6	$3d^3(a^2F)4p$	$w^3F^\circ$	2 3 4	128753.9 128782.2 128849.4	28.3 67.2
$3d^3(a^4F)4p$	$z^3D^\circ$	1 2 3	97076.9 97306.1 97683.0	229.2 376.9	$3d^3(a^2F)4p$	$w^3G^\circ$	3 4 5	131118.1 131267.3 131448.8	149.2 181.5
$3d^3(a^4F)4p$	$z^3G^\circ$	3 4 5	99840.7 100099.5 100421.4	258.8 321.9	$3d^3(a^2F)4p$	$v^3D^\circ$	1 2 3	138362.4? 138975.5	613.1
$3d^3(a^4F)4p$	$z^3F^\circ$	2 3 4	101443.7 101745.3 102099.6	301.6 354.3	$3d^3(b^2D)4p$	$v^3F^\circ$	2 3 4	150972.5	
$3d^3(a^4P)4p$	$z^5P^\circ$	1 2 3	108248.3 108459.2 108793.3	210.9 334.1	$3d^3(a^4F)4d$	$e^5H$	3 4 5 6 7	152927.3 153099.1 153314.6 153571.7 153871.7	171.8 215.5 257.1 300.0
$3d^3(a^4P)4p$	$y^5D^\circ$	0 1 2 3 4	109145.9 109237.4 109434.2 109721.4 110154.0	91.5 196.8 287.2 432.6	$3d^3(a^4F)4d$	$e^5F$	1 2 3 4 5	153729.8 153893.5 154085.7 154457.1 154849.6	163.7 192.2 371.4 392.5
$3d^3(a^2G)4p$	$z^3H^\circ$	4 5 6	109533.5 109943.9 110505.0	410.4 561.1	$3d^3(a^4F)4d$	$e^5G$	2 3 4 5 6	154854.6	
$3d^3(a^4P?)4p$	$z^3P^\circ$	0 1 2	109569.7		$3d^3(a^4F)4d$	$e^5D$	0 1 2 3 4	155064.0	
$3d^3(a^2G)4p$	$y^3G^\circ$	3 4 5	111375.0 111643.3 111854.0	268.3 210.7	$3d^3(a^4F)5s$	$f^5F$	1 2 3 4 5	157303.2 157435.1 157637.3 157908.0 158241.8	131.9 202.2 270.7 333.8
$3d^3(a^2G)4p$	$y^3F^\circ$	4 3 2	112371.2 112466.2 112398.5	—95.0 67.7	$3d^3(a^4F)4d$	$e^3H$	4 5 6	157668.9	
$3d^3(a^4P)4p$	$z^5S^\circ$	2	113355.7		$3d^3(a^4F)4d$	$e^3G$	3 4 5	158066.7 158442.9	376.2
$3d^3(a^2G)4p$	$z^1G^\circ$	4	114354.9		$3d^3(a^4F)5s$	$f^3F$	2 3 4	159031.8 159375.6 159803.3	343.8 427.7
$3d^3(a^4P)4p$	$y^3D^\circ$	1 2 3	114715.9 115181.8 115552.7	465.9 370.9	$3d^3(a^4F)4d$	$e^3F$	2 3 4	158328.3 158463.6 158623.7	135.3 160.1
$3d^3(a^2H)4p$	$y^3H^\circ$	4 5 6	115570.2 115668.9 115843.5	98.7 174.6	$3d^3(a^2G)4d$	$f^3H$	4 5 6	168582.3	
$3d^3(a^2D)4p$	$x^3F^\circ$	2 3 4	116391.6 116532.1 116967.0	140.5 434.9	$3d^3(a^2H)4d$	$g^3H$	4 5 6	173565.9 173926.6	360.7
$3d^3(a^2H)4p$	$y^1G^\circ$	4	117099.3		$3d^3(a^2H)4d$	$f^3I$	5 6 7	173200.5 173662.8 173876.3	462.3 213.5
$3d^3(a^2H)4p$	$z^3I^\circ$	5 6 7	117145.2 117487.5 117922.3	342.3 434.8					
$3d^3(a^2G)4p$	$z^1H^\circ$	5	117186.9						
$3d^3(a^2D)4p$	$w^3D^\circ$	1 2 3	118055.2 118423.3 118598.2	368.1 174.9					
$3d^3(a^2H)4p$	$y^1H^\circ$	5	119039.9						
					Cr IV ( $a^4F_{15/2}$ )	Limit	-----	249700	



Config. $1s^2 2s^2 2p^6 3s^2 3p^6 +$	Observed Terms		
$3d^4$	$\left\{ \begin{array}{lll} a^5D & a^3F & a^3G & a^3H \\ a^3P & b^3F & & \\ b^3P & a^1F & b^1G & \end{array} \right.$		
	$ns (n \geq 4)$	$np (n \geq 4)$	$nd (n \geq 4)$
$3d^3(a^4F)nx$	$\left\{ \begin{array}{l} a, f^3F \\ c, f^3F \end{array} \right.$	$\begin{array}{lll} z^5D^\circ & z^5F^\circ & z^5G^\circ \\ z^3D^\circ & z^3F^\circ & z^3G^\circ \end{array}$	$\begin{array}{llll} e^5D & e^5F & e^5G & e^5H \\ & e^3F & e^3G & e^3H \end{array}$
$3d^3(a^4P)nx$	$\left\{ \begin{array}{l} a^3P \\ c^3P \end{array} \right.$	$\begin{array}{lll} z^5S^\circ & z^5P^\circ & y^5D^\circ \\ & z^3P^\circ & y^3D^\circ \end{array}$	
$3d^3(a^3P)nx$	$d^3P$		
$3d^3(a^3G)nx$	$\left\{ \begin{array}{l} b^3G \\ c^3G \end{array} \right.$	$\begin{array}{lll} y^3F^\circ & y^3G^\circ & z^3H^\circ \\ & z^1G^\circ & z^1H^\circ \end{array}$	$f^3H$
$3d^3(a^3D)nx$	$b^3D$	$w^3D^\circ \quad x^3F^\circ$	
$3d^3(a^3H)nx$	$\left\{ \begin{array}{l} b^3H \\ a^3H \end{array} \right.$	$\begin{array}{lll} x^3G^\circ & y^3H^\circ & z^3I^\circ \\ y^1G^\circ & y^1H^\circ & \end{array}$	$g^3H \quad f^3I$
$3d^3(a^3F)nx$	$d^3F$	$v^3D^\circ \quad w^3F^\circ \quad w^3G^\circ$	
$3d^3(b^3D)nx$		$v^3F^\circ$	

\*For predicted terms in the spectra of the Ti I isoelectronic sequence, see Volume I, p. xxxvii.

## Cr IV

(Sc I sequence; 21 electrons)

$Z=24$

Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^3 {}^4F_{1/2}$

$a {}^4F_{1/2} 400000? \text{ cm}^{-1}$

I. P. 49.6 volts

The analysis was begun by White in 1929 and carried further by Bowen in 1937. It has recently been revised and extended by F. L. Moore, Jr., especially for inclusion here. The new observations extend from 500 Å to 2050 Å. At present Moore has more than 200 classified lines. The doublet and quartet terms are connected by observed intersystem combinations.

Moore's provisional value of the limit, derived from the  $ns {}^4, {}^2F$  series ( $n=4,5$ ), is quoted above.

The prefix "a" has here been ascribed by the writer to the limit terms  ${}^1G$  and  ${}^1S$ , although these terms have not yet been observed in Cr v.

## REFERENCES

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 I. S. Bowen, Phys. Rev. **52**, 1153 (1937). (T) (C L)  
 F. L. Moore, Jr., unpublished material (May 1951). (I P) (T) (C L)



## Cr IV

## Cr IV

Config.	Desig.	<i>J</i>	Level	Interval	Config.	Desig.	<i>J</i>	Level	Interval
$3d^3$	$a^4F$	$1\frac{1}{2}$	0		$3d^2(a^3P)4p$	$y^4D^\circ$	$0\frac{1}{2}$		
		$2\frac{1}{2}$	244	244			$1\frac{1}{2}$	173674	429
		$3\frac{1}{2}$	561	317			$2\frac{1}{2}$	174103	
		$4\frac{1}{2}$	956	395			$3\frac{1}{2}$	174854	751
$3d^3$	$a^4P$	$0\frac{1}{2}$	14072		$3d^2(a^1D)4p$	$y^2F^\circ$	$2\frac{1}{2}$		
		$1\frac{1}{2}$	14215	143			$3\frac{1}{2}$	175166	
		$2\frac{1}{2}$	14481	266					
$3d^3$	$a^3P$	$1\frac{1}{2}$	14185		$3d^2(a^1G)4p$	$y^2G^\circ$	$3\frac{1}{2}$	177926	110
		$0\frac{1}{2}$	14317	— 132			$4\frac{1}{2}$	178036	
$3d^3$	$a^2G$	$3\frac{1}{2}$	15064		$3d^2(a^1S)4p$	$x^2P^\circ$	$0\frac{1}{2}$	182029	85
		$4\frac{1}{2}$	15414	350			$1\frac{1}{2}$	182114	
$3d^3$	$a^2D$	$1\frac{1}{2}$	20218		$3d^2(a^1G)4p$	$z^2H^\circ$	$4\frac{1}{2}$	182391	62
		$2\frac{1}{2}$	20667	449			$5\frac{1}{2}$	183453	
$3d^3$	$a^2H$	$4\frac{1}{2}$	21078		$3d^2(a^1G)4p$	$x^2F^\circ$	$2\frac{1}{2}$		
		$5\frac{1}{2}$	21328	250			$3\frac{1}{2}$	184868	
$3d^3$	$a^2F$	$3\frac{1}{2}$	36490		$3d^2(a^3F)4d$	$e^4G$	$2\frac{1}{2}$	232573	332
		$2\frac{1}{2}$	37062	— 572			$3\frac{1}{2}$	232905	339
							$4\frac{1}{2}$	233244	411
$3d^2(a^3F)4s$	$b^4F$	$1\frac{1}{2}$	104003		$3d^2(a^3F)4d$	$e^2G$	$3\frac{1}{2}$	232889	632
		$2\frac{1}{2}$	104265	262			$4\frac{1}{2}$	233521	
		$3\frac{1}{2}$	104637	372					
		$4\frac{1}{2}$	105113	476					
$3d^2(a^3F)4s$	$b^3F$	$2\frac{1}{2}$	109950		$3d^2(a^3F)4d$	$e^4H$	$3\frac{1}{2}$	233365	353
		$3\frac{1}{2}$	110700	750			$4\frac{1}{2}$	233718	390
$3d^2(a^1G)4s$	$b^2G$	$4\frac{1}{2}$	127202		$3d^2(a^3F)4d$	$e^2F$	$5\frac{1}{2}$	234108	400
		$3\frac{1}{2}$	127218	— 16			$6\frac{1}{2}$	234508	
$3d^2(a^3F)4p$	$z^4G^\circ$	$2\frac{1}{2}$	157369		$3d^2(a^3F)4d$	$e^4F$	$2\frac{1}{2}$	233446	201
		$3\frac{1}{2}$	157942	573			$3\frac{1}{2}$	233647	
		$4\frac{1}{2}$	158638	696					
		$5\frac{1}{2}$	159458	820					
$3d^2(a^3F)4p$	$z^4F^\circ$	$1\frac{1}{2}$	158536		$3d^2(a^3F)5s$	$f^4F?$	$1\frac{1}{2}$	234094	
		$2\frac{1}{2}$	158901	365			$1\frac{1}{2}$	252073	239
		$3\frac{1}{2}$	159360	459			$2\frac{1}{2}$	252312	371
		$4\frac{1}{2}$	159872	512			$3\frac{1}{2}$	252683	
$3d^2(a^3F)4p$	$z^2F^\circ$	$2\frac{1}{2}$	160313		$3d^2(a^3F)5s$	$f^2F?$	$4\frac{1}{2}$		
		$3\frac{1}{2}$	160946	633			$2\frac{1}{2}$	253426	553
$3d^2(a^3F)4p$	$z^4D^\circ$	$0\frac{1}{2}$	160512		$3d^2(a^1G)4d$	$e^2H$	$3\frac{1}{2}$	253979	
		$1\frac{1}{2}$	160999	487			$4\frac{1}{2}$	258397	1409
		$2\frac{1}{2}$	161506	507			$5\frac{1}{2}$	259806	
		$3\frac{1}{2}$	162072	566					
$3d^2(a^3F)4p$	$z^2D^\circ$	$1\frac{1}{2}$	161765		$3d^2(a^1G)4d$	$f^2G$	$3\frac{1}{2}$	259504	
		$2\frac{1}{2}$	162310	545			$4\frac{1}{2}$		
$3d^2(a^3F)4p$	$z^2G^\circ$	$3\frac{1}{2}$	164920		$3d^2(a^3F)4f$	$y^4G^\circ$	$5\frac{1}{2}$	300340	
		$4\frac{1}{2}$	165440	520			$3\frac{1}{2}$	300366	
$3d^2(a^1D)4p$	$y^2D^\circ$	$2\frac{1}{2}$	169260				$3\frac{1}{2}$		
		$1\frac{1}{2}$	169849	— 589			$2\frac{1}{2}$		
$3d^2(a^3P)4p$	$x^2D^\circ$	$1\frac{1}{2}$			Cr v ( $^3F_2$ )	Limit			
		$2\frac{1}{2}$	174978						
								400000?	

May 1951.

Config. $1s^2 2s^2 2p^6 3s^2 3p^6 +$	Observed Terms			
$3d^3$	$\left\{ \begin{array}{cccc} a^4P & a^4D & a^4F & a^4G & a^4H \\ a^2P & a^2D & a^2F & a^2G & a^2H \end{array} \right.$			
	$ns (n \geq 4)$	$np (n \geq 4)$	$nd (n \geq 4)$	$nf (n \geq 4)$
$3d^2(a^3F)nx$	$\left\{ \begin{array}{c} b, f^4F \\ b, f^2F \end{array} \right.$	$\begin{array}{ccc} z^4D^\circ & z^4F^\circ & z^4G^\circ \\ z^2D^\circ & z^2F^\circ & z^2G^\circ \end{array}$	$\begin{array}{ccc} e^4F & e^4G & e^4H \\ e^2F & e^2G & \end{array}$	$y^4G^\circ?$
$3d^2(a^1D)nx$		$y^2D^\circ \quad y^2F^\circ$		
$3d^2(a^3P)nx$	$\left\{ \right.$	$\begin{array}{c} y^4D^\circ \\ x^2D^\circ \end{array}$		
$3d^2(a^1G)nx$	$b^2G$	$x^2F^\circ \quad y^2G^\circ \quad z^2H^\circ$	$f^2G \quad e^2H$	
$3d^2(a^1S)nx$		$x^2P^\circ$		

\*For predicted terms in the spectra of the Sc I isoelectronic sequence, see Volume I, p. xxxvi.

## Cr V

(Ca I sequence; 20 electrons)

$Z=24$

Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^2 {}^3F_2$

$a^3F_2$  589700  $\text{cm}^{-1}$

I. P. 73 volts

This spectrum is incompletely analyzed. In 1929 White published 55 classified lines in the region between 433 Å and 1820 Å. Cady has also made some observations and revised White's intersystem combinations and singlet terms. Edlén, who obtained Cady's unpublished material from Bowen, has furnished this material, together with additional revisions. One term ( ${}^1S_0$ ) has been rejected, and three ( $a^1G$ ,  $b^1D$ , and  $z^1F^\circ$ ) are not connected with the rest, as indicated by  $x$  in the table. Edlén's estimated value of  $a^1G$  is entered in brackets.

The observed tabular values are from Cady's list for terms having configurations  $3d^2$  and  $3d({}^2D) 4p$ . The remaining term values have been adjusted to these by means of the combinations observed by White. The small numerical differences in the two lists of triplet terms are due only to discrepancies in the measured wavelengths used for each, and not to differences in interpretation.

White's estimated ionization potential, based on extrapolation of isoelectronic sequence data, has been used to derive the limit entered in brackets in the table.

## REFERENCES

- H. E. White, Phys. Rev. **33**, 538 (1929). (I P) (T) (C L)  
W. M. Cady, unpublished material (1939?). (T) (C L)  
B. Edlén, unpublished material (1949). (T)

## Cr v

## Cr v

Config.	Desig.	<i>J</i>	Level	Interval	Config.	Desig.	<i>J</i>	Level	Interval
$3d^2$	$a^3F$	2	0		$3d(^2D)4p$	$z^3F^\circ$	2	229556	
		3	513	513			3	230328	772
		4	1146	633			4	231408	1080
$3d^2$	$a^1D$	2	13200		$3d(^2D)4p$	$z^3P^\circ$	0	234680	-55
$3d^2$	$a^3P$	0	15500				1	234625	
		1	15684	184			2	234857	232
		2	16052	368	$3d(^2D)4p$	$z^1F^\circ$	3	237568+x	
$3d^2$	$a^1G$	4	[22060]+x		$3d(^2D)4p$	$z^1P^\circ$	1	239939	
$3d(^2D)4s$	$a^3D$	1	167184		$3d(^2D)4d$	$e^3G$	3	319451	
		2	167497	313			4	319811	360
		3	168099	602			5	320406	595
$3d(^2D)4s$	$b^1D$	2	171736+x		-----	-----	-----	-----	
$3d(^2D)4p$	$z^1D^\circ$	2	226130		Cr vi ( $^2D_{1/2}$ )	Limit	-----	[589700]	
$3d(^2D)4p$	$z^3D^\circ$	1	228006						
		2	228497	491					
		3	229127	630					

March 1949.

## Cr v OBSERVED TERMS\*

Config. $1s^2 2s^2 2p^6 3s^2 3p^6 +$	Observed Terms		
$3d^2$	{ $a^3P$ $a^1D$ $a^3F$ $a^1G$ }		
	$ns$ ( $n \geq 4$ )	$np$ ( $n \geq 4$ )	$nd$ ( $n \geq 4$ )
	{ $a^3D$ $b^1D$ }	$z^3P^\circ$ $z^3D^\circ$ $z^3F^\circ$ $z^1P^\circ$ $z^1D^\circ$ $z^1F^\circ$	$e^3G$
$3d(^2D)nx$			

\*An array of predicted terms in the spectra of the Ca I isoelectronic sequence is given in Vol. 1, p. xxxv. Owing to the change in binding energies of the  $3d$  and  $4s$  electrons along this sequence the arrangement of the arrays of observed and predicted terms is not identical. In Cr v the prefixes  $a, b, \dots, e, z$  replace those indicating the running electron.

Cr VI

(K I sequence; 19 electrons)

Z=24

Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d\ ^2D_{1\frac{1}{2}}$

$3d\ ^2D_{1\frac{1}{2}}$  730900  $\text{cm}^{-1}$

I. P. 90.6 volts

The analysis is very incomplete. Six lines have been classified, in the range between 209A and 1455 A. The terms have been calculated chiefly from the data by Gibbs and White. The limit is from an estimate by Kruger and Weissberg, based on isoelectronic sequence data.

REFERENCES

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R. C. Gibbs and H. E. White, Phys. Rev. **33**, 162 (1929). (C L)  
P. G. Kruger and S. G. Weissberg, Phys. Rev. **52**, 316 (1937). (I P) (C L)

Cr VI

Config.	Desig.	<i>J</i>	Level	Interval
$3p^6(^1S)3d$	$3d\ ^2D$	$1\frac{1}{2}$ $2\frac{1}{2}$	$0$ 957	957
$3p^6(^1S)4s$	$4s\ ^2S$	$0\frac{1}{2}$	227775	
$3p^6(^1S)4p$	$4p\ ^2P^o$	$0\frac{1}{2}$ $1\frac{1}{2}$	296489 298311	1822
$3p^6(^1S)4f$	$4f\ ^2F^o$	$\left\{ \begin{smallmatrix} 2\frac{1}{2} \\ 3\frac{1}{2} \end{smallmatrix} \right\}$	476255	
-----	-----	-----	-----	
Cr VII ( $^1S_0$ )	<i>Limit</i>	-----	[730900]	

May 1948.



## Cr VII

(A I sequence; 18 electrons)

 $Z=24$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 {}^1S_0$  $3p^6 {}^1S_0$  1299700  $\text{cm}^{-1}$ 

I. P. 161.1 volts

Four lines are classified in the region between 104 Å and 148 Å, as combinations with the ground term. The values listed in the table have been rounded off in the last places.

For convenience, the Paschen notation has been added by the writer in column one under the heading "A I". As for A I, the  $jl$ -coupling notation in the general form suggested by Racah is here introduced, although  $LS$ -designations as indicated in column two under the heading "Authors" are perhaps preferable for the terms thus far identified.

## REFERENCES

- P. G. Kruger and S. G. Weissberg, Phys. Rev. **48**, 659 (1935). (I P) (T) (C L)  
 P. G. Kruger, S. G. Weissberg and L. W. Phillips, Phys. Rev. **51**, 1090, (1937). (I P) (T)  
 G. Racah, Phys. Rev. **61**, 537 (L) (1942).

## Cr VII

A I	Authors	Config.	Desig.	$J$	Level
$1p_0$	$3p^6 {}^1S$	$3p^6$	$3p^6 {}^1S$	0	0
$1s_4$	$3p^5 4s {}^3P^o$	$3p^5 ({}^2P_{1/2}) 4s$	$4s [1\frac{1}{2}]^o$	$\begin{smallmatrix} 2 \\ 1 \end{smallmatrix}$	672330
$1s_2$	$3p^5 4s {}^1P^o$	$3p^5 ({}^2P_{3/2}) 4s$	$4s' [0\frac{1}{2}]^o$	$\begin{smallmatrix} 0 \\ 1 \end{smallmatrix}$	682440
$2s_4$	$3p^5 5s {}^3P^o$	$3p^5 ({}^2P_{1/2}) 5s$	$5s [1\frac{1}{2}]^o$	$\begin{smallmatrix} 2 \\ 1 \end{smallmatrix}$	951110
$2s_2$	$3p^5 5s {}^1P^o$	$3p^5 ({}^2P_{3/2}) 5s$	$5s' [0\frac{1}{2}]^o$	$\begin{smallmatrix} 0 \\ 1 \end{smallmatrix}$	960340
		-----	-----	---	-----
		Cr VIII ( ${}^2P_{1/2}$ )	<i>Limit</i>	---	1299700
		Cr VIII ( ${}^2P_{3/2}$ )	<i>Limit</i>	---	1309640

May 1948.

Cr VIII

(Cl I sequence; 17 electrons)

$Z=24$

Ground state  $1s^2 2s^2 2p^6 3s^2 3p^5 \ ^2P_{1/2}$

$3p^5 \ ^2P_{1/2}$  1491000  $\text{cm}^{-1}$

I. P. 185 volts

All of the terms except  $3p^6 \ ^2S$  are from the paper by Edlén. Twelve lines in the region between 124 Å and 430 Å have been classified as combinations from the ground term. Edlén has estimated the value of the limit by extrapolation along the isoelectronic sequence, as indicated by brackets in the table.

His unit,  $10^3 \text{ cm}^{-1}$ , has here been changed to  $\text{cm}^{-1}$ .

REFERENCES

S. G. Weissberg and P. G. Kruger, Phys. Rev. **49**, 872 (A) (1936). (C L)  
B. Edlén, Zeit Phys. **104**, 407 (1937). (I P) (T) (C L)

Cr VIII

Config.	Desig.	<i>J</i>	Level	Interval
$3s^2 3p^5$	$3p^5 \ ^2P^\circ$	$1\frac{1}{2}$ $0\frac{1}{2}$	$0$ 9900	— 9900
$3s 3p^6$	$3p^6 \ ^2S$	$0\frac{1}{2}$	242131	
$3s^2 3p^4(^3P)4s$	$4s \ ^4P$	$2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	735880 741060	— 5180
$3s^2 3p^4(^3P)4s$	$4s \ ^2P$	$1\frac{1}{2}$ $0\frac{1}{2}$	749650 755740	— 6090
$3s^2 3p^4(^1D)4s$	$4s' \ ^2D$	$2\frac{1}{2}$ $1\frac{1}{2}$	769240 769560	— 320
$3s^2 3p^4(^1S)4s$	$4s'' \ ^2S$	$0\frac{1}{2}$	805260	
-----	-----	-----	-----	
Cr IX ( $^3P_2$ )	<i>Limit</i>	-----	[1491000]	

January 1948.

Cr IX

(S I sequence; 16 electrons)

$Z=24$

Ground state  $1s^2 2s^2 2p^6 3s^2 3p^4 \ ^3P_2$

$3p^4 \ ^3P_2$  1691000  $\text{cm}^{-1}$

I. P. 209.6 volts

Edlén has classified 11 lines in the interval between 117 Å and 123 Å, and extrapolated the value of the limit from isoelectronic sequence data.

The singlet and triplet terms are not connected by observed intersystem combinations. By analogy with Fe XI, Edlén has revised the interpolated values of the singlet terms for inclusion here, and the uncertainty,  $x$ , is probably not large.

Edlén's unit,  $10^3 \text{ cm}^{-1}$ , has here been changed to  $\text{cm}^{-1}$ .

REFERENCE

B. Edlén, Zeit. Phys. **104**, 188 (1937). (I P) (T) (C L)  
B. Edlén, letter (January 1950). (T)

## Cr IX

Config.	Desig.	<i>J</i>	Level	Interval
$3s^2 3p^4$	$3p^4 \ ^3P$	2	0	-7860 -1740
		1	7860	
		0	9600	
$3s^2 3p^4$	$3p^4 \ ^1D$	2	$30270+x$	350 1590
$3s^2 3p^4$	$3p^4 \ ^1S$	0	$66940+x$	
$3s^2 3p^3 \ (^4S^\circ) 4s$	$4s \ ^3S^\circ$	1	821150	
$3s^2 3p^3 \ (^2D^\circ) 4s$	$4s' \ ^3D^\circ$	1	845930	
		2	846280	
		3	847870	
$3s^2 3p^3 \ (^2D^\circ) 4s$	$4s' \ ^1D^\circ$	2	$854720+x$	
$3s^2 3p^3 \ (^2P^\circ) 4s$	$4s'' \ ^1P^\circ$	1	$881800+x$	
-----	-----	-----	-----	
Cr x ( $^4Si_{3/2}$ )	<i>Limit</i>	-----	[1691000]	

January 1950.

## Cr XII

(Al I sequence; 13 electrons)

 $Z=24$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p \ ^2P_{0\frac{1}{2}}$  $3p \ ^2P_{0\frac{1}{2}}$  cm<sup>-1</sup>

I. P. volts

This spectrum has not been analyzed, but Edlén has classified 2 lines as follows:

I. A.	Int.	Wave No.	Desig.
75. 815	2	1319000	} $3p \ ^2P^\circ - 4d \ ^2D$
76. 488	3	1307400	

His unit, 10<sup>3</sup> cm<sup>-1</sup>, is here changed to cm<sup>-1</sup>.

## REFERENCE

B. Edlén, Zeit. Phys. **103**, 540 (1936). (C L)

December 1947.



Cr XIII

(Mg I sequence; 12 electrons)

Z=24

Ground state  $1s^2 2s^2 2p^6 3s^2 1S_0$

$3s^2 1S_0$  2862000  $\text{cm}^{-1}$

I. P. 355 volts

Edlén has classified 14 lines in the region between 53 Å and 91 Å. No intersystem combinations have been observed and the triplet terms are not all connected by observed combinations. He has determined the relative positions of the various groups of terms and also the ionization potential by extrapolation along the isoelectronic sequence. His estimated value of the limit is entered in brackets in the table. His unit,  $10^3 \text{ cm}^{-1}$ , has here been changed to  $\text{cm}^{-1}$ .

REFERENCE

B. Edlén, Zeit. Phys. 103, 536 (1936). (I P) (T) (C L)

Cr XIII

Cr XIII

Config.	Desig.	<i>J</i>	Level	Interval	Config.	Desig.	<i>J</i>	Level	Interval
$3s^2$	$3s^2 1S$	0	0		$3s(^2S)4f$	$4f 3F^\circ$	2 3 4		
$3s(^2S)3p$	$3p 3P^\circ$	0 1 2	$203030+x$ $206960+x$ $216150+x$	3930 9190	$3s(^2S)5d$	$5d 3D$	1 2 3	$1682940+x$	
$3s(^2S)3d$	$3d 3D$	1 2 3	$594270+x$		$3s(^2S)5f$	$5f 3F^\circ$	2 3 4	$2076100+x$	
$3s(^2S)4s$	$4s 3S$	1	$1384840+x$					$2110160+x$	
$3s(^2S)4p$	$4p 1P^\circ$	1	$1492920$		-----	-----	-----	-----	
$3s(^2S)4d$	$4d 3D$	1 2 3	$1615620+x$ $1616020+x$ $1616750+x$	400 730	Cr XIV ( $^2S_{1/2}$ )	Limit	-----	[2862000]	

August 1947.

## Cr XIV

(Na I sequence; 11 electrons)

 $Z=24$ Ground state  $1s^2 2s^2 2p^6 3s^2 S_{1/2}$  $3s^2 S_{1/2}$  3099630  $\text{cm}^{-1}$ 

I. P. 384.20 volts

Edlén classified 16 lines in the interval 46 Å to 86 Å and extrapolated the absolute value of the ground term from isoelectronic sequence data. His unit,  $10^3 \text{ cm}^{-1}$ , has here been changed to  $\text{cm}^{-1}$ .

## REFERENCE

B. Edlén, Zeit. Phys. **100**, 621 (1936). (I P) (T) (C L)

## Cr XIV

## Cr XIV

Config.	Desig.	$J$	Level	Interval	Config.	Desig.	$J$	Level	Interval
3s	$3s^2 S$	$0\frac{1}{2}$	0		5p	$5p^2 P^o$	$0\frac{1}{2}$ $1\frac{1}{2}$	2149290 2152020	2730
3p	$3p^2 P^o$	$0\frac{1}{2}$ $1\frac{1}{2}$	242400 256320	13920	5d	$5d^2 D$	$1\frac{1}{2}$ $2\frac{1}{2}$	2210440 2210900	460
3d	$3d^2 D$	$1\frac{1}{2}$ $2\frac{1}{2}$	588910 590620	1710	5f	$5f^2 F^o$	$2\frac{1}{2}$ $3\frac{1}{2}$	2236380 2236550	170
4s	$4s^2 S$	$0\frac{1}{2}$	1478250		6f	$6f^2 F^o$	$2\frac{1}{2}$ $3\frac{1}{2}$	2500370	
4p	$4p^2 P^o$	$0\frac{1}{2}$ $1\frac{1}{2}$	1574180 1579550	5370					
4d	$4d^2 D$	$1\frac{1}{2}$ $2\frac{1}{2}$	1700870 1701760	890	Cr xv ( $1S_0$ )	Limit	-----	[3099630]	
4f	$4f^2 F^o$	$2\frac{1}{2}$ $3\frac{1}{2}$	1750930 1751220	290					

June 1947.

## Cr XV

(Ne I sequence; 10 electrons)

 $Z=24$ Ground state  $1s^2 2s^2 2p^6 1S_0$  $2p^6 1S_0$  8172300  $\text{cm}^{-1}$ 

I. P. 1013.0 volts

Nine lines have been classified by Tyrén in the interval between 15 Å and 21 Å, as combinations with the ground term. His absolute term values have been derived by extrapolation along the Ne I isoelectronic sequence.

By analogy with Ne I the  $j\ell$ -coupling notation in the general form suggested by Racah is introduced.

The unit adopted by Tyrén,  $10^3 \text{ cm}^{-1}$ , has here been changed to  $\text{cm}^{-1}$ .

## REFERENCES

- F. Tyrén, Zeit. Phys. **111**, 314 (1938). (I P) (T) (C L)  
G. Racah, Phys. Rev. **61**, 537 (L) (1942).

Cr xv

Cr xv

Author	Config.	Desig.	J	Level	Author	Config.	Desig.	J	Level
2p 1S	2p <sup>6</sup>	2p <sup>6</sup> 1S	0	0	3p' 3P <sub>1</sub>	2p <sup>6</sup> ( <sup>2</sup> S)3p	3p 3P <sup>o</sup>	2 1 0	5894500
3s 3P <sub>1</sub>	2p <sup>6</sup> ( <sup>2</sup> P <sub>1/2</sub> )3s	3s [1½] <sup>o</sup>	2 1	4727500	3p' 1P <sub>1</sub>	2p <sup>6</sup> ( <sup>2</sup> S)3p	3p 1P <sup>o</sup>	1	5921000
3s 1P <sub>1</sub>	2p <sup>6</sup> ( <sup>2</sup> P <sub>3/2</sub> )3s	3s' [0½] <sup>o</sup>	0 1	4793200	4d 1P <sub>1</sub>	2p <sup>6</sup> ( <sup>2</sup> P <sub>1/2</sub> )4d	4d [1½] <sup>o</sup>	1	6576000
3d 3P <sub>1</sub>	2p <sup>6</sup> ( <sup>2</sup> P <sub>1/2</sub> )3d	3d [0½] <sup>o</sup>	0 1	5259000	4d 3D <sub>1</sub>	2p <sup>6</sup> ( <sup>2</sup> P <sub>3/2</sub> )4d	4d' [1½] <sup>o</sup>	1	6641000
3d 1P <sub>1</sub>	"	3d [1½] <sup>o</sup>	1	5324200		-----	-----	---	-----
3d 3D <sub>1</sub>	2p <sup>6</sup> ( <sup>2</sup> P <sub>3/2</sub> )3d	3d' [1½] <sup>o</sup>	1	5406300		Cr xvi ( <sup>2</sup> P <sub>1/2</sub> )	Limit	---	[8172300]
						Cr xvi ( <sup>2</sup> P <sub>3/2</sub> )	Limit	---	8242400

April 1947.

Cr xv OBSERVED LEVELS\*

Config. 1s <sup>2</sup> +	Observed Terms		
2s <sup>2</sup> 2p <sup>6</sup>	2p <sup>6</sup> 1S		
	ns (n ≥ 3)	np (n ≥ 3)	nd (n ≥ 3)
	$\left\{ \begin{array}{l} 3s \text{ } ^3\text{P}^\circ \\ 3s \text{ } ^1\text{P}^\circ \end{array} \right.$		$\begin{array}{l} 3d \text{ } ^3\text{P}^\circ \quad 3, 4d \text{ } ^3\text{D}^\circ \\ 3, 4d \text{ } ^1\text{P}^\circ \end{array}$
2s <sup>2</sup> 2p <sup>5</sup> ( <sup>2</sup> P°)nx	$\left\{ \begin{array}{l} 3s \text{ } ^3\text{P}^\circ \\ 3s \text{ } ^1\text{P}^\circ \end{array} \right.$	$\begin{array}{l} 3p \text{ } ^3\text{P}^\circ \\ 3p \text{ } ^1\text{P}^\circ \end{array}$	
2s 2p <sup>6</sup> ( <sup>2</sup> S)nx			
j <i>l</i> —Coupling Notation			
Config. 1s <sup>2</sup> +	Observed Pairs		
2s <sup>2</sup> 2p <sup>5</sup> ( <sup>2</sup> P <sub>1/2</sub> )nx	ns (n ≥ 3)		nd (n ≥ 3)
	3s [1½]°		$\begin{array}{l} 3d \text{ } [0\frac{1}{2}]^\circ \\ 3, 4d \text{ } [1\frac{1}{2}]^\circ \end{array}$
	3s'[0½]°		3, 4d'[1½]°
2s <sup>2</sup> 2p <sup>5</sup> ( <sup>2</sup> P <sub>3/2</sub> )nx'			

\*For predicted levels in the spectra of the Ne i isoelectronic sequence, see Vol. 1, p. xxxi.



## MANGANESE

## Mn I

25 electrons

 $Z=25$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 4s^2 {}^6S_{2\frac{1}{2}}$  $a {}^6S_{2\frac{1}{2}}$  59960  $\text{cm}^{-1}$ 

I. P. 7.432 volts

Manganese occupies one of the most important places in the development of spectrum analysis. It was in the spectra of this element that M. A. Catalán first discovered multiplets. This led directly to further analysis of complex spectra, and culminated in the development of the Hund theory, which is beautifully confirmed in detail by observation.

During his recent visit to the United States, Catalán extended his early work on Mn I as well as that of Back, Meggers, Russell, Dunham, and others, to include more than 1500 classified lines and over 400 multiplets. The observations of the spectrum now cover the region from 600 Å to 17607 Å. The present term list has been furnished by him in advance of publication especially for inclusion here. Some terms and configurations have been contributed by Olga García-Riquelme in connection with her doctoral thesis prepared under the direction of Catalán.

The terms of all four multiplicities are connected by observed intersystem combinations.

A detailed discussion of asymmetrical Zeeman patterns of Mn I is given in the references. For example, Catalán lists two  $g$  values, 1.068 and 1.003, for the level  $z {}^6F_{1\frac{1}{2}}$ , and two (1.068 and 0.906) for  $y {}^6F_{1\frac{1}{2}}$ , one for each of the magnetic levels. Only one entry for each of these levels is included in the table.

## REFERENCES

- M. A. Catalán, Phil. Trans. Roy. Soc. (London) [A] **223**, 127 (1922). (I P) (T) (C L)  
 J. E. Mack, Rev. Mod. Phys. **22**, No. 1 64, (1950). (Summary hfs)  
 M. A. Catalán and R. Velasco, J. Opt. Soc. Am. **40**, 653 (1950). (Z E)  
 M. A. Catalán, J. Research Nat. Bur. Std. **47**, 502, RP2278 (1951). (Z E)  
 M. A. Catalán and Olga García-Riquelme, unpublished material (November 1951). (I P) (T) (C L) (Z E)

## Mn I

## Mn I

Config.	Desig.	$J$	Level	Interval	Obs. $g$	Config.	Desig.	$J$	Level	Interval	Obs. $g$
$3d^5 4s^2$	$a {}^6S$	$2\frac{1}{2}$	0. 00		1. 999	$3d^5 4s^2$	$a {}^4P$	$2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	27201. 54 27248. 00 27281. 85	—46. 46 —33. 85	1. 597 1. 730 2. 666
$3d^6(a {}^5D)4s$	$a {}^6D$	$4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	17052. 29 17282. 00 17451. 52 17568. 48 17637. 15	—229. 71 —169. 52 —116. 96 —68. 67	1. 559 1. 584 1. 657 1. 866 3. 327	$3d^5 4s^2$	$b {}^4D$	$3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	30354. 21 30419. 61 30425. 71 30411. 74	—65. 40 —6. 10 13. 97	1. 423
$3d^5 4s(a {}^7S)4p$	$z {}^8P^o$	$2\frac{1}{2}$ $3\frac{1}{2}$ $4\frac{1}{2}$	18402. 46 18531. 64 18705. 37	129. 18 173. 73	2. 284 1. 938 1. 779	$3d^5 4s(a {}^5S)4p$	$z {}^4P^o$	$2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	31001. 15 31076. 42 31124. 95	—75. 27 —48. 53	1. 600 1. 732
$3d^6(a {}^5D)4s$	$a {}^4D$	$3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	23296. 67 23549. 20 23719. 52 23818. 87	—252. 53 —170. 32 —99. 35	1. 427 1. 368 1. 198 0. 000	$3d^6(a {}^3P)4s$	$b {}^4P$	$2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	33825. 49 34463. 37 34845. 26	—637. 88 —381. 89	1. 604
$3d^5 4s(a {}^7S)4p$	$z {}^6P^o$	$1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$	24779. 32 24788. 05 24802. 25	8. 73 14. 20	2. 364 1. 714	$3d^6(a {}^3H)4s$	$a {}^4H$	$6\frac{1}{2}$ $5\frac{1}{2}$ $4\frac{1}{2}$ $3\frac{1}{2}$	34138. 88 34250. 52 34343. 90 34423. 27	—111. 64 —93. 38 —79. 37	1. 231 1. 135 0. 971 0. 665
$3d^5 4s^2$	$a {}^4G$	$5\frac{1}{2}$ $4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$	25265. 74 25285. 43 25287. 74 25281. 04	—19. 69 —2. 31 6. 70	1. 270	$3d^6(a {}^3F)4s$	$a {}^4F$	$4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$	34938. 70 35041. 37 35114. 98 35165. 05	—102. 67 —73. 61 —50. 07	1. 328 1. 238

## Mn I—Continued

Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>
$3d^5 4s(a^5S)4p$	<i>y</i> $^6P^\circ$	$1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$	35689. 98 35725. 85 35769. 97	35. 87 44. 12	2. 400 1. 886 1. 712
$3d^5(a^3G)4s$	<i>b</i> $^4G$	$5\frac{1}{2}$ $4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$	37420. 24 37630. 82 37737. 22 37789. 93	—210. 58 —106. 40 —52. 71	1. 263 1. 163 0. 989
$3d^5(a^3H)4s$	<i>a</i> $^3H$	$5\frac{1}{2}$ $4\frac{1}{2}$	38008. 70 38120. 18	—111. 48	
$3d^5(a^3F)4s$	<i>a</i> $^3F$	$3\frac{1}{2}$ $2\frac{1}{2}$	38669. 60		
$3d^5 4s(a^7S)5s$	<i>e</i> $^8S$	$3\frac{1}{2}$	39431. 31		2. 000
$3d^5 4s(a^7S)5s$	<i>e</i> $^8S$	$2\frac{1}{2}$	41403. 93		
$3d^5(a^5D)4p$	<i>z</i> $^6D^\circ$	$4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	41789. 48 41932. 64 42053. 73 42143. 57 42198. 56	—143. 16 —121. 09 —89. 84 —54. 99	1. 556 1. 587 1. 653 1. 867 3. 317
$3d^5(a^5D)4p$	<i>z</i> $^6F^\circ$	$5\frac{1}{2}$ $4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	43314. 23 43428. 58 43524. 08 43595. 50 43644. 45 43672. 96	—114. 35 —95. 50 —71. 42 —48. 95 —28. 51	1. 464 1. 431 1. 395 1. 310 1. 068 —0. 602
$3d^5(a^5D)4p$	<i>z</i> $^4F^\circ$	$4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$	44288. 76 44523. 45 44696. 29 44814. 73	—234. 69 —172. 84 —118. 44	1. 317 1. 240 1. 030 0. 400
$3d^7$	<i>c</i> $^4F$	$1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$ $4\frac{1}{2}$	44978. 98 45013. 55 45060. 81 45130. 16	34. 57 47. 26 69. 35	
$3d^5(a^5D)4p$	<i>x</i> $^6P^\circ$	$3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$	44993. 92 45156. 11 45259. 17	—162. 19 —103. 06	1. 717 1. 885 2. 399
$3d^5(a^5D)4p$	<i>z</i> $^4D^\circ$	$3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	45754. 27 45940. 93 46083. 89 46169. 93	—186. 66 —142. 96 —86. 04	1. 427 1. 372 1. 200 0. 000
$3d^5 4s(a^7S)5p$	<i>y</i> $^8P^\circ$	$2\frac{1}{2}$ $3\frac{1}{2}$ $4\frac{1}{2}$	45981. 40 46001. 92 46028. 87	20. 52 26. 95	
$3d^5 4s(a^7S)4d$	<i>e</i> $^8D$	$1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$ $4\frac{1}{2}$ $5\frac{1}{2}$	46706. 09 46707. 03 46708. 33 46710. 15 46712. 58	0. 94 1. 30 1. 82 2. 43	
$3d^5(a^5D)4p$	<i>y</i> $^4P^\circ$	$2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	46901. 13 47154. 51 47299. 29	—253. 38 —144. 78	1. 595 1. 732 2. 666
$3d^5 4s(a^7S)4d$	<i>e</i> $^6D$	$4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	47207. 28 47212. 06 47215. 61 47218. 15 47219. 64	—4. 78 —3. 55 —2. 54 —1. 49	
$3d^5 4s(a^7S)5p$	<i>w</i> $^6P^\circ$	$3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$	47387. 62 47659. 52 47782. 43	—271. 90 —122. 91	1. 713 1. 952 2. 336
$3d^5 4s(a^5P)4p$	<i>y</i> $^6D^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$ $4\frac{1}{2}$	47452. 16 47466. 66 47753. 99 47774. 52 47903. 80	14. 50 287. 33 20. 53 129. 28	3. 174 1. 820 1. 594 1. 540

## Mn I—Continued

Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>
$3d^5 4s(a^5G)4p$	<i>y</i> $^6F^\circ$	$5\frac{1}{2}$ $4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	48021. 43 48168. 01 48225. 99 48270. 91 48300. 98 48318. 12	—146. 58 —57. 98 —44. 92 —30. 07 —17. 14	1. 460 1. 432 1. 403 1. 319 1. 068 —0. 496
$3d^5 4s(a^5S)5s$	<i>f</i> $^6S$	$2\frac{1}{2}$	49415. 35		
$3d^5 4s(a^5S)5s$	<i>e</i> $^4S$	$1\frac{1}{2}$	49591. 51		
$3d^5 4s(a^5P)4p$	<i>v</i> $^6P^\circ$	$3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$	49888. 08 50012. 53 50099. 16	—124. 45 —86. 63	1. 711 1. 888 2. 398
$3d^5 4s(a^5G)4p$	<i>z</i> $^4H^\circ$	$3\frac{1}{2}$ $4\frac{1}{2}$ $5\frac{1}{2}$ $6\frac{1}{2}$	50065. 46 50072. 59 50081. 31 50094. 60	7. 13 8. 72 13. 29	
$3d^5 4s(a^7S)6s$	<i>f</i> $^8S$	$3\frac{1}{2}$	50157. 63		1. 995
$3d^5 4s(a^5G)4p$	<i>y</i> $^4F^\circ$	$4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$	50341. 30 50359. 28 50373. 23 50383. 27	—17. 98 —13. 95 —10. 04	
$3d^5 4s(b^5D)4p$	<i>x</i> $^6F^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$ $4\frac{1}{2}$ $5\frac{1}{2}$	50818. 64 50863. 05 50931. 42 51014. 95 51100. 49 51169. 18	44. 41 68. 37 83. 53 85. 54 68. 69	
$3d^5 4s(a^7S)6s$	<i>g</i> $^8S$	$2\frac{1}{2}$	50904. 68		
$3d^5 4s(a^5P)4p$	<i>x</i> $^4P^\circ$	$2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	51305. 41 51445. 65 51552. 78	—140. 24 —107. 13	1. 591 1. 728 2. 664
$3d^5 4s(a^5G)4p$	<i>z</i> $^4G^\circ$	$2\frac{1}{2}$ $3\frac{1}{2}$ $4\frac{1}{2}$ $5\frac{1}{2}$	51515. 63 51530. 61 51546. 27 51560. 93	14. 98 15. 66 14. 66	1. 273
$3d^7$	<i>c</i> $^4P$	$2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	51638. 17 51718. 22 51787. 92	—80. 05 —69. 70	
$3d^5 4s(b^5D)4p$	<i>u</i> $^6P^\circ$	$1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$	52015. 00 52128. 65 52253. 24	113. 65 124. 59	
$3d^5 4s(a^7S)5d$	<i>f</i> $^8D$	$1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$ $4\frac{1}{2}$ $5\frac{1}{2}$	52702 52703 52705	1 2	
$3d^5 4s(a^7S)5d$	<i>f</i> $^6D$	$4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	52726. 39 52730. 41 52733. 22 52735. 01 52735. 83	—4. 02 —2. 81 —1. 79 —0. 82	
$3d^5 4s(b^5D)4p$	<i>x</i> $^6D^\circ$	$4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	52758. 11 52870. 10 52883. 87 52883. 87 52883. 10	—111. 99 —13. 77 0. 00 0. 77	1. 552
$3d^5 4s(a^7S)4f$	<i>z</i> $^8F^\circ$	$0\frac{1}{2}$ to $6\frac{1}{2}$	52977. 96		
$3d^5 4s(a^5P)4p$	<i>y</i> $^4D^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$	53101. 32 53103. 19 53109. 21 53124. 09	1. 87 6. 02 14. 88	1. 423



## Mn I—Continued

## Mn I—Continued

Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>	Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>
$3d^5 4s(a^7S)6p$	$t^6P^\circ$	$3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$	53261. 42 53291. 58 53311. 37	—30. 16 —19. 79		$3d^5 4s(b^3P)4p$	$y^4S^\circ$	$1\frac{1}{2}$	57512. 16		2. 000
$3d^5 4s(a^7S)7s$	$g^8S$	$3\frac{1}{2}$	54180			$3d^5 4s(a^7S)8d$	$i^8D$	$1\frac{1}{2}$ to $5\frac{1}{2}$	57651. 93		
$3d^5 4s(a^5P)4p$	$z^4S^\circ$	$1\frac{1}{2}$	54218. 71			$3d^5 4s(a^7S)7f$	$w^8F^\circ$	$0\frac{1}{2}$ to $6\frac{1}{2}$	57695. 3		
$3d^5 4s(a^7S)7s$	$h^8S$	$2\frac{1}{2}$	54460. 30			$3d^5(a^3H)4p$	$y^4G^\circ$	$5\frac{1}{2}$ $4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$	58075. 06 58110. 24 58136. 69 58159. 73	—35. 18 —26. 45 —23. 04	1. 269 1. 168 0. 980 0. 578
$3d^5 4s(a^5S)4d$	$g^6D$	$4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	54938. 71 54945. 28 54950. 66 54953. 02 54949. 90	—6. 57 —5. 38 —2. 36 3. 12		$3d^5 4s(a^7S)9d$	$j^8D$	$1\frac{1}{2}$ to $5\frac{1}{2}$	58199. 7		
	$x^4D^\circ$	$3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	55107. 52 55186. 17 55279. 91	—78. 65 —93. 74	1. 407 1. 365 0. 826	$3d^5(a^3H)4p$	$y^4H^\circ$	$6\frac{1}{2}$ $5\frac{1}{2}$ $4\frac{1}{2}$ $3\frac{1}{2}$	58338. 67 58427. 30 58485. 52 58519. 90	—88. 63 —58. 22 —34. 38	1. 228 1. 133 0. 968 0. 665
$3d^5 4s(b^5D)4p$	$w^4P^\circ$	$2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	55405. 14 55368. 66 55457. 20	36. 48 —88. 54		$3d^5(a^3H)4p$	$z^4I^\circ$	$7\frac{1}{2}$ $6\frac{1}{2}$ $5\frac{1}{2}$ $4\frac{1}{2}$	58852. 60 58843. 39 58851. 49 58866. 66	9. 21 —8. 10 —15. 17	
$3d^5 4s(a^7S)6d$	$g^8D$	$1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$ $4\frac{1}{2}$ $5\frac{1}{2}$	55374 55375 55376	1 1		$3d^5(a^3P)4p$	$t^4P^\circ$	$2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	59116. 60 59384. 45 59568. 29	—267. 85 —183. 84	
$3d^5 4s(a^7S)5f$	$y^8F^\circ$	$0\frac{1}{2}$ to $6\frac{1}{2}$	55499. 08			$3d^5(a^3F)4p$	$w^4F^\circ$	$4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$	59257. 44 59290. 23 59360. 72 59416. 15	—32. 79 —70. 49 —55. 43	1. 327
$3d^5 4s(a^7S)6d$	$h^6D$	$4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	55681. 9 55688. 1 55690. 8 55691. 9 55692. 4	—6. 2 —2. 7 —1. 1 —0. 5		$3d^5(a^3P)4p$	$v^4D^\circ$	$3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	59339. 49 59600. 35 59989. 77 60141. 98	—260. 86 —389. 42 —152. 21	
	$1^\circ$	$2\frac{1}{2}$	55923. 81			$3d^5(a^3F)4p$	$u^4D^\circ$	$3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	59470. 14 59480. 80 59527. 89 59527. 36	—10. 66 —47. 09 0. 53	
$3d^5 4s(a^5S)5p$	$s^6P^\circ$	$1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$	55996. 62 56007. 91 56012. 42	11. 29 4. 51		$3d^5(a^3H)4p$	$z^2I^\circ$	$6\frac{1}{2}$ $5\frac{1}{2}$	59617. 12 59827. 88	—210. 76	
$3d^5 4s(a^7S)8s$	$h^8S$	$3\frac{1}{2}$	56144. 16			$3d^5(a^3F)4p$	$x^4G^\circ$	$5\frac{1}{2}$ $4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$	59652. 90 59731. 94 59784. 31 59817. 70	—79. 04 —52. 37 —33. 39	
$3d^5(a^5D)5s$	$i^6D$	$4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	56189. 45 56356. 21 56490. 79 56567. 93 56666. 06	—166. 76 —134. 58 —77. 14 —98. 13		Mn II ( $^7S_3$ )	<b>Limit</b>		59960		
	$e^4D$	$3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	56462. 08 56561. 95 56601. 63 56646. 9 ?	—99. 87 —39. 68 —45. 3		$3d^5(a^3P)4p$	$x^4S^\circ$	$1\frac{1}{2}$	60126. 81		
$3d^5 4s(a^7S)7d$	$h^8D$	$1\frac{1}{2}$ to $5\frac{1}{2}$	56801. 4			$3d^5(a^3F)4p$	$z^2G^\circ$	$4\frac{1}{2}$ $3\frac{1}{2}$	60668. 49 60739. 42	—70. 93	
$3d^5 4s(a^7S)6f$	$x^8F^\circ$	$0\frac{1}{2}$ to $6\frac{1}{2}$	56863			$3d^5 4s(^3I)4p$	$x^4H^\circ$	$6\frac{1}{2}$ $5\frac{1}{2}$ $4\frac{1}{2}$ $3\frac{1}{2}$	60891. 48 60933. 73 60955. 88 60957. 21	—42. 25 —22. 15 —1. 33	1. 228 1. 134
$3d^5 4p^2$	$e^8P$	$2\frac{1}{2}$ $3\frac{1}{2}$ $4\frac{1}{2}$	57086. 33 57218. 15 57388. 90	131. 82 170. 75		$3d^5 4s(^3I)4p$	$y^2G^\circ$	$3\frac{1}{2}$ $4\frac{1}{2}$	60902. 80 60938. 97	36. 17	
$3d^5 4s(b^3P)4p$	$u^4P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$	57228. 30 57360. 78 57487. 08	132. 48 126. 30	1. 736		$y^4I^\circ$	$7\frac{1}{2}$ $6\frac{1}{2}$ $5\frac{1}{2}$ $4\frac{1}{2}$	61204. 54 61225. 55 61225. 77 61211. 43	—21. 01 —0. 22 14. 34	
$3d^5(a^5D)5s$	$f^4D$	$3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	57305. 62 57485. 97 57621. 90 57705. 83	—180. 35 —135. 93 —83. 93			$w^4G^\circ$	$5\frac{1}{2}$ $4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$	61469. 21 61485. 34 61480. 60 61471. 23	—16. 13 4. 74 9. 37	



## Mn I—Continued

## Mn I—Continued

Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>	Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>		
3 <i>d</i> <sup>5</sup> ( <i>a</i> <sup>5</sup> D)4 <i>d</i>	<i>e</i> <sup>6</sup> F	5½	61713. 62	-316. 56 -264. 48	1. 329	3 <i>d</i> <sup>5</sup> 4 <i>s</i> ( <i>a</i> <sup>5</sup> G)5 <i>s</i>	15°	2½	64823. 21	-49. 70	1. 160 1. 259		
		4½	62030. 18				16°	3½	64988. 22				
		3½	62294. 66				<i>w</i> <sup>2</sup> G°	4½ 3½	65262. 28				
		2½					17°	3½	65617. 37				
		1½					18°	4½	65768. 81				
		0½					<i>v</i> <sup>4</sup> G°	2½ 3½ 4½ 5½	65873. 40 65876. 34 65908. 92 65887. 31			2. 94 32. 58 -21. 61	
	2°	3½	61710. 98	<i>x</i> <sup>2</sup> D°			2½ 1½	65946. 87 65961. 90	-15. 03				
	3°	4½	61714. 52	<i>y</i> <sup>2</sup> F°			2½ 3½	66020. 63 66149. 10	128. 47				
	4°	5½	61744. 04	<i>u</i> <sup>4</sup> H°			3½ 4½ 5½ 6½	66334. 47 66356. 40 66418. 55 66568. 58	21. 93 62. 15 150. 03				
	5°	3½	61785. 94	<i>u</i> <sup>4</sup> G°			2½ 3½ 4½ 5½	66395. 19 66454. 27 66522. 62 66573. 60	59. 08 68. 35 50. 98				
3 <i>d</i> <sup>5</sup> ( <i>a</i> <sup>5</sup> D)4 <i>d</i>	<i>e</i> <sup>6</sup> G	6½	62001. 09	-133. 36 -166. 18 -125. 85 -88. 11 -58. 52			1. 231	19°	1½	66504. 21		-71. 94	1. 266
		5½	62134. 45					20°	3½	66600. 17			
		4½	62300. 63					21°	4½	66630. 92			
		3½	62426. 48					22°	2½	66654. 65			
		2½	62514. 59					23°	2½, 3½	66737. 82			
		1½	62573. 11					24°	2½, 3½	66783. 05			
	<i>z</i> <sup>2</sup> F°	3½ 2½	62034. 04 62075. 02	25°				2½	66837. 64				
		6°	4½	62345. 73				26°	1½	66843. 79			
		3 <i>d</i> <sup>5</sup> ( <i>a</i> <sup>3</sup> G)4 <i>p</i>	<i>v</i> <sup>4</sup> F°	1½ 2½ 3½ 4½	62390. 20 62487. 36 62505. 29 62392. 82	97. 16 17. 93 -112. 47		27°	4½	66855. 00			
				3 <i>d</i> <sup>5</sup> 4 <i>s</i> ( <i>a</i> <sup>5</sup> F)4 <i>p</i>	<i>w</i> <sup>6</sup> D°	4½ 3½ 2½ 1½ 0½		62670. 81 62851. 47 62761. 33 62787. 63 62768. 16	-180. 66 90. 14 -26. 30 19. 47	28°	2½		
7°	2½					63139. 70		29°	3½	66981. 30			
<i>z</i> <sup>2</sup> H°	5½ 4½					63288. 78 63374. 53		85. 75	30°	4½	67024. 41		
	8°	3½	63288. 78			31°		5½, 6½	67206. 00				
9°	4½	63347. 91	1. 236 1. 137 0. 974			<i>w</i> <sup>2</sup> H°		5½ 4½	67504. 90 67576. 84	-71. 94			
<i>w</i> <sup>4</sup> H°	6½ 5½ 4½ 3½	63363. 54 63457. 85 63444. 61 63395. 45			-94. 31 13. 24 49. 16	32°		5½	67664. 49				
	<i>y</i> <sup>2</sup> H°	5½ 4½			63449. 13 63548. 49	-99. 36		<i>t</i> <sup>4</sup> G°	5½ 4½ 3½ 2½	67752. 84 67819. 17 67891. 36 67965. 04	-66. 33 -72. 19 -73. 68		
		10°			2½	63523. 82		<i>v</i> <sup>2</sup> G°	4½ 3½	68286. 44 68338. 59	-52. 15		
	11°	3½			63546. 30	3 <i>d</i> <sup>5</sup> 4 <i>s</i> ( <i>a</i> <sup>5</sup> G)5 <i>s</i>		<i>e</i> <sup>4</sup> G	5½ 4½ 3½ 2½	68692. 02 68716. 22 68746. 67 68762. 8	-24. 20 -30. 45 -16. 1		
12°	1½, 2½	63583. 84	33°		5½		69722. 96						
<i>z</i> <sup>2</sup> D°	2½ 1½	63764. 90 63845. 32	-80. 42										
	<i>x</i> <sup>2</sup> H°	5½ 4½	64051. 91 64055. 37	-3. 46									
13°		3½	64409. 69										
3 <i>d</i> <sup>5</sup> 4 <i>s</i> ( <i>a</i> <sup>5</sup> F)4 <i>p</i>	<i>x</i> <sup>2</sup> G°	4½ 3½	64585. 44 64649. 20	-63. 76									
		14°	0½	64638. 68									
	<i>y</i> <sup>2</sup> D°	1½ 2½	64683. 95 64712. 94	28. 99									
		<i>v</i> <sup>4</sup> H°	6½ 5½ 4½ 3½	64731. 88 64819. 53 64888. 00 64920. 33	-87. 65 -68. 47 -32. 33								

## Mn I OBSERVED TERMS\*

Config. 1s <sup>2</sup> 2s <sup>2</sup> 2p <sup>6</sup> 3s <sup>2</sup> 3p <sup>6</sup> +	Observed Terms				
	$ns$ ( $n \geq 4$ )	$np$ ( $n \geq 4$ )	$nd$ ( $n \geq 4$ )	$nf$ ( $n \geq 4$ )	
$3d^5 4s^2$	$\{ \begin{array}{l} a^6S \\ a^4P \\ c^4P \\ e^8P \end{array} \begin{array}{l} a^4D \\ b^4D \\ c^4F \end{array} \begin{array}{l} a^4G \end{array}$				
$3d^7$					
$3d^5 4p^2$					
$3d^5 4s(a^1S)nx$	$\{ \begin{array}{l} e, f, g, h^8S \\ e, g, h^6S \end{array}$				$z, y, x, w^8F^o$
$3d^5 4s(a^3S)nx$	$\{ \begin{array}{l} f^6S \\ e^4S \end{array}$				
$3d^5(a^5D)nx$	$\{ \begin{array}{l} a, i^6D \\ a, f^4D \end{array}$	$z^6D^o$ $z^4D^o$	$z^6F^o$ $z^4F^o$	$e, f, g, h, i, j^8D$ $e, f, h^6D$	
$3d^5 4s(a^5G)nx$	$\{ \begin{array}{l} e^4G \end{array}$	$y^6F^o$ $y^4F^o$	$z^6H^o$	$g^6D$	$e^6F$ $e^6G$
$3d^5(a^3P)nx$	$\{ \begin{array}{l} b^4P \end{array}$	$x^4S^o$ $t^4P^o$	$v^4D^o$		
$3d^5 4s(a^3P)nx$		$v^6P^o$ $x^4P^o$	$y^6D^o$ $y^4D^o$		
$3d^5(a^3H)nx$			$y^4G^o$ $y^4H^o$		
$3d^5(a^3F)nx$			$u^4D^o$ $w^4F^o$ $x^4G^o$	$z^4I^o$ $z^2I^o$	
$3d^5 4s(b^3D)nx$		$u^6P^o$ $w^4P^o$	$x^6D^o$		
$3d^5(a^3G)nx$			$v^4F^o$		
$3d^5 4s(b^3P)nx$		$y^4S^o$ $u^4P^o$	$w^6D^o$		
$3d^5 4s(a^5F)nx$				$x^4H^o$ $y^4I^o$	
$3d^5 4s(^3I)nx$					

\*For predicted terms in the spectra of the Mn I isoelectronic sequence, see Vol. II, Introduction.

## Mn II

(Cr I sequence; 24 electrons)

 $Z=25$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 4s^1 S_3$  $4s^1 S_3$  126147  $\text{cm}^{-1}$ 

I. P. 15.64 volts

When Catalán announced his important discovery of multiplets in the spectrum of Mn I he listed, also, 24 lines of Mn II as members of four multiplets. Subsequently, Russell and, independently, Duffendack and Black, confirmed the regularities suggested by Catalán, and extended the list to include 33 lines classified as combinations among seven terms.

The leading investigation of this spectrum has, however, been carried on by Curtis, who has extended his earlier work and furnished the present analysis in advance of publication, for inclusion here. His line list now includes nearly 1100 classified lines in the interval from 900 Å to 6500 Å. The terms of all three multiplicities are connected by observed intersystem combinations. Curtis has calculated the limit from four members of the  $3d^5(^6S)\eta f^7F^\circ$  series, well represented by a Ritz formula.

The writer has changed the author's notation to that adopted for complex spectra and described in detail in the text of Volume I, p. XII, namely that with the prefixes  $a, b, c, \dots z, y, x$ , etc., throughout. For convenience in cross reference, Curtis' notation is entered in column 1.

This spectrum is important astrophysically. The present investigation will be extremely useful in the interpretation of stellar spectra.

The observed  $g$ -values have been derived by Catalán from observations of the Zeeman Effect made with the Bitter magnet and large grating spectrographs at the Massachusetts Institute of Technology, with the generous cooperation of Harrison.

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## Mn II

## Mn II

Curtis	Config.	Desig.	J	Level	Interval	Obs. g	Curtis	Config.	Desig.	J	Level	Interval	Obs. g
4s 7S <sub>3</sub>	3d <sup>5</sup> (a 6S)4s	a 7S	3	0. 00		2. 00	4p 5P <sub>3</sub>	3d <sup>5</sup> (a 6S)4p	z 5P <sup>o</sup>	3	43370. 37		1. 67
4s 5S <sub>2</sub>	3d <sup>5</sup> (a 6S)4s	a 5S	2	9472. 86		2. 00	4p 5P <sub>2</sub>		2	43484. 50	-114. 13	1. 83	
							4p 5P <sub>1</sub>		1	43557. 03	-72. 53	2. 49	
3d 5D <sub>4</sub>	3d <sup>6</sup>	a 5D	4	14325. 64	-267. 98	1. 49	b 5D <sub>0</sub>	3d <sup>4</sup> 4s <sup>2</sup>	c 5D	0	54846. 0		
3d 5D <sub>3</sub>			3	14593. 62	-187. 41	1. 49	b 5D <sub>1</sub>		1	54938. 1	92. 1		
3d 5D <sub>2</sub>			2	14781. 03	-120. 03	1. 49	b 5D <sub>2</sub>		2	55115. 8	177. 7		
3d 5D <sub>1</sub>			1	14901. 06	-58. 62	1. 49	b 5D <sub>3</sub>		3	55371. 3	255. 5		
3d 5D <sub>0</sub>			0	14959. 68		0. 00	b 5D <sub>4</sub>		4	55696. 5	325. 2		
a 5G <sub>6</sub>	3d <sup>5</sup> (a 4G)4s	a 5G	6	27546. 90	-24. 05	1. 33	z 5G <sub>2</sub>	3d <sup>5</sup> (a 4G)4p	z 5G <sup>o</sup>	2	64456. 33		1. 31
a 5G <sub>5</sub>			5	27570. 95	-12. 35	1. 26	z 5G <sub>3</sub>		3	64473. 13	16. 80	1. 26	
a 5G <sub>4</sub>			4	27583. 30	-4. 93		z 5G <sub>4</sub>		4	64493. 83	20. 70		
a 5G <sub>3</sub>			3	27588. 23	-0. 80		z 5G <sub>5</sub>		5	64518. 57	24. 74		
a 5G <sub>2</sub>			2	27589. 03			z 5G <sub>6</sub>		6	64549. 72	31. 15		
3d 3P <sub>2</sub>	3d <sup>6</sup>	a 3P	2	29869. 11	-815. 70		z 5H <sub>3</sub>	3d <sup>5</sup> (a 4G)4p	z 5H <sup>o</sup>	3	65482. 66		1. 30
3d 3P <sub>1</sub>			1	30684. 81			z 5H <sub>4</sub>		4	65565. 68	83. 02	1. 21	
3d 3P <sub>0</sub>			0				z 5H <sub>5</sub>		5	65658. 30	92. 62		
a 5P <sub>3</sub>	3d <sup>5</sup> (a 4P)4s	a 5P	3	29889. 31	-29. 91	1. 66	z 5H <sub>6</sub>		6	65754. 50	96. 20		
a 5P <sub>2</sub>			2	29919. 22	-31. 90	1. 84	z 5H <sub>7</sub>		7	65846. 61	92. 11		
a 5P <sub>1</sub>			1	29951. 12		2. 42?	z 5F <sub>5</sub>	3d <sup>5</sup> (a 4G)4p	z 5F <sup>o</sup>	5	66542. 26	-100. 75	1. 40
3d 3H <sub>6</sub>	3d <sup>6</sup>	a 3H	6	30523. 45	-155. 79	1. 15	z 5F <sub>4</sub>		4	66643. 01	-43. 44		
3d 3H <sub>5</sub>			5	30679. 24	-116. 51	1. 04	z 5F <sub>3</sub>		3	66686. 45	9. 89		
3d 3H <sub>4</sub>			4	30795. 75		0. 81	z 5F <sub>2</sub>		2	66676. 56	31. 78		
							z 5F <sub>1</sub>		1	66644. 78			
3d 3F <sub>4</sub>	3d <sup>6</sup>	a 3F	4	31514. 35	-147. 37	1. 25		3d <sup>5</sup> (a 4P)4p	z 5D <sup>o</sup>	0			
3d 3F <sub>3</sub>			3	31661. 72	-99. 21	1. 07	z 5D <sub>1</sub>		1	66893. 79	7. 35		
3d 3F <sub>2</sub>			2	31760. 93		0. 66	z 5D <sub>2</sub>		2	66901. 14	107. 79		
a 5D <sub>4</sub>	3d <sup>5</sup> (a 4D)4s	b 5D	4	32787. 60	-69. 35		z 5D <sub>3</sub>		3	67008. 93	286. 23	1. 45	
a 5D <sub>3</sub>			3	32856. 95	-1. 89		z 5D <sub>4</sub>		4	67295. 16		1. 49	
a 5D <sub>2</sub>			2	32858. 84	22. 44		z 5S <sub>2</sub> ?	3d <sup>5</sup> (a 4P)4p	z 5S <sup>o</sup>	2	66929. 22		
a 5D <sub>1</sub>			1	32836. 40	18. 30		z 3H <sub>6</sub>	3d <sup>5</sup> (a 4G)4p	z 3H <sup>o</sup>	6	67744. 08	-101. 85	1. 16
a 5D <sub>0</sub>			0	32818. 10			z 3H <sub>5</sub>		5	67845. 93	-64. 33	1. 03	
a 3G <sub>5</sub>	3d <sup>6</sup>	a 3G	5	33147. 39	-100. 93	1. 20	z 3H <sub>4</sub>		4	67910. 26		0. 78	
a 3G <sub>4</sub>			4	33248. 32	-30. 07	1. 04	z 3F <sub>2</sub>	3d <sup>5</sup> (a 4G)4p	z 3F <sup>o</sup>	2	67766. 51		0. 66
a 3G <sub>3</sub>			3	33278. 39		0. 75	z 3F <sub>3</sub>		3	67811. 75	45. 24	1. 08	
3d 3G <sub>5</sub>	3d <sup>5</sup> (a 4G)4s	b 3G	5	34761. 81	-148. 62	1. 21	z 3F <sub>4</sub>		4	67865. 63	53. 88	1. 25	
3d 3G <sub>4</sub>			4	34910. 43	-94. 00	1. 05	z 3P <sub>3</sub>	3d <sup>5</sup> (a 4P)4p	y 3P <sup>o</sup>	3	68284. 38	-132. 96	1. 65
3d 3G <sub>3</sub>			3	35004. 43		0. 75	z 3P <sub>2</sub>		2	68417. 34	-79. 03		
a 3P <sub>2</sub>	3d <sup>5</sup> (a 4P)4s	b 3P	2	36274. 29	-90. 01	1. 48	z 3P <sub>1</sub>	3d <sup>5</sup> (a 4P)4p	z 3P <sup>o</sup>	2	69044. 61	-171. 12	1. 49
a 3P <sub>1</sub>			1	36364. 30	-63. 59	1. 48	z 3P <sub>0</sub>		1	69215. 73	-103. 28	1. 49	
a 3P <sub>0</sub>			0	36427. 89		0. 00			0	69319. 01		0. 00	
3d 3D <sub>1</sub>	3d <sup>6</sup>	a 3D	1	37811. 57		0. 52	y 5F <sub>1</sub>	3d <sup>5</sup> (a 4D)4p	y 5F <sup>o</sup>	1	70150. 39	80. 68	
3d 3D <sub>2</sub>			2	37847. 90	36. 33	1. 17	y 5F <sub>2</sub>		2	70231. 07	111. 51		
3d 3D <sub>3</sub>			3	37851. 15	3. 25	1. 35	y 5F <sub>3</sub>		3	70342. 58	154. 86		
4p 7P <sub>2</sub>	3d <sup>5</sup> (a 6S)4p	z 7P <sup>o</sup>	2	38366. 07	176. 89	2. 32	y 5F <sub>4</sub>		4	70497. 44	159. 74	1. 39?	
4p 7P <sub>3</sub>			3	38542. 96	263. 57	1. 94?	y 5F <sub>5</sub>		5	70657. 18		1. 40	
4p 7P <sub>4</sub>			4	38806. 53		1. 76							
a 3D <sub>3</sub>	3d <sup>5</sup> (a 4D)4s	b 3D	3	39808. 14	-5. 24	1. 34	z 3G <sub>3</sub>	3d <sup>5</sup> (a 4G)4p	z 3G <sup>o</sup>	3	70517. 72	28. 30	0. 75
a 3D <sub>2</sub>			2	39813. 38	-13. 19	1. 15	z 3G <sub>4</sub>		4	70546. 02	-18. 70	1. 15?	
a 3D <sub>1</sub>			1	39826. 57		0. 50	z 3G <sub>5</sub>		5	70527. 32		1. 20	
a 5F <sub>1</sub>	3d <sup>5</sup> (a 4F)4s	a 5F	1	43311. 0	28. 1		z 3D <sub>3</sub>	3d <sup>5</sup> (a 4P)4p	z 3D <sup>o</sup>	3	70745. 08	-195. 16	1. 33
a 5F <sub>2</sub>			2	43339. 1	55. 9		z 3D <sub>2</sub>		2	70940. 24	-137. 94	1. 16	
a 5F <sub>3</sub>			3	43395. 0	141. 9		z 3D <sub>1</sub>		1	71078. 18		0. 50	
a 5F <sub>4</sub>			4	43536. 9	-8. 6		y 5P <sub>1</sub>	3d <sup>5</sup> (a 4D)4p	x 5P <sup>o</sup>	1	71263. 92	59. 23	
a 5F <sub>5</sub>			5	43528. 3			y 5P <sub>2</sub>		2	71323. 15	66. 99		
							y 5P <sub>3</sub>		3	71390. 14			

## Mn II—Continued

Curtis	Config.	Desig.	J	Level	Interval	Obs. <i>g</i>
$y^5D_4$	$3d^5(a^4D)4p$	$y^5D^\circ$	4	72010.75	—236.63	1.48
$y^5D_3$			3	72247.38	—59.43	
$y^5D_2$			2	72306.81	—13.81	
$y^5D_1$			1	72320.62	—1.45	
$y^5D_0$			0	72322.07		
$y^3D_1$	$3d^5(a^4D)4p$	$y^3D^\circ$	1	73385.15	10.82	
$y^3D_2$			2	73395.97	—0.85	
$y^3D_3$			3	73395.12		
$y^3F_4$	$3d^5(a^4D)4p$	$y^3F^\circ$	4	73683.11	—97.70	1.24
$y^3F_3$			3	73780.81	—4.44	1.09
$y^3F_2$			2	73785.25		0.75
$z^3S_1$	$3d^5(a^4P)4p$	$z^3S^\circ$	1	73911.31		
$5s^7S_3$	$3d^5(a^6S)5s$	$e^7S$	3	74559.97		2.00
	$3d^5(a^4D)4p$	$y^3P^\circ$	0			
$y^3P_1$			1	75719.59	199.14	
$y^3P_2$			2	75918.73		
$5s^5S_2$	$3d^5(a^6S)5s$	$e^5S$	2	76374.56		2.00
$4d^7D_1$	$3d^5(a^6S)4d$	$e^7D$	1	79540.76	3.75	
$4d^7D_2$			2	79544.51	5.77	
$4d^7D_3$			3	79550.28	8.10	
$4d^7D_4$			4	79558.38	10.72	
$4d^7D_5$			5	79569.10		
$4d^5D_4$	$3d^5(a^6S)4d$	$e^5D$	4	82136.20	—8.14	
$4d^5D_3$			3	82144.34	—6.73	
$4d^5D_2$			2	82151.07	—4.65	
$4d^5D_1$			1	82155.72	—2.44	
$4d^5D_0$			0	82158.16		
$z^7P_2$	$3d^4 4s(a^6D)4p?$	$y^7P^\circ$	2	83255.8	119.8	
$z^7P_3$			3	83375.6	153.8	
$z^7P_4$			4	83529.4		
$5p^7P_2$	$3d^5(a^6S)5p?$	$x^7P^\circ$	2	85895.27	65.14	
$5p^7P_3$			3	85960.41	96.99	
$5p^7P_4$			4	86057.40		
$5p^5P_3$	$3d^5(a^6S)5p$	$w^5P^\circ$	3	86897.7	—39.1	
$5p^5P_2$			2	86936.8	—24.2	
$5p^5P_1$			1	86961.0		
$x^5P_1$	$3d^4 4s(a^6D)4p?$	$v^5P^\circ$	1	88839.6	239.3	
$x^5P_2$			2	89078.9	349.9	
$x^5P_3$			3	89428.8		
$6s^7S_3$	$3d^5(a^6S)6s$	$f^7S$	3	97728.0		
$6s^5S_2$	$3d^5(a^6S)6s$	$f^5S$	2	98410.1		
$4f^7F_6$	$3d^5(a^6S)4f$	$z^7F^\circ$	6	98423.5	—0.2	
$4f^7F_5$			5	98423.7	—0.1	
$4f^7F_4$			4	98423.8	—0.2	
$4f^7F_3$			3	98424.0	—0.1	
$4f^7F_2$			2	98424.1		
			1			
			0			
$4f^5F_1$	$3d^5(a^6S)4f$	$x^5F^\circ$	1	98461.76	0.58	
$4f^5F_2$			2	98462.34	0.82	
$4f^5F_3$			3	98463.16	1.00	
$4f^5F_4$			4	98464.16	0.99	
$4f^5F_5$			5	98465.15		

## Mn II—Continued

Curtis	Config.	Desig.	J	Level	Interval	Obs. <i>g</i>
	$3d^5(a^6S)5d$	$f^7D$	1			
$5d^7D_2$			2	99892.5	2.3	
$5d^7D_3$			3	99894.8	3.8	
$5d^7D_4$			4	99898.6	4.5	
$5d^7D_5$			5	99903.1		
$5d^5D_4$	$3d^5(a^6S)5d$	$f^5D$	4	100682.3	—5.8	
$5d^5D_3$			3	100688.1	—4.5	
$5d^5D_2$			2	100692.6	—2.7	
$5d^5D_1$			1	100695.3		
			0			
$e^5G_6$	$3d^5(a^4G)5s$	$e^5G$	6	101467.58	—21.73	
$e^5G_5$			5	101489.31	—9.72	
$e^5G_4$			4	101499.03	—2.27	
$e^5G_3$			3	101501.30	1.46	
$e^5G_2$			2	101499.84		
$e^3G_5$	$3d^5(a^4G)5s$	$e^3G$	5	102680.09	—23.25	
$e^3G_4$			4	102703.34	—2.03	
$e^3G_3$			3	102705.37		
$e^5P_3$	$3d^5(a^4P)5s$	$e^5P$	3	103803.44	—32.73	
$e^5P_2$			2	103836.17	—31.97	
$e^5P_1$			1	103868.14		
$e^3P_0$	$3d^5(a^4P)5s$	$e^3P$	0	104914.18?	106.49	
$e^3P_1$			1	105020.67	34.76	
$e^3P_2$			2	105055.43		
$e^5H_3$	$3d^5(a^4G)4d$	$e^5H$	3	106157.4	6.8	
$e^5H_4$			4	106164.2	4.7	
$e^5H_5$			5	106168.9	1.0	
$e^5H_6$			6	106169.9	—2.2	
$e^5H_7$			7	106167.7		
$w^5F_1$	$3d^4 4s(b^4D)4p$	$w^5F^\circ$	1	106265.3	108.4	
$w^5F_2$			2	106373.7	152.1	
$w^5F_3$			3	106525.8	181.5	
$w^5F_4$			4	106707.3	186.5	
$w^5F_5$			5	106893.8		
$w^5P_1$	$3d^4 4s(b^4D)4p$	$u^5P^\circ$	1	106479.2	270.8	
$w^5P_2$			2	106750.0	422.8	
$w^5P_3$			3	107172.8		
$e^5I_4$	$3d^5(a^4G)4d$	$e^5I$	4	106512.1	7.0	
$e^5I_5$			5	106519.1	3.4	
$e^5I_6$			6	106522.5	—2.7	
$e^5I_7$			7	106519.8	—11.7	
$e^5I_8$			8	106508.1		
$e^5D_4$	$3d^5(a^4D)5s$	$g^5D$	4	106885.90	—64.34	
$e^5D_3$			3	106950.24	—16.70	
$e^5D_2$			2	106966.94	4.38	
$e^5D_1$			1	106962.56	6.14	
$e^5D_0$			0	106956.42		
$e^3D_3$	$3d^5(a^4D)5s$	$e^3D$	3	108102.25	—68.20	
$e^3D_2$			2	108170.45	—2.09	
$e^2D_1$			1	108172.54?		
$7s^7S_3$	$3d^5(a^6S)7s$	$g^7S$	3	108126.2		
$5f^7F_{6,5}$	$3d^5(a^6S)5f$	$y^7F^\circ$	{6 5}	108409.8	—0.3	
$5f^7F_4$			4	108410.1	—0.1	
$5f^7F_3$			3	108410.2	—0.1	
$5f^7F_2$			2	108410.3		
			1			
			0			



## Mn II—Continued

## Mn II—Continued

Curtis	Config.	Desig.	J	Level	Interval	Obs. g	Curtis	Config.	Desig.	J	Level	Interval	Obs. g
5f <sup>5</sup> F <sub>1</sub>	3d <sup>5</sup> (a <sup>6</sup> S)5f	v <sup>5</sup> F°	1	108435.6			6f <sup>7</sup> F <sub>6</sub>	3d <sup>5</sup> (a <sup>6</sup> S)6f	x <sup>7</sup> F°	6	113840.0		
5f <sup>5</sup> F <sub>2</sub>			2	108437.2	1.6		6f <sup>7</sup> F <sub>5</sub>			5	113840.1	-0.1	
5f <sup>5</sup> F <sub>3</sub>			3	108439.0	1.8		6f <sup>7</sup> F <sub>4</sub>			4	113840.2	-0.1	
5f <sup>5</sup> F <sub>4</sub>			4	108441.4	2.4					3	113840.3	-0.1	
5f <sup>5</sup> F <sub>5</sub>			5	108443.0	1.6					2			
7s <sup>5</sup> S <sub>2</sub>	3d <sup>5</sup> (a <sup>6</sup> S)7s	g <sup>5</sup> S	2	108447.6				3d <sup>5</sup> (a <sup>6</sup> S)8s	h <sup>5</sup> S	2	113895.2		
v <sup>5</sup> G <sub>2</sub>							8s <sup>5</sup> S <sub>2</sub>						
v <sup>5</sup> G <sub>3</sub>			2	108485.4	17.6								
v <sup>5</sup> G <sub>4</sub>			3	108503.0	21.7		6g <sup>5</sup> G <sub>6</sub>		f <sup>5</sup> G	{6 5 4 3 2}	113932.0		
v <sup>5</sup> G <sub>5</sub>			4	108524.7	26.0		6g <sup>5</sup> G <sub>5</sub>						
v <sup>5</sup> G <sub>6</sub>			5	108550.7	37.2		6g <sup>5</sup> G <sub>4</sub>						
			6	108587.9			6g <sup>5</sup> G <sub>3</sub>						
							6g <sup>5</sup> G <sub>2</sub>						
v <sup>5</sup> P <sub>1</sub>		t <sup>5</sup> P°	1	108726.4				3d <sup>5</sup> (a <sup>6</sup> S)6g	e <sup>7</sup> G	{7 to 1}	113932		
v <sup>5</sup> P <sub>2</sub>			2	108974.7	148.3		6g <sup>7</sup> G						
v <sup>5</sup> P <sub>3</sub>			3	109378.9	404.2								
v <sup>5</sup> F <sub>1</sub>		u <sup>5</sup> F°	1	108994.0				3d <sup>5</sup> (a <sup>6</sup> S)6f	r <sup>5</sup> F°	1	114023.5		
v <sup>5</sup> F <sub>2</sub>			2	109045.7	51.7		6f <sup>5</sup> F <sub>1</sub>			2	114024.8	1.3	
v <sup>5</sup> F <sub>3</sub>			3	109122.4	76.7		6f <sup>5</sup> F <sub>2</sub>			3	114026.3	1.5	
v <sup>5</sup> F <sub>4</sub>			4	109221.1	98.7		6f <sup>5</sup> F <sub>3</sub>			4	114027.8	1.5	
v <sup>5</sup> F <sub>5</sub>			5	109327.1	106.0		6f <sup>5</sup> F <sub>4</sub>			5	114026.8	-1.0	
w <sup>5</sup> D <sub>0</sub>		x <sup>5</sup> D°	0	109167.7			6f <sup>5</sup> F <sub>5</sub>						
w <sup>5</sup> D <sub>1</sub>			1	109235.3	67.6			3d <sup>5</sup> (a <sup>6</sup> S)7d	h <sup>7</sup> D	1	114344.18		
w <sup>5</sup> D <sub>2</sub>			2	109343.7	108.4		7d <sup>7</sup> D <sub>1</sub>			2	114344.84	0.66	
w <sup>5</sup> D <sub>3</sub>			3	109476.3	132.6		7d <sup>7</sup> D <sub>2</sub>			3	114345.87	1.03	
w <sup>5</sup> D <sub>4</sub>			4	109607.8	131.5		7d <sup>7</sup> D <sub>3</sub>			4	114347.25	1.38	
							7d <sup>7</sup> D <sub>4</sub>			5	114349.06	1.81	
6d <sup>7</sup> D <sub>1</sub>	3d <sup>5</sup> (a <sup>6</sup> S)6d	g <sup>7</sup> D	1	109241.31			7d <sup>7</sup> D <sub>5</sub>	3d <sup>5</sup> (a <sup>6</sup> S)7d	h <sup>5</sup> D	4	114932.2	-11.7	
6d <sup>7</sup> D <sub>2</sub>			2	109242.36	1.05		7d <sup>5</sup> D <sub>4</sub>			3	114943.9	-8.0	
6d <sup>7</sup> D <sub>3</sub>			3	109243.95	1.59		7d <sup>5</sup> D <sub>3</sub>			2	114951.9	-4.6	
6d <sup>7</sup> D <sub>4</sub>			4	109246.15	2.20		7d <sup>5</sup> D <sub>2</sub>			1	114956.5	-1.6	
6d <sup>7</sup> D <sub>5</sub>			5	109249.00	2.85		7d <sup>5</sup> D <sub>1</sub>			0	114958.1		
	3d <sup>4</sup> 4s(b <sup>4</sup> D)4p	w <sup>5</sup> D°	0	109958.0			7d <sup>5</sup> D <sub>0</sub>						
v <sup>5</sup> D <sub>0</sub>			1	109994.3	36.3			3d <sup>5</sup> (a <sup>6</sup> S)9s	i <sup>7</sup> S	3	117031.1		
v <sup>5</sup> D <sub>1</sub>			2	110068.5	74.2		9s <sup>7</sup> S <sub>3</sub>						
v <sup>5</sup> D <sub>2</sub>			3	110204.9	136.4		7f <sup>7</sup> F <sub>6</sub>		w <sup>7</sup> F°	6	117112.9		
v <sup>5</sup> D <sub>3</sub>			4	110428.7	223.8		7f <sup>7</sup> F <sub>5</sub>			5	117113.0	-0.1	
							7f <sup>7</sup> F <sub>4,3</sub>			{4 3 2 1 0}	117113.1	-0.1	
v <sup>5</sup> H <sub>3</sub>		y <sup>5</sup> H°	3	110547.5				3d <sup>5</sup> (a <sup>6</sup> S)7f	q <sup>5</sup> F°	1			
v <sup>5</sup> H <sub>4</sub>			4	110602.0	54.5					2			
v <sup>5</sup> H <sub>5</sub>			5	110692.2	90.2					3			
v <sup>5</sup> H <sub>6</sub>			6	110795.0	102.8					4	117137.8		
v <sup>5</sup> H <sub>7</sub>			7	110926.0	131.0					5	117148.3	10.5	
u <sup>5</sup> F <sub>1</sub>		t <sup>5</sup> F°	1	111017.5				3d <sup>5</sup> (a <sup>6</sup> S)7f	p <sup>5</sup> F°	1	117164.7		
u <sup>5</sup> F <sub>2</sub>			2	111060.5	43.0					2	117231.7	67.0	
u <sup>5</sup> F <sub>3</sub>			3	111115.4	54.9					3	117314.6	82.9	
u <sup>5</sup> F <sub>4</sub>			4	111159.2	43.8		7f <sup>5</sup> F <sub>4</sub>			4	117399.3	84.7	
u <sup>5</sup> F <sub>5</sub>			5	111160.5	1.3		7f <sup>5</sup> F <sub>5</sub>			5	117483.2	83.9	
u <sup>5</sup> P <sub>1</sub>		s <sup>5</sup> P°	1	111162.3			s <sup>5</sup> F <sub>1</sub>			1	117164.7		
u <sup>5</sup> P <sub>2</sub>			2	111178.8	16.5		s <sup>5</sup> F <sub>2</sub>			2	117231.7		
u <sup>5</sup> P <sub>3</sub>			3	111212.8	34.0		s <sup>5</sup> F <sub>3</sub>			3	117314.6		
							s <sup>5</sup> F <sub>4</sub>			4	117399.3		
							s <sup>5</sup> F <sub>5</sub>			5	117483.2		
u <sup>5</sup> G <sub>2</sub>		x <sup>5</sup> G°	2	113093.0				3d <sup>5</sup> (a <sup>6</sup> S)10s	j <sup>7</sup> S	3	119185.6		
u <sup>5</sup> G <sub>3</sub>			3	113110.3	17.3								
u <sup>5</sup> G <sub>4</sub>			4	113181.7	71.4								
u <sup>5</sup> G <sub>5</sub>			5	113250.8	69.1								
u <sup>5</sup> G <sub>6</sub>			6	113323.0	72.2								
t <sup>5</sup> F <sub>1</sub>		s <sup>5</sup> F°	1	113645.5				3d <sup>5</sup> (a <sup>6</sup> S)8f	o <sup>5</sup> F°	{1 to 5}	119253		
t <sup>5</sup> F <sub>2</sub>			2	113645.0	-0.5								
t <sup>5</sup> F <sub>3</sub>			3	113641.4	-3.6								
t <sup>5</sup> F <sub>4</sub>			4	113646.7	5.3								
t <sup>5</sup> F <sub>5</sub>			5	113658.0	11.3								
8s <sup>7</sup> S <sub>3</sub>	3d <sup>5</sup> (a <sup>6</sup> S)8s	h <sup>7</sup> S	3	113697.6				Mn III (a <sup>6</sup> S <sub>234</sub> )	Limit	---	126147		

November 1951.



Mn II OBSERVED TERMS\*

Config. $1s^2 2s^2 2p^6 3s^2 3p^4 +$	Observed Terms			
$3d^6$	{ $a^3P$ $a^5D$ $a^3D$ $a^3F$ $a^3G$ $a^3H$ $c^5D$ }			
$3d^4 4s^2$	$ns$ ( $n \geq 4$ )	$np$ ( $n \geq 4$ )	$nd$ ( $n \geq 4$ )	
$3d^5(a^6S)nx$	{ $a, e, f, g, h, i, j^1S$ ( $a, e, f, g, h$ )	$z, x^7P^o$ $z, w^5P^o$	$z^5F^o$ $z^3F^o$	$e, f, g, h^7D$ $e, f, h^5D$
$3d^5(a^4G)nx$		$z^5S^o$ $z^3S^o$	$z^5D^o$ $z^3D^o$	$e^5H$ $e^5I$
$3d^5(a^4P)nx$		$a, e^5P$ $b, e^3P$	$z^5D^o$ $z^3D^o$	
$3d^5(a^4D)nx$		$b, g^5D$ $b, e^3D$	$x^5P^o$ $y^5D^o$ $y^3P^o$ $y^3D^o$	
$3d^5(a^4F)nx$		$a^5F$	$y^5F^o$	
$3d^4 4s(a^6D)nx$	$nf$ ( $n \geq 4$ )	$y^7P^o$ $y^5P^o$	$u^5P^o$ $w^5D^o$ $w^5F^o$	
$3d^4 4s(b^4D)nx$				
$3d^5(a^6S)nx$	{ $z, y, x, w^7F^o$ $x, v, r, g, o^5F^o$ }	$ng$ ( $n \geq 5$ )	$e^7G$ $f^5G$	

\*For predicted terms in the spectra of the Cr I isoelectronic sequence, see Vol. II, Introduction.

## Mn III

(V I sequence; 23 electrons)

 $Z=25$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 {}^6S_{5/2}$  $a {}^6S_{5/2}$  271800  $\text{cm}^{-1}$ 

I. P. 33.69 volts

The early analysis by Gibbs and White has been extended by Catalán and Miss García-Riquelme especially for inclusion here. The present observations extend from 594 Å to 3997 Å. The resonance lines reported by Kruger and Miss Gilroy have been confirmed. Fifteen new terms are listed in the current manuscript.

Catalán has derived the limit from the  $ns {}^6D$  series ( $n=4,5$ ) by means of a Ritz formula, with the assumed value of  $\alpha$  equal to  $3.3 \times 10^{-6}$ . The total number of classified lines is 173. Observed intersystem combinations connect the systems of terms of different multiplicity.

## REFERENCES

- R. C. Gibbs and H. E. White, Proc. Nat. Acad. Sci. **13**, 525 (1927). (T) (C L)  
 P. G. Kruger and H. T. Gilroy, Phys. Rev. **48**, 720 (1935). (T) (C L)  
 M. A. Catalán and O. García-Riquelme, unpublished material (1951). (I P) (T) (C L)

## Mn III

## Mn III

Config.	Desig.	$J$	Level	Interval	Config.	Desig.	$J$	Level	Interval
$3d^5$	$a {}^6S$	$2\frac{1}{2}$	0. 0		$3d^4({}^5D)4p$	$z {}^4F^\circ$	$1\frac{1}{2}$	116581. 6	
$3d^5$	$a {}^4G$	$5\frac{1}{2}$	26824. 5	—27. 9			$2\frac{1}{2}$	116693. 5	111. 9
		$4\frac{1}{2}$	26852. 4	—7. 9			$3\frac{1}{2}$	116853. 0	159. 5
		$3\frac{1}{2}$	26860. 3	3. 4			$4\frac{1}{2}$	117064. 4	211. 4
		$2\frac{1}{2}$	26856. 9		$3d^4({}^5D)4p$	$z {}^4D^\circ$	$0\frac{1}{2}$	120977. 2	
$3d^5$	$a {}^4P$	$2\frac{1}{2}$	29168. 9	—74. 1			$1\frac{1}{2}$	121094. 2	117. 0
		$1\frac{1}{2}$	29243. 0				$2\frac{1}{2}$	121270. 5	176. 3
		$0\frac{1}{2}$					$3\frac{1}{2}$	121483. 7	213. 2
$3d^5$	$a {}^4D$	$3\frac{1}{2}$	32308. 9	—76. 8	$3d^4({}^5D)4d$	$e {}^6G$	$1\frac{1}{2}$	172444. 6	
		$2\frac{1}{2}$	32385. 7				$2\frac{1}{2}$	172548. 0	103. 4
		$1\frac{1}{2}$					$3\frac{1}{2}$	172683. 6	135. 6
		$0\frac{1}{2}$					$4\frac{1}{2}$	172856. 2	172. 6
$3d^5$	$a {}^4F$	$4\frac{1}{2}$	43574. 2	—30. 0			$5\frac{1}{2}$	173064. 4	208. 2
		$3\frac{1}{2}$	43604. 2	—66. 3	$3d^4({}^5D)4d$	$e {}^6P$	$1\frac{1}{2}$	172571. 7	
		$2\frac{1}{2}$	43670. 5	—5. 1			$2\frac{1}{2}$	172616. 2	44. 5
		$1\frac{1}{2}$	43675. 6				$3\frac{1}{2}$	172758. 5	142. 3
$3d^4({}^5D)4s$	$a {}^6D$	$0\frac{1}{2}$	62456. 7	111. 2	$3d^4({}^5D)4d$	$e {}^6D$	$0\frac{1}{2}$		
		$1\frac{1}{2}$	62567. 9	179. 4			$1\frac{1}{2}$		
		$2\frac{1}{2}$	62747. 3	241. 6			$2\frac{1}{2}$		
		$3\frac{1}{2}$	62988. 9	296. 3			$3\frac{1}{2}$	174175. 7	
		$4\frac{1}{2}$	63285. 2				$4\frac{1}{2}$	174419. 1	243. 4
$3d^4({}^5D)4s$	$b {}^4D$	$0\frac{1}{2}$	71396. 5	169. 0	$3d^4({}^5D)4d$	$e {}^6F$	$0\frac{1}{2}$		
		$1\frac{1}{2}$	71565. 5	267. 9			$1\frac{1}{2}$		
		$2\frac{1}{2}$	71833. 4	351. 4			$2\frac{1}{2}$		
		$3\frac{1}{2}$	72184. 8				$3\frac{1}{2}$	174576. 8	298. 8
$3d^4({}^5D)4p$	$z {}^6F^\circ$	$0\frac{1}{2}$	110036. 8	137. 1			$4\frac{1}{2}$	174875. 6	100. 7
		$1\frac{1}{2}$	110173. 9	225. 7			$5\frac{1}{2}$	174976. 3	
		$2\frac{1}{2}$	110399. 6	313. 2	$3d^4({}^5D)5s$	$f {}^6D$	$0\frac{1}{2}$	176100. 0	106. 0
		$3\frac{1}{2}$	110712. 8	400. 0			$1\frac{1}{2}$	176206. 0	186. 0
		$4\frac{1}{2}$	111112. 8	490. 2			$2\frac{1}{2}$	176392. 0	250. 0
		$5\frac{1}{2}$	111603. 0				$3\frac{1}{2}$	176642. 0	304. 4
$3d^4({}^5D)4p$	$z {}^6P^\circ$	$1\frac{1}{2}$	111778. 0	107. 4			$4\frac{1}{2}$	176946. 4	
		$2\frac{1}{2}$	111885. 4	174. 3	$3d^4({}^5D)4d$	$e {}^6S$	$2\frac{1}{2}$	181951. 3	
		$3\frac{1}{2}$	112059. 7						
$3d^4({}^5D)4p$	$z {}^4P^\circ$	$0\frac{1}{2}$	112815. 8	264. 4					
		$1\frac{1}{2}$	113080. 2	598. 2	Mn IV ( ${}^5D_0$ )	Limit		271800	
		$2\frac{1}{2}$	113678. 4						
$3d^4({}^5D)4p$	$z {}^6D^\circ$	$0\frac{1}{2}$	113993. 3	103. 4					
		$1\frac{1}{2}$	114096. 7	193. 1					
		$2\frac{1}{2}$	114289. 8	—78. 9					
		$3\frac{1}{2}$	114210. 9	292. 1					
		$4\frac{1}{2}$	114503. 0						

Mn III OBSERVED TERMS\*

Config. 1s <sup>2</sup> 2s <sup>2</sup> 2p <sup>6</sup> 3s <sup>2</sup> 3p <sup>6</sup> +	Observed Terms	
3d <sup>5</sup>	{ a <sup>6</sup> S    a <sup>4</sup> P    a <sup>4</sup> D    a <sup>4</sup> F    a <sup>4</sup> G	
3d <sup>4</sup> ( <sup>5</sup> D)nx	ns (n ≥ 4)	np (n ≥ 4)
	{ a, f <sup>6</sup> D b <sup>4</sup> D	z <sup>6</sup> P°    z <sup>6</sup> D°    z <sup>6</sup> F° z <sup>4</sup> P°    z <sup>4</sup> D°    z <sup>4</sup> F°
	nd (n ≥ 4)	
3d <sup>4</sup> ( <sup>5</sup> D)nx	e <sup>6</sup> S    e <sup>6</sup> P    e <sup>6</sup> D    e <sup>6</sup> F    e <sup>6</sup> G	

\*For predicted terms in the spectra of the V I isoelectronic sequence, see Vol. I, p. xxxvii.

Mn IV

(Ti I sequence; 22 electrons) Z=25

Ground state 1s<sup>2</sup> 2s<sup>2</sup> 2p<sup>6</sup> 3s<sup>2</sup> 3p<sup>6</sup> 3d<sup>4</sup> <sup>5</sup>D<sub>0</sub>

a <sup>5</sup>D<sub>0</sub>                      cm<sup>-1</sup>                                      I. P.                      volts

The analysis is from Bowen, who has extended White's early work and published 156 classified lines, 100 in the range 540 A to 675 A, and 56 in the range 1442 A to 1973 A. The triplet and quartet systems of terms are connected by observed intersystem combinations. F. L. Moore, Jr., has recently observed this spectrum in more detail and with higher accuracy. He confirms the multiplet by White (3d<sup>3</sup> 4s <sup>5</sup>F—3d<sup>3</sup> 4p <sup>5</sup>G°) without doubt, and expects to carry the analysis much further in the near future. No series have been found.

REFERENCES

I. S. Bowen, Phys. Rev. **52**, 1153 (1937). (T) (C L)  
F. L. Moore, Jr., private communication (May 1951).



## Mn IV

## Mn IV

Config.	Desig.	<i>J</i>	Level	Interval	Config.	Desig.	<i>J</i>	Level	Interval
$3d^4$	$a^5D$	0	0		$3d^3(a^4F)4p$	$z^5D^\circ$	0		
		1	92	92			1		
		2	280	188			2	170861	
		3	547	267			3	171272	411
		4	880	333			4	171760	488
$3d^4$	$a^3P$	0	20646		$3d^3(a^4F)4p$	$z^5F^\circ$	1	171381	
		1	21274	628			2	171694	313
		2	22321	1047			3	172076	382
$3d^4$	$a^3H$	4	21273				4	172471	395
		5	21469	196			5	172863	392
		6	21676	207	$3d^3(a^4F)4p$	$z^3D^\circ$	1	172081	
$3d^4$	$a^3F$	2	22786				2	172391	310
		3	22859	73			3	172948	557
		4	22957	98	$3d^3(a^4F)4p$	$z^3G^\circ$	3	175422	
$3d^4$	$a^3G$	3	25434				4	175804	382
		4	25666	232			5	176283	479
		5	25875	209	$3d^3(a^4F)4p$	$z^3F^\circ$	2	177624	
$3d^3(a^4F)4s$	$a^5F$	1	111502				3	178070	446
		2	111706	204			4	178573	503
		3	112006	300	$3d^3(a^4P)4p$	$z^5P^\circ$	1	184560	
		4	112402	398			2	184896	336
		5	112877	475			3	185430	534
$3d^3(a^4F)4s$	$b^3F$	2	119431		$3d^3(a^3G)4p$	$y^3G^\circ$	3	188753	
		3	119955	524			4	189207	454
		4	120599	644			5	189553	346
$3d^3(a^4F)4p$	$z^5G^\circ$	2	167885		$3d^3(a^3H)4p$	$x^3G^\circ$	5	200186	
		3	168295	410			4	200284	-98
		4	168830	535			3	200324	-40
		5	169492	662					
		6	170278	786					

May 1951.

## Mn IV OBSERVED TERMS\*

Config. $1s^2 2s^2 2p^6 3s^2 3p^6 +$	Observed Terms	
$3d^4$	{ $a^3P$ $a^5D$ $a^3F$ $a^3G$ $a^3H$	
	$ns$ ( $n \geq 4$ )	$np$ ( $n \geq 4$ )
	{ $a^5F$ $b^3F$	$z^5D^\circ$ $z^5F^\circ$ $z^5G^\circ$ $z^3D^\circ$ $z^3F^\circ$ $z^3G^\circ$  $z^5P^\circ$     $y^3G^\circ$    $x^3G^\circ$
$3d^3(a^4F)nx$		
$3d^3(a^4P)nx$		
$3d^3(a^3G)nx$		
$3d^3(a^3H)nx$		

\*For predicted terms in the spectra of the Ti I isoelectronic sequence, see Vol. I, p. xxxvii.

## Mn v

(Sc I sequence; 21 electrons)

Z=25

Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 {}^4F_{1/2}$  $a {}^4F_{1/2} 613200 \pm \text{cm}^{-1}$ 

I. P. 76 volts

The analysis is incomplete. The first work was by White who found twelve multiplets giving three of the leading low terms from the  $3d^3$  configuration, two terms from  $3d^2 4s$  and five from  $3d^2 4p$ . Later Bowen extended the analysis and observed intersystem combinations connecting the doublet and quartet terms. About one hundred lines are now classified, in the region from 382 Å to 1620 Å.

The terms are mostly from Bowen's 1935 paper. Two of his terms have been added from the 1940 reference below. The two terms  $b {}^4F$  and  $b {}^2F$  are from White with values slightly adjusted by the writer to fit Bowen's term array, since the two sets of measures of the extreme ultraviolet lines are not completely accordant.

White's  ${}^2F$  term is here called  $b {}^2F$  on the assumption that the  ${}^2F$  term having the configuration  $3d^3$ , which is not yet known, will probably be lower and should, therefore, be designated  $a {}^2F$ .

The limit (entered in brackets in the table) has been calculated from White's estimated ionization potential, which in turn is based on his extrapolation of isoelectronic sequence data.

## REFERENCES

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## Mn v

## Mn v

Config.	Desig.	<i>J</i>	Level	Interval	Config.	Desig.	<i>J</i>	Level	Interval
$3d^3$	$a {}^4F$	$1\frac{1}{2}$	0		$3d^2(a {}^3F)4p$	$z {}^2F^\circ$	$2\frac{1}{2}$	245486	821
		$2\frac{1}{2}$	349	349			$3\frac{1}{2}$	246307	
		$3\frac{1}{2}$	827	478	$3d^2(a {}^3F)4p$	$z {}^4D^\circ$	$0\frac{1}{2}$	246530	-387 737 806
		$4\frac{1}{2}$	1406	579			$1\frac{1}{2}$	246143	
$3d^3$	$a {}^4P$	$0\frac{1}{2}$	16420	160	$3d^2(a {}^3F)4p$	$z {}^2D^\circ$	$2\frac{1}{2}$	246880	
		$1\frac{1}{2}$	16580	456			$3\frac{1}{2}$	247686	
		$2\frac{1}{2}$	17036						
$3d^3$	$a {}^2G$	$3\frac{1}{2}$	17878	504	$3d^2(a {}^3F)4p$	$z {}^2G^\circ$	$1\frac{1}{2}$	248074	751
		$4\frac{1}{2}$	18382				$4\frac{1}{2}$	250949	
$3d^3$	$a {}^2P$	$1\frac{1}{2}$	22902	-176	$3d^2(a {}^3P)4p$	$z {}^4S^\circ$	$1\frac{1}{2}$	251700	
		$0\frac{1}{2}$	23078					257424	
$3d^3$	$a {}^2D$	$2\frac{1}{2}$	24610	-41	$3d^2(a {}^3P)4p$	$y {}^4D^\circ$	$0\frac{1}{2}$	260808	652 1106
		$1\frac{1}{2}$	24651				$1\frac{1}{2}$	261460	
$3d^3$	$a {}^2H$	$4\frac{1}{2}$	24953	362	$3d^2(a {}^3P)4p$	$z {}^4P^\circ$	$2\frac{1}{2}$	262566	
		$5\frac{1}{2}$	25315				$3\frac{1}{2}$	264382	
$3d^2(a {}^3F)4s$	$b {}^4F$	$1\frac{1}{2}$	176937	377	$3d^2(a {}^3P)4p$	$y {}^2G^\circ$	$0\frac{1}{2}$	264712	330 756
		$2\frac{1}{2}$	177314	548			$1\frac{1}{2}$	265468	
		$3\frac{1}{2}$	177862	698			$2\frac{1}{2}$	265555	
		$4\frac{1}{2}$	178560				$4\frac{1}{2}$	265715	
$3d^2(a {}^3F)4s$	$b {}^2F$	$2\frac{1}{2}$	183528	1105	$3d^2(a {}^1G)4p$	$z {}^2H^\circ$	$4\frac{1}{2}$	271475	1149
		$3\frac{1}{2}$	184633				$5\frac{1}{2}$	272624	
$3d^2(a {}^3F)4p$	$z {}^4G^\circ$	$2\frac{1}{2}$	241906	847	$3d^2(a {}^1G)4p$	$z {}^2H^\circ$	$4\frac{1}{2}$	271475	1149
		$3\frac{1}{2}$	242753	1037			$5\frac{1}{2}$	272624	
		$4\frac{1}{2}$	243790	1246					
		$5\frac{1}{2}$	245036						
$3d^2(a {}^3F)4p$	$z {}^4F^\circ$	$1\frac{1}{2}$	243115	552	Mn vi ( ${}^3F_2$ )	Limit		[613200]	
		$2\frac{1}{2}$	243667	703					
		$3\frac{1}{2}$	244370	755					
		$4\frac{1}{2}$	245125						

## Mn v OBSERVED TERMS\*

Config. 1s <sup>2</sup> 2s <sup>2</sup> 2p <sup>6</sup> 3s <sup>2</sup> 3p <sup>5</sup> +	Observed Terms	
3d	$\begin{Bmatrix} a^4P \\ a^2P \end{Bmatrix}$ $a^2D$ $a^4F$ $a^2G$ $a^2H$	
	$ns$ ( $n \geq 4$ )	$np$ ( $n \geq 4$ )
3d <sup>2</sup> (a <sup>3</sup> F) $nx$	$\begin{Bmatrix} b^4F \\ b^2F \end{Bmatrix}$	$z^4D^\circ$ $z^4F^\circ$ $z^4G^\circ$ $z^2D^\circ$ $z^2F^\circ$ $z^2G^\circ$
3d <sup>2</sup> (a <sup>3</sup> P) $nx$		$z^4S^\circ$ $z^4P^\circ$ $y^4D^\circ$
3d <sup>2</sup> (a <sup>1</sup> G) $nx$		$y^2G^\circ$ $z^2H^\circ$

\*For predicted terms in the spectra of the Sc I isoelectronic sequence see Vol. I, p. xxxvi.

## Mn VI

(Ca I sequence; 20 electrons)

$Z=25$

Ground state 1s<sup>2</sup> 2s<sup>2</sup> 2p<sup>6</sup> 3s<sup>2</sup> 3p<sup>6</sup> 3d<sup>2</sup> <sup>3</sup>F<sub>2</sub>

$a^3F_2$           cm<sup>-1</sup>

I. P.          volts

The analysis is incomplete. Thirty lines were classified by Cady in the range between 307 Å and 329 Å. The present term list is from an unpublished manuscript by Edlén, who has revised Cady's analysis, by using unpublished wavelengths by Bowen.

## REFERENCES

W. M. Cady, Phys. Rev. **43**, 324 (1933). (T) (C L)  
 B. Edlén, unpublished material (Feb. 1949). (T)

## Mn VI

## Mn VI

Config.	Desig.	$J$	Level	Interval	Config.	Desig.	$J$	Level	Interval
3d <sup>2</sup>	$a^3F$	2	0	746					
		3	746	923	3d( <sup>2</sup> D)4p	$z^3F^\circ$	2	323795	1053
		4	1669				3	324848	1521
							4	326369	
3d <sup>2</sup>	$a^1D$	2	15336		3d( <sup>2</sup> D)4p	$z^3P^\circ$	0	329732	
3d <sup>2</sup>	$a^1P$	0	17782	275			1	329635	-97
		1	18057	571			2	329995	360
		2	18628		3d( <sup>2</sup> D)4p	$z^1F^\circ$	3	333063	
3d <sup>2</sup>	$a^1G$	4	25511		3d( <sup>2</sup> D)4p	$z^1P^\circ$	1	336126	
3d( <sup>2</sup> D)4p	$z^1D^\circ$	2	319811						
3d( <sup>2</sup> D)4p	$z^1D^\circ$	1	321695	714					
		2	322409	874					
		3	323283						

March 1949.



## Mn VI OBSERVED TERMS\*

Config. $1s^2 2s^2 2p^6 3s^2 3p^6 +$	Observed Terms
$3d^2$	$\left\{ \begin{array}{cccc} a^3P & & a^3F & \\ & a^1D & & a^1G \end{array} \right.$
	$np \ (n \geq 4)$
$3d(3D)nx$	$\left\{ \begin{array}{ccc} z^3P^\circ & z^3D^\circ & z^3F^\circ \\ z^1P^\circ & z^1D^\circ & z^1F^\circ \end{array} \right.$

\*For predicted terms in the spectra of the Ca I isoelectronic sequence, see Vol. I, p. xxxv.

## Mn VII

(K I sequence; 19 electrons)

$Z=25$

Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^2 D_{13/2}$

$3d^2 D_{13/2}$  962001  $\text{cm}^{-1}$

I. P. 119.24 volts

Twenty-two lines have been classified in the range from 111 Å to 1267 Å. The terms are from the paper by Kruger and Weissberg.

## REFERENCES

- R. C. Gibbs and H. E. White, Proc. Nat. Acad. Sci. **12**, 676 (1926). (C L)  
P. G. Kruger and S. G. Weissberg, Phys. Rev. **52**, 316 (1937). (I P) (T) (C L)

## Mn VII

## Mn VII

Config.	Desig.	$J$	Level	Interval	Config.	Desig.	$J$	Level	Interval
$3p^6(1S)3d$	$3d^2D$	$1\frac{1}{2}$ $2\frac{1}{2}$	0 1355	1355	$3p^6(1S)6f$	$6f^2F^\circ$	$\left\{ \begin{array}{c} 2\frac{1}{2} \\ 3\frac{1}{2} \end{array} \right\}$	807760	
$3p^6(1S)4s$	$4s^2S$	$0\frac{1}{2}$	318734		$3p^6(1S)7f$	$7f^2F^\circ$	$\left\{ \begin{array}{c} 2\frac{1}{2} \\ 3\frac{1}{2} \end{array} \right\}$	848838	
$3p^6(1S)4p$	$4p^2P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	397647 400112	2465	$3p^6(1S)8f$	$8f^2F^\circ$	$\left\{ \begin{array}{c} 2\frac{1}{2} \\ 3\frac{1}{2} \end{array} \right\}$	875534	
$3p^6(1S)5s$	$5s^2S$	$0\frac{1}{2}$	613934		$3p^6(1S)9f$	$9f^2F^\circ$	$\left\{ \begin{array}{c} 2\frac{1}{2} \\ 3\frac{1}{2} \end{array} \right\}$	893742	
$3p^6(1S)4f$	$4f^2F^\circ$	$2\frac{1}{2}$ $3\frac{1}{2}$	615957 616108	151					
$3p^6(1S)5f$	$5f^2F^\circ$	$2\frac{1}{2}$ $3\frac{1}{2}$	739771 739945	174					
$3p^6(1S)6s$	$6s^2S$	$0\frac{1}{2}$	752144		Mn VIII (1S <sub>0</sub> )	Limit	-----	962001	

May 1948.

## Mn VIII

(A I sequence; 18 electrons)

 $Z=25$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 {}^1S_0$  $3p^6 {}^1S_0$  1585000  $\text{cm}^{-1}$ 

I. P. 196 volts

Two lines, at 122 Å and 124 Å, respectively, are classified as combinations with the ground term. The limit and the 5s-levels are apparently extrapolated from isoelectronic sequence data, as indicated by brackets in the table. The listed values have been rounded off in the last places.

For convenience, the Paschen notation has been added by the writer in column one under the heading "A I". As for A I, the  $jl$ -coupling notation in the general form suggested by Racah is here introduced, although  $LS$ -designations as indicated in column two under the heading "Authors" are perhaps preferable for the terms thus far identified.

## REFERENCES

P. G. Kruger, S. G. Weissberg and L. W. Phillips, Phys. Rev. **51**, 1090 (1937). (I P) (T) (C L)  
G. Racah, Phys. Rev. **61**, 537 (L) (1942).

## Mn VIII

A I	Authors	Config.	Desig.	$J$	Level
$1p_0$	$3p^6 {}^1S$	$3p^6$	$3p^6 {}^1S$	0	0
$1s_4$	$3p^5 4s {}^3P^o$	$3p^5 ({}^2P_{1/2}) 4s$	$4s [1\frac{1}{2}]^o$	2 1	806100
$1s_2$	$3p^5 4s {}^1P^o$	$3p^5 ({}^2P_{3/2}) 4s$	$4s' [0\frac{1}{2}]^o$	0 1	818500
$2s_4$	$3p^5 5s {}^3P^o$	$3p^5 ({}^2P_{1/2}) 5s$	$5s [1\frac{1}{2}]^o$	2 1	[1146000]
$2s_2$	$3p^5 5s {}^1P^o$	$3p^5 ({}^2P_{3/2}) 5s$	$5s' [0\frac{1}{2}]^o$	0 1	[1159000]
		-----	-----	---	-----
		Mn IX ( ${}^2P_{1/2}$ )	Limit	---	[1585000]

May 1948.

Mn IX

(Cl I sequence; 17 electrons)

Z=25

Ground state  $1s^2 2s^2 2p^6 3s^2 3p^5 \ ^2P_{1/2}$

$3p^5 \ ^2P_{1/2}$  1791000 cm<sup>-1</sup>

I. P. 222 volts

All of the terms except  $3p^5 \ ^2S$  are from the paper by Edlén. Eleven lines in the region between 105 Å and 395 Å have been classified as combinations from the ground term. Edlén has estimated the value of the limit by extrapolation along the isoelectronic sequence, as indicated by brackets in the table. His unit, 10<sup>3</sup> cm<sup>-1</sup>, has here been changed to cm<sup>-1</sup>.

REFERENCES

S. G. Weissberg and P. G. Kruger, Phys. Rev. **49**, 872 (A) (1936). (C L)  
B. Edlén, Zeit. Phys. **104**, 407 (1937). (I P) (T) (C L)

Mn IX

Config.	Desig.	J	Level	Interval
$3s^2 3p^5$	$3p^5 \ ^2P^o$	$1\frac{1}{2}$ $0\frac{1}{2}$	<sup>0</sup> 12530	-12530
$3p^6$	$3p^6 \ ^2S$	$0\frac{1}{2}$	265291	
$3s^2 3p^4(^3P)4s$	$4s \ ^4P$	$2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	873580 880070	-6490
$3s^2 3p^4(^3P)4s$	$4s \ ^2P$	$1\frac{1}{2}$ $0\frac{1}{2}$	889560 896860	-7300
$3s^2 3p^4(^1D)4s$	$4s' \ ^2D$	$2\frac{1}{2}$ $1\frac{1}{2}$	910890 911310	-420
$3s^2 3p^4(^1S)4s$	$4s'' \ ^2S$	$0\frac{1}{2}$	950060	
-----	-----	-----	-----	
Mn x ( $^3P_2$ )	Limit	-----	[1791000]	

January 1948.



**Mn x**

(S I sequence; 16 electrons)

Z=25

Ground state  $1s^2 2s^2 2p^6 3s^2 3p^4 {}^3P_2$  $3p^4 {}^3P_2$  2004000  $\text{cm}^{-1}$ 

I. P. 248 volts

Edlén has classified 11 lines in the interval between 100 Å and 104 Å, and extrapolated a value of the limit from isoelectronic sequence data.

The singlet and triplet terms are not connected by observed intersystem combinations. By analogy with Fe XI, Edlén has revised the interpolated values of the singlet terms for inclusion here, and the uncertainty,  $x$ , is probably not large.

Edlén's unit,  $10^3 \text{ cm}^{-1}$ , has here been changed to  $\text{cm}^{-1}$

## REFERENCES

B. Edlén, Zeit. Phys. **104**, 188 (1937). (I P) (T) (C L)

B. Edlén, letter (January 1950). (T)

**Mn x**

Config.	Desig.	$J$	Level	Interval
$3s^2 3p^4$	$3p^4 {}^3P$	2	0	-10000 -1700
		1	10000	
		0	11700	
$3s^2 3p^4$	$3p^4 {}^1D$	2	$33810+x$	430 1980
$3s^2 3p^4$	$3p^4 {}^1S$	0	$73400+x$	
$3s^2 3p^3 ({}^4S^\circ) 4s$	$4s {}^3S^\circ$	1	965990	
$3s^2 3p^3 ({}^2D^\circ) 4s$	$4s' {}^3D^\circ$	1	991770	
		2	992200	
		3	994180	
$3s^2 3p^3 ({}^2D^\circ) 4s$	$4s' {}^1D^\circ$	2	$1002150+x$	
$3s^2 3p^3 ({}^2P^\circ) 4s$	$4s'' {}^1P^\circ$	1	$1032080+x$	
-----	-----	-----	-----	
Mn XI ( ${}^4S_{3/2}$ )	Limit	-----	[2004000]	

January 1950.

Mn xiii

(Al i sequence; 13 electrons)

Z=25

Ground state  $1s^2 2s^2 2p^6 3s^2 3p^2 P^{\circ}_{3/2}$

$3p^2 P^{\circ}_{3/2}$ 

cm<sup>-1</sup>

I. P.

volts

This spectrum has not been analyzed, but Edlén has classified 2 lines as follows:

I. A.	Int.	Wave No.	Desig.
66. 574 67. 215	1 2	1502090 1487760	} $3p^2 P^{\circ} - 4d^2 D$

His unit, 10<sup>3</sup> cm<sup>-1</sup>, is here changed to cm<sup>-1</sup>.

REFERENCE

B. Edlén, Zeit. Phys. **103**, 540 (1936). (C L)

---

December 1947.

Mn xiv

(Mg i sequence; 12 electrons)

Z=25

Ground state  $1s^2 2s^2 2p^6 3s^2 ^1S_0$

$3s^2 ^1S_0$  3260000 cm<sup>-1</sup>

I. P. 404 volts

Edlén has classified 13 lines in the region between 57 Å and 79 Å. No intersystem combinations have been observed and the triplet terms are not all connected by observed combinations. He has determined the relative positions of the various groups of terms and also the ionization potential by extrapolation along the isoelectronic sequence. His estimated value of the limit is entered in brackets in the table.

His unit, 10<sup>3</sup> cm<sup>-1</sup>, has here been changed to cm<sup>-1</sup>.

REFERENCE

B. Edlén, Zeit. Phys. **103**, 536 (1936). (I P) (T) (C L)

Mn xiv

Mn xiv

Config.	Desig.	J	Level	Interval	Config.	Desig.	J	Level	Interval
$3s^2$	$3s^2 ^1S$	0	0		$3s(^2S)4d$	$4d ^3D$	1 2 3	1818250+x 1818750+x 1819640+x	500 890
$3s(^2S)3p$	$3p ^3P^{\circ}$	0 1 2	$218910+x$ $223700+x$ $235080+x$	4790 11380	$3s(^2S)4f$	$4f ^3F^{\circ}$	2 3 4	$1892970+x$	
$3s(^2S)3d$	$3d ^3D$	1 2 3	$640240+x$		$3s(^2S)5f$	$5f ^3F^{\circ}$	2 3 4	$2387760+x$	
$3s(^2S)4s$	$4s ^3S$	1	$1569110+x$						
$3s(^2S)4p$	$4p ^3P^{\circ}$	1	$1685630$						
					-----	-----	-----	-----	
					Mn xv ( $^2S_{1/2}$ )	Limit	-----	[3260000]	

August 1947.

**Mn xv**

(Na I sequence; 11 electrons)

 $Z=25$ Ground state  $1s^2 2s^2 2p^6 3s^2 S_{0\frac{1}{2}}$  $3s^2 S_{0\frac{1}{2}}$  **3511210**  $\text{cm}^{-1}$ 

I. P. 435 volts

Edlén has classified 12 lines in the interval 45 Å to 75 Å and extrapolated the absolute value of the ground term from isoelectronic sequence data. His unit,  $10^3 \text{ cm}^{-1}$ , has here been changed to  $\text{cm}^{-1}$ .

**REFERENCE**B. Edlén, Zeit. Phys. **100**, 621 (1936). (I P) (T) (C L)**Mn xv****Mn xv**

Config.	Desig.	$J$	Level	Interval	Config.	Desig.	$J$	Level	Interval
3s	3s $^2S$	$0\frac{1}{2}$	0		4f	4f $^2F^\circ$	$2\frac{1}{2}$ $3\frac{1}{2}$	1962870 1963250	380
3p	3p $^2P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	259450 276650	17200	5d	5d $^2D$	$1\frac{1}{2}$ $2\frac{1}{2}$	2492130	
3d	3d $^2D$	$1\frac{1}{2}$ $2\frac{1}{2}$	632760 634950	2190	5f	5f $^2F^\circ$	$2\frac{1}{2}$ $3\frac{1}{2}$	2520370 2520600	230
4s	4s $^2S$	$0\frac{1}{2}$	1666950		-----	-----	-----	-----	
4p	4p $^2P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	1770410 1777150	6740	Mn xvi ( $^1S_0$ )	<b>Limit</b>	-----	[3511210]	
4d	4d $^2D$	$1\frac{1}{2}$ $2\frac{1}{2}$	1906350 1907470	1120					

June 1947.

**Mn xvi**

(Ne I sequence; 10 electrons)

 $Z=25$ Ground state  $1s^2 2s^2 2p^6 ^1S_0$  $2p^6 ^1S_0$  **9164300**  $\text{cm}^{-1}$ 

I. P. 1135.9 volts

Tyrén has classified nine lines, between 13 Å and 18 Å, as combinations with the ground term. His absolute term values have been derived by extrapolation along the Ne I isoelectronic sequence.

By analogy with Ne I the  $j\bar{l}$ -coupling notation in the general form suggested by Racah is introduced.

The unit adopted by Tyrén,  $10^3 \text{ cm}^{-1}$ , has here been changed to  $\text{cm}^{-1}$ .

**REFERENCES**

F. Tyrén, Zeit. Phys. **111**, 314 (1938). (I P) (T) (C L)  
G. Racah, Phys. Rev. **61**, 537 (L) (1942).



Mn XVI

Mn XVI

Author	Config.	Desig.	<i>J</i>	Level	Author	Config.	Desig.	<i>J</i>	Level
2 <i>p</i> <sup>1</sup> S <sub>0</sub>	2 <i>s</i> <sup>2</sup> 2 <i>p</i> <sup>6</sup>	2 <i>p</i> <sup>6</sup> <sup>1</sup> S	0	0	3 <i>p</i> ' <sup>3</sup> P <sub>1</sub>	2 <i>s</i> 2 <i>p</i> <sup>6</sup> ( <sup>2</sup> S)3 <i>p</i>	3 <i>p</i> <sup>3</sup> P <sup>o</sup>	2 1 0	6530800
3 <i>s</i> <sup>3</sup> P <sub>1</sub>	2 <i>s</i> <sup>2</sup> 2 <i>p</i> <sup>5</sup> ( <sup>2</sup> P <sub>1/2</sub> )3 <i>s</i>	3 <i>s</i> [1½] <sup>o</sup>	2 1	5281200	3 <i>p</i> <sup>1</sup> P <sub>1</sub>	2 <i>s</i> 2 <i>p</i> <sup>6</sup> ( <sup>2</sup> S)3 <i>p</i>	3 <i>p</i> <sup>1</sup> P <sup>o</sup>	1	6562500
3 <i>s</i> <sup>1</sup> P <sub>1</sub>	2 <i>s</i> <sup>2</sup> 2 <i>p</i> <sup>5</sup> ( <sup>2</sup> P <sub>3/2</sub> )3 <i>s</i>	3 <i>s</i> '[0½] <sup>o</sup>	0 1	5360800	4 <i>d</i> <sup>1</sup> P <sub>1</sub>	2 <i>s</i> <sup>2</sup> 2 <i>p</i> <sup>5</sup> ( <sup>2</sup> P <sub>1/2</sub> )4 <i>d</i>	4 <i>d</i> [1½] <sup>o</sup>	1	7348000
3 <i>d</i> <sup>3</sup> P <sub>1</sub>	2 <i>s</i> <sup>2</sup> 2 <i>p</i> <sup>5</sup> ( <sup>2</sup> P <sub>1/2</sub> )3 <i>d</i>	3 <i>d</i> [0½] <sup>o</sup>	0 1	5849700	4 <i>d</i> <sup>3</sup> D <sub>1</sub>	2 <i>s</i> <sup>2</sup> 2 <i>p</i> <sup>5</sup> ( <sup>2</sup> P <sub>3/2</sub> )4 <i>d</i> '	4 <i>d</i> '[1½] <sup>o</sup>	1	7429000
3 <i>d</i> <sup>1</sup> P <sub>1</sub>		3 <i>d</i> [1½] <sup>o</sup>	1	5923500					
3 <i>d</i> <sup>3</sup> D <sub>1</sub>	2 <i>s</i> <sup>2</sup> 2 <i>p</i> <sup>5</sup> ( <sup>2</sup> P <sub>3/2</sub> )3 <i>d</i>	3 <i>d</i> '[1½] <sup>o</sup>	1	6018300		Mn XVII ( <sup>2</sup> P <sub>1/2</sub> )	Limit	---	[9164300]
						Mn XVII ( <sup>2</sup> P <sub>3/2</sub> )	Limit	---	9249600

April 1947.

Mn XVI OBSERVED LEVELS\*

Config. 1 <i>s</i> <sup>2</sup> +	Observed Terms		
2 <i>s</i> <sup>2</sup> 2 <i>p</i> <sup>6</sup>	2 <i>p</i> <sup>6</sup> <sup>1</sup> S		
	<i>ns</i> ( <i>n</i> ≥ 3)	<i>np</i> ( <i>n</i> ≥ 3)	<i>nd</i> ( <i>n</i> ≥ 3)
2 <i>s</i> <sup>2</sup> 2 <i>p</i> <sup>5</sup> ( <sup>2</sup> P <sup>o</sup> ) <i>nx</i>	{ 3 <i>s</i> <sup>3</sup> P <sup>o</sup> 3 <i>s</i> <sup>1</sup> P <sup>o</sup>		3 <i>d</i> <sup>3</sup> P <sup>o</sup> 3, 4 <i>d</i> <sup>3</sup> D <sup>o</sup> 3, 4 <i>d</i> <sup>1</sup> P <sup>o</sup>
2 <i>s</i> 2 <i>p</i> <sup>6</sup> ( <sup>2</sup> S) <i>nx</i>	{	3 <i>p</i> <sup>3</sup> P <sup>o</sup> 3 <i>p</i> <sup>1</sup> P <sup>o</sup>	
<i>jl</i> -Coupling Notation			
Config. 1 <i>s</i> <sup>2</sup> +	Observed Pairs		
2 <i>s</i> <sup>2</sup> 2 <i>p</i> <sup>5</sup> ( <sup>2</sup> P <sub>1/2</sub> ) <i>nx</i>	<i>ns</i> ( <i>n</i> ≥ 3)		<i>nd</i> ( <i>n</i> ≥ 3)
	3 <i>s</i> [1½] <sup>o</sup>		3 <i>d</i> [0½] <sup>o</sup> 3, 4 <i>d</i> [1½] <sup>o</sup>
	3 <i>s</i> '[0½] <sup>o</sup>		3, 4 <i>d</i> '[1½] <sup>o</sup>
2 <i>s</i> <sup>2</sup> 2 <i>p</i> <sup>5</sup> ( <sup>2</sup> P <sub>3/2</sub> ) <i>nx</i> '			

\*For predicted levels in the spectra of the Ne I isoelectronic sequence see Vol. I, p. xxxi.

## IRON

## Fe I

26 electrons

 $Z=26$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^6 4s^2 {}^5D_4$  $a {}^5D_4$  63700  $\text{cm}^{-1}$ I. P.  $7.90 \pm 0.01$  volts

The terms are from the paper by Russell, Moore, and Weeks, which is "based on the work of many investigators, including unpublished studies by Miguel A. Catalán," which were not published because of the Spanish war. He contributed 89 new levels including the first singlet terms to be found in Fe I. Their table of all classified lines that have been observed in the laboratory extends from 1855 Å to 11973 Å and includes 3,606 lines. In addition they give a table of 1,254 predicted lines that have been accepted as present in the solar spectrum and graded "Good" or "Fair". It is reasonably certain that more faint solar lines may be correctly attributed to Fe I than are included in the present conservative list.

Intersystem combinations connecting the terms of all four multiplicities have been observed. One small change has been incorporated here. The miscellaneous level labeled  $8^\circ$  is here designated  $x {}^3S^\circ$ , as was tentatively suggested by the authors.

The ionization potential is well determined from three series.

The analysis could be carried further if laboratory observations of faint lines were extended. The present analysis is, however, remarkably complete for such a complex spectrum. The present lists contain 4,860 classified lines arising from combinations among 464 energy levels. With the aid of extensive Zeeman data all but 18 of these have been grouped into 147 terms, which combine to give 1,348 multiplets. "The general result of this analysis is that the iron arc spectrum, despite its complexity, is highly regular." The detailed confirmation of theory is conspicuous.

## REFERENCES

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(C L) (Z E)  
J. E. Mack, Rev. Mod. Phys. **22**, No. 1, 64 (1950). (Summary hfs)  
L. A. Fisher, unpublished infrared data (June 1950). ( $x {}^7P^\circ$  term added in proof.)

## Fe I

## Fe I

Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>	Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>
3d <sup>6</sup> 4s <sup>2</sup>	<i>a</i> <sup>5</sup> D	4 3 2 1 0	0. 000 415. 933 704. 003 888. 132 978. 074	—415. 933 —288. 070 —184. 129 —89. 942	1. 496 1. 497 1. 494 1. 498	3d <sup>6</sup> 4s( <i>a</i> <sup>6</sup> D)4 <i>p</i>	<i>z</i> <sup>5</sup> F°	5 4 3 2 1	26874. 562 27166. 837 27394. 703 27559. 598 27666. 362	—292. 275 —227. 866 —164. 895 —106. 764	1. 399 1. 355 1. 250 1. 004 —0. 012
3d <sup>7</sup> ( <i>a</i> <sup>4</sup> F)4 <i>s</i>	<i>a</i> <sup>5</sup> F	5 4 3 2 1	6928. 280 7376. 775 7728. 071 7985. 795 8154. 725	—448. 495 —351. 296 —257. 724 —168. 930	1. 404 1. 349 1. 248 0. 995 —0. 014	3d <sup>7</sup> ( <i>a</i> <sup>2</sup> P)4 <i>s</i>	<i>a</i> <sup>1</sup> P	1	27543. 00		0. 817
3d <sup>7</sup> ( <i>a</i> <sup>4</sup> F)4 <i>s</i>	<i>a</i> <sup>3</sup> F	4 3 2	11976. 260 12560. 953 12968. 573	—584. 693 —407. 620	1. 254 1. 086 0. 670	3d <sup>7</sup> ( <i>a</i> <sup>2</sup> D)4 <i>s</i>	<i>a</i> <sup>1</sup> D	2	28604. 61		1. 028
3d <sup>7</sup> ( <i>a</i> <sup>4</sup> P)4 <i>s</i>	<i>a</i> <sup>5</sup> P	3 2 1	17550. 210 17727. 017 17927. 411	—176. 807 —200. 394	1. 666 1. 820 2. 499	3d <sup>7</sup> ( <i>a</i> <sup>2</sup> H)4 <i>s</i>	<i>a</i> <sup>1</sup> H	5	28819. 98		1. 000
3d <sup>6</sup> 4s <sup>2</sup>	<i>a</i> <sup>3</sup> P	2 1 0	18378. 215 19552. 493 20037. 86	—1174. 278 —485. 37	1. 506 1. 500	3d <sup>6</sup> 4s( <i>a</i> <sup>6</sup> D)4 <i>p</i>	<i>z</i> <sup>5</sup> P°	3 2 1	29056. 341 29469. 033 29732. 749	—412. 692 —263. 716	1. 657 1. 835 2. 487
3d <sup>6</sup> 4s( <i>a</i> <sup>6</sup> D)4 <i>p</i>	<i>z</i> <sup>1</sup> D°	5 4 3 2 1	19350. 894 19562. 457 19757. 040 19912. 511 20019. 648	—211. 563 —194. 583 —155. 471 —107. 137	1. 597 1. 642 1. 746 2. 008 2. 999	3d <sup>6</sup> 4s <sup>2</sup>	<i>a</i> <sup>1</sup> I	6	29313. 04		1. 014
3d <sup>6</sup> 4s <sup>2</sup>	<i>a</i> <sup>3</sup> H	6 5 4	19390. 197 19621. 036 19788. 280	—230. 839 —167. 244	1. 163 1. 038 0. 811	3d <sup>6</sup> 4s <sup>2</sup>	<i>b</i> <sup>3</sup> D	1 2 3	29320. 05 29356. 78 29371. 86	36. 73 15. 08	1. 326
3d <sup>6</sup> 4s <sup>2</sup>	<i>b</i> <sup>3</sup> F	4 3 2	20641. 144 20874. 521 21039. 021	—233. 377 —164. 500	1. 235 1. 073 0. 663	3d <sup>6</sup> 4s <sup>2</sup>	<i>b</i> <sup>1</sup> G	4	29798. 96		0. 979
3d <sup>7</sup> ( <i>a</i> <sup>2</sup> G)4 <i>s</i>	<i>a</i> <sup>3</sup> G	5 4 3	21715. 770 21999. 167 22249. 461	—283. 397 —250. 294	1. 197 1. 051 0. 756	3d <sup>6</sup> 4s( <i>a</i> <sup>4</sup> D)4 <i>p</i>	<i>z</i> <sup>3</sup> F°	4 3 2	31307. 272 31805. 097 32134. 014	—497. 825 —328. 917	1. 250 1. 086 0. 682
3d <sup>6</sup> 4s( <i>a</i> <sup>6</sup> D)4 <i>p</i>	<i>z</i> <sup>1</sup> F°	6 5 4 3 2 1 0	22650. 427 22845. 880 22996. 686 23110. 948 23192. 508 23244. 847 23270. 392	—195. 453 —150. 806 —114. 262 —81. 560 —52. 339 —25. 545	1. 498 1. 498 1. 493 1. 513 1. 504 1. 549	3d <sup>6</sup> 4s( <i>a</i> <sup>4</sup> D)4 <i>p</i>	<i>z</i> <sup>3</sup> D°	3 2 1	31322. 639 31686. 377 31937. 350	—363. 738 —250. 973	1. 321 1. 168 0. 513
3d <sup>7</sup> ( <i>a</i> <sup>4</sup> P)4 <i>s</i>	<i>b</i> <sup>3</sup> P	2 1 0	22838. 360 22946. 860 23051. 790	—108. 500 —104. 930	1. 498 1. 489	3d <sup>6</sup>	<i>c</i> <sup>3</sup> F	4 3 2	32873. 68 33412. 78 33765. 33	—539. 10 —352. 55	1. 264 1. 066 0. 677
3d <sup>6</sup> 4s( <i>a</i> <sup>6</sup> D)4 <i>p</i>	<i>z</i> <sup>1</sup> P°	4 3 2	23711. 467 24180. 876 24506. 928	—469. 409 —326. 052	1. 747 1. 908 2. 333	3d <sup>7</sup> ( <i>a</i> <sup>4</sup> F)4 <i>p</i>	<i>y</i> <sup>5</sup> D°	4 3 2 1 0	33095. 962 33507. 144 33801. 595 34017. 127 34121. 623	—411. 182 —294. 451 —215. 532 —104. 496	1. 496 1. 492 1. 495 1. 492
3d <sup>6</sup> 4s <sup>2</sup>	<i>b</i> <sup>3</sup> G	5 4 3	23783. 654 24118. 854 24338. 805	—335. 200 —219. 951	1. 200 1. 048 0. 761	3d <sup>7</sup> ( <i>a</i> <sup>4</sup> F)4 <i>p</i>	<i>y</i> <sup>5</sup> F°	5 4 3 2 1	33695. 418 34039. 540 34328. 775 34547. 235 34692. 172	—344. 122 —289. 235 —218. 460 —144. 937	1. 417 1. 344 1. 244 0. 998 —0. 016
3d <sup>7</sup> ( <i>a</i> <sup>2</sup> P)4 <i>s</i>	<i>c</i> <sup>3</sup> P	2 1 0	24335. 804 24772. 060 25091. 62	—436. 256 —319. 56	1. 484 1. 466	3d <sup>6</sup> 4s( <i>a</i> <sup>4</sup> D)4 <i>p</i>	<i>z</i> <sup>3</sup> P°	2 1 0	33946. 965 34362. 890 34555. 64	—415. 925 —192. 75	1. 493 1. 496
3d <sup>7</sup> ( <i>a</i> <sup>2</sup> G)4 <i>s</i>	<i>a</i> <sup>1</sup> G	4	24574. 690		1. 001	3d <sup>6</sup> 4s <sup>2</sup>	<i>b</i> <sup>1</sup> D	2	34636. 82		
3d <sup>6</sup> 4s( <i>a</i> <sup>6</sup> D)4 <i>p</i>	<i>z</i> <sup>5</sup> D°	4 3 2 1 0	25900. 002 26140. 193 26339. 708 26479. 393 26550. 495	—240. 191 —199. 515 —139. 685 —71. 102	1. 502 1. 500 1. 503 1. 495	3d <sup>7</sup> ( <i>a</i> <sup>4</sup> F)4 <i>p</i>	<i>z</i> <sup>5</sup> G°	6 5 4 3 2	34843. 980 34782. 448 35257. 345 35611. 649 35856. 424	61. 532 —474. 897 —354. 304 —244. 775	1. 332 1. 218 1. 103 0. 887 0. 335
3d <sup>7</sup> ( <i>a</i> <sup>2</sup> H)4 <i>s</i>	<i>b</i> <sup>3</sup> H	6 5 4	26105. 95 26351. 09 26627. 64	—245. 14 —276. 55	1. 165 1. 032 0. 811	3d <sup>7</sup> ( <i>a</i> <sup>4</sup> F)4 <i>p</i>	<i>z</i> <sup>3</sup> G°	5 4 3	35379. 237 35767. 591 36079. 395	—388. 354 —311. 804	1. 248 1. 100 0. 791
3d <sup>7</sup> ( <i>a</i> <sup>2</sup> D)4 <i>s</i>	<i>a</i> <sup>3</sup> D	3 2 1	26225. 03 26623. 73 26406. 49	—398. 70 217. 24	1. 335 1. 178 0. 731	3d <sup>7</sup> ( <i>a</i> <sup>4</sup> F)4 <i>p</i>	<i>y</i> <sup>3</sup> F°	4 3 2	36686. 204 37162. 770 37521. 186	—476. 566 —358. 416	1. 246 1. 086 0. 688
						3d <sup>6</sup> 4s( <i>a</i> <sup>4</sup> D)4 <i>p</i>	<i>y</i> <sup>5</sup> P°	3 2 1	36766. 998 37157. 594 37409. 575	—390. 596 —251. 981	1. 661 1. 836 2. 502
						3d <sup>7</sup> ( <i>b</i> <sup>2</sup> F)4 <i>s</i>	<i>d</i> <sup>3</sup> F	2 3 4	36940. 60 36975. 64 37046. 00	35. 04 70. 36	
						3d <sup>7</sup> ( <i>a</i> <sup>4</sup> F)4 <i>p</i>	<i>y</i> <sup>3</sup> D°	3 2 1	38175. 382 38678. 067 38995. 764	—502. 685 —317. 697	1. 324 1. 151 0. 493



## Fe I—Continued

## Fe I—Continued

Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>	Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>
$3d^6 4s(a^4D)4p$	$x^5D^\circ$	4 3 2 1 0	39625.829 39969.880 40231.365 40404.544 40491.312	—344.051 —261.485 —173.179 —86.768	1.489 1.504 1.501 1.498	$3d^6 4s(b^4F)4p$	$x^5G^\circ$	6 5 4 3 2	45608.35: 45726.18 45833.24 45913.53 45964.98	—117.83 —107.06 —80.29 —51.45	1.336 1.269 1.158 0.928 0.323
$3d^6 4s^2(a^6S)4p$	$y^7P^\circ$	2 3 4	40052.08 40207.12 40421.89	155.04 214.77	2.340 1.908 1.75:	$3d^6 4s(a^4H)4p$	$z^3I^\circ$	7 6 5	45978.04: 46026.98 46135.92	—48.94 —108.94	1.149 1.040 0.833
$3d^6 4s(a^4D)4p$	$x^5F^\circ$	5 4 3 2 1	40257.367 40594.47 40842.13 41018.06 41130.62	—337.10 —247.66 —165.93 —112.56	1.390 1.328 1.254 0.998 —0.006	$3d^6 4s^2(a^6S)4p$	$w^5P^\circ$	3 2 1	46137.14 46313.61 46410.44	—176.47 —96.83	1.658 1.822 2.436
$3d^7(b^2F)4s$	$a^1F$	3	40534.18:			$3d^6 4s(b^4P)4p$	$z^3S^\circ$	1	46600.884		1.888
	X	3 2	40871.46 41178.36	—306.90		$3d^7(a^4P)4p$	$y^3P^\circ$	0 1 2	46672.57 46901.892 46727.137	229.32 —174.755	1.600 1.444
$3d^6 4s(b^4P)4p$	$z^3S^\circ$	2	40895.022		1.985	$3d^7(a^4P)4p$	$u^5D^\circ$	4 3 2 1 0	46720.85 46745.03 46888.582 47177.25 47171.52:	—24.18 —143.55 —288.67 5.73	1.341 1.397 1.260 1.410
$3d^6 4s(b^4P)4p$	$x^5P^\circ$	3 2 1	42532.76 42859.829 43079.05	—327.07 —219.22	1.650 1.822 2.464	$3d^7(a^2G)4p$	$x^3F^\circ$	4 3 2	46889.207 47092.776 47197.074	—203.569 —104.298	1.344 1.159 0.743
$3d^6 4s(a^4H)4p$	$y^5G^\circ$	6 5 4 3 2	42784.387 42911.918 43022.998 43137.511 43210.044	—127.531 —111.080 —114.513 —72.533	1.342 1.203 1.024 0.905 0.331	$3d^6 4s(a^4H)4p$	$z^3H^\circ$	6 5 4	46982.383 47008.423 47106.544	—26.045 —98.116	1.200 1.060 0.880
$3d^6 4s(a^6D)5s$	$e^7D$	5 4 3 2 1	42815.855 43163.327 43434.633 43633.535 43763.982	—347.472 —271.306 —198.902 —130.447	1.585 1.655 1.755 2.009 3.002	$3d^7(a^4F)5s$	$e^5F$	5 4 3 2 1	47005.510 47377.967 47755.538 48036.667 48221.323	—372.457 —377.571 —281.129 —184.656	1.421 1.331 1.236 0.991 0.007
$3d^6 4s(a^4H)4p$	$z^5H^\circ$	7 6 5 4 3	43321.12: 42991.66 43108.944 43325.98	329.46 —117.28 —217.04	1.054 0.871 0.509	$3d^7(a^4P)4p$	$w^3D^\circ$	3 2 1	47017.239 47136.142 47272.095	—118.903 —135.953	1.346 1.216 0.767
$3d^6 4s(b^4P)4p$	$w^5D^\circ$	4 3 2 1 0	43499.54 43922.70 44183.64 44411.18 44458.96	—423.16 —260.94 —227.54 —47.78	1.492 1.481 1.533 1.315	$3d^6 4s(a^4G)4p$	$w^5G^\circ$	6 5 4 3 2	47363.39 47420.23 47590.07 47693.289 47831.20	—56.84 —169.84 —103.22 —137.91	1.306 1.305 1.145 0.931 0.472
$3d^6 4s(b^4F)4p$	$w^5F^\circ$	5 4 3 2 1	44243.67 44022.55 44166.24 44285.48 44378.42:	221.12 —143.69 —119.24 —92.94	1.382 1.444 1.351 1.117 0.283	$3d^7(a^2G)4p:$	$z^1G^\circ$	4	47452.770		1.025
$3d^6 4s(b^4F)4p$	$v^5D^\circ$	4 3 2 1 0	44415.13 44551.44 44664.13 44760.79 44826.92	—136.31 —112.69 —96.66 —66.13	1.401 1.386 1.378 1.389	$3d^7(a^4P)4p$	$y^3S^\circ$	1	47555.63		1.884
$3d^6 4s(b^4F)4p$	$v^5D^\circ$	4 3 2 1 0	44415.13 44551.44 44664.13 44760.79 44826.92	—136.31 —112.69 —96.66 —66.13	1.401 1.386 1.378 1.389	$3d^6 4s(a^4G)4p$	$v^5F^\circ$	5 4 3 2 1	47606.10 47930.04 48122.97 48238.903 48350.62	—323.94 —192.93 —115.93 —111.72	1.317 1.264 1.236 1.267 0.230
$3d^7(a^4P)4p$	$y^5S^\circ$	2	44511.86		1.888	$3d^6 4s(b^4F)4p$	$x^3G^\circ$	3 4 5	47834.26 47812.18 47834.622	—22.08 22.44	0.668 1.061 1.203
$3d^6 4s(a^6D)5s$	$e^5D$	4 3 2 1 0	44677.010 45061.334 45333.880 45509.155 45595.084	—384.324 —272.546 —175.275 —85.929	1.502 1.508 1.503 1.518	$3d^7(a^4F)5s$	$e^3F$	4 3 2	47960.973 48531.896 48928.423	—570.923 —396.527	1.288 1.107 0.622
$3d^6 4s(b^4P)4p$	$x^3D^\circ$	3 2 1	45220.738 45281.889 45551.833	—61.151 —269.944	1.352 1.200 0.556	$3d^7(a^4P)4p$	$v^5P^\circ$	3 2 1	47966.63 48163.49 48289.89	—196.86 —126.40	1.646 1.740 2.213
$3d^6 4s(a^4H)4p$	$y^3G^\circ$	5 4 3	45294.86 45428.456 45563.026	—133.60 —134.570	1.207 1.053 0.765		$w^3G^\circ$	5 4 3	48231.33 48361.92 48475.74	—130.59 —113.82	1.27: 0.934 0.584

## Fe I—Continued

Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>
$3d^6 4s(b^4P)4p$	$x^3P^\circ$	2	48304. 707	-211. 44 56. 03	1. 263
		1	48516. 15		1. 547
		0	48460. 12		
$3d^7(a^2G)4p$	$z^1H^\circ$	5	48382. 63		1. 018
$3d^7(a^2H)4p:$	$y^1G^\circ$	4	48702. 57		1. 063
		2	49052. 93		
$3d^6 4s(b^4F)4p$	$w^3F^\circ$	4	49108. 94	-134. 01 -190. 23	1. 181
		3	49242. 950		1. 165
		2	49433. 18		0. 677
$3d^6 4s(b^4F)4p$	$v^3D^\circ$	3	49135. 08	-107. 60 -54. 98	1. 211
		2	49242. 68		0. 954
		1	49297. 66		0. 562
	$3^\circ$	3	49227. 16		
$3d^7(a^2G)4p$	$y^3H^\circ$	6	49434. 20	-170. 25 -122. 61	1. 17 :
		5	49604. 45		1. 075
		4	49727. 058		0. 929
$3d^7(a^2G)4p$	$v^3G^\circ$	5	49460. 92	-167. 00 -222. 69	1. 163
		4	49627. 92		0. 914
		3	49850. 61		0. 763
	$z^1D^\circ$	2	49477. 10		0. 92 :
$3d^6 4s(a^6D)5p$	$x^7P^\circ$	4	49558. 5	-246. 4 -241. 0	
		3	49804. 9		
		2	50045. 9		
$3d^7(a^2D)4p:$	$w^3P^\circ$	0	49951. 36	91. 89 143. 62	
		1	50043. 25		1. 389
		2	50186. 87		1. 469
$3d^6 4s(a^6D)4d$	$e^7F$	6	50342. 180	-491. 305 -358. 835 43. 45 -182. 22 123. 05	1. 490
		5	50833. 485		1. 505
		4	51192. 320		1. 617
		3	51148. 87		1. 499
		2	51331. 090		
		1	51208. 04		2. 490
		0			
$3d^6 4s(a^6D)4d$	$f^7D$	5	50377. 92	-430. 13 -53. 80 -136. 84 -49. 41	1. 510
		4	50808. 053		1. 574
		3	50861. 85		
		2	50998. 686		1. 844
		1	51048. 10		
$3d^6 4s(a^6D)4d$	$f^5D$	4	50423. 185	-111. 250 -164. 231 -181. 486 -100. 87	1. 514
		3	50534. 435		1. 615
		2	50698. 666		1. 614
		1	50880. 152		1. 662
		0	50981. 02		
$3d^6 4s(a^6D)4d$	$e^7P$	4	50475. 32	-135. 98 -250. 02	1. 585
		3	50611. 303		1. 687
		2	50861. 32		
$3d^6 4s(a^6D)4d$	$e^5G$	6	50522. 94	-180. 97 -275. 715 -239. 432 -151. 125	1. 351
		5	50703. 912		1. 360
		4	50979. 627		1. 238
		3	51219. 059		1. 294
		2	51370. 184		0. 953
$3d^7(a^2G)4p:$	$z^1F^\circ$	3	50586. 89		1. 018
	$x^1G^\circ$	4	50614. 02		0. 978
$3d^6 4s(a^6D)4d$	$e^7G$	7	50651. 76:	-316. 11 -260. 722 -106. 34 -125. 59 -79. 24 -27. 09	
		6	50967. 873		1. 415
		5	51228. 595		1. 379
		4	51334. 94		1. 338
		3	51460. 53		1. 244
		2	51539. 77		
		1	51566. 86		-0. 374

## Fe I—Continued

Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>
$3d^6 4s(a^6D)5p$	$u^5F^\circ$	5	51016. 72:	-364. 76 -237. 66 -208. 45 -118. 27	
		4	51381. 48		
		3	51619. 14:		
		2	51827. 59:		
		1	51945. 86:		
$3d^6 4s(a^4G)4p:$	$x^3H^\circ$	6	51023. 19	-45. 58	1. 161
		5	51068. 77		1. 038
		4			
$3d^6 4s(a^6D)5p$	$t^5D^\circ$	4	51076. 68	-284. 78 -268. 61 -206. 80 -104. 89	1. 486
		3	51361. 46		
		2	51630. 07:		
		1	51836. 87:		
		0	51941. 76:		
$3d^6 4s(a^6D)4d$	$f^5F$	5	51103. 237	-358. 470 -142. 439 -100. 906 -49. 482	1. 384
		4	51461. 707		1. 355 :
		3	51604. 146		
		2	51705. 052		0. 967
		1	51754. 534		
$3d^6 4s(a^6D)4d$	$e^5S$	2	51148. 892		1. 952
$3d^6 4s(a^4G)4p:$	$v^3F^\circ$	2	51201. 33	163. 97 -60. 65	0. 803
		3	51365. 30		1. 096
		4	51304. 65		1. 122
$3d^6 4s(a^4D)5s$	$e^3D$	3	51294. 262	-445. 702 -299. 975	1. 345
		2	51739. 964		1. 125
		1	52039. 939		0. 801
$3d^6 4s(a^4D)5s$	$g^5D$	4	51350. 505	-420. 072 -279. 24 -164. 51 -43. 00	1. 487
		3	51770. 577		1. 492
		2	52049. 82		1. 57 :
		1	52214. 33		
		0	52257. 33		
$3d^7(a^2H)4p$	$u^3G^\circ$	5	51373. 96	-294. 26 -157. 58	1. 140
		4	51668. 22		1. 067
		3	51825. 80		0. 801
	$4^\circ$	4	51409. 18		0. 953
	$5^\circ$	3	51435. 90:		
$3d^6 4s(a^6D)4d$	$e^7S$	3	51570. 16		1. 92 :
	$6^\circ$	5	51630. 23		1. 061
$3d^6 4s(a^6D)5p$	$u^5P^\circ$	3	51691. 98:	-253. 33 -165. 0	
		2	51945. 31:		2. 633
		1	52110. 3:		
$3d^7(a^2P)4p$	$y^1D^\circ$	2	51708. 33		1. 025
	$7^\circ$	2	51756. 16		
	$x^1D^\circ$	2	51762. 12		0. 883
$3d^6 4s(a^6D)4d$	$e^5P$	3	51837. 279	-230. 17 47. 74	1. 664
		2	52067. 45		
		1	52019. 706		2. 432
$3d^7(a^2P)4p$	$u^3D^\circ$	3	51969. 14	-327. 82 -215. 50	1. 306
		2	52296. 96		1. 156
		1	52512. 46		0. 700
$3d^7(a^2D)4p:$	$t^3D^\circ$	1?	52180. 82	502. 11 -469. 64	0. 801
		2	52682. 93		1. 145
		3	52213. 29		1. 317
$3d^7(a^2H)4p$	$w^3H^\circ$	6	52431. 47	-181. 61 -155. 70	1. 177
		5	52613. 08		1. 033
		4	52768. 78		0. 810
$3d^7(a^2H)4p$	$y^3I^\circ$	7	52655. 04:	141. 45 -385. 47	1. 147
		6	52513. 59		1. 019
		5	52899. 06		0. 830
$3d^7(a^2P)4p$	$x^3S^\circ$	1	52857. 84		1. 246



## Fe I—Continued

## Fe I—Continued

Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>	Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>
$3d^7(a^2P)4p$	$v^3P^\circ$	2 1 0	52916.33 53808.37	—892.04	1.495 1.418	$3d^7(a^4F)4d$	$f^3F$	4 3 2	54683.39 55124.974 55378.842	—441.58 —253.868	1.141 1.071 0.676
	$s^3D^\circ$	3 2 1	52953.68: 53275.27	—321.59	1.231		$w^1G^\circ$	4	54810.82		1.001
$3d^7(a^4F)4d$	$g^3F$	5 4 3 2 1	53061.28 53393.715 53830.96 54257.52 54386.16	—332.44 —437.24 —426.56 —128.64		$3d^7(a^4F)4d$	$e^3P$	2 1 0	54879.720 55376.117 55726.54:	—496.397 —350.42	1.459 1.459
$3d^7(a^2H)4p$	$z^1I^\circ$	6	53093.60		1.010		$v^3H^\circ$	4 5 6	55446.06 55429.89 55489.81	—16.17 59.92	0.804 1.057 1.169
$3d^7(a^4F)4d$	$h^3D$	4 3 2 1 0	53155.13 53545.882 53966.720 54132.48	—390.75 —420.838 —165.76	1.435	$3d^7(a^2D)4p$	$w^1D^\circ$	2	55754.29		0.990
	$f^3P$	3 2 1	53160.53 53568.72 53925.26	—408.19 —356.54			$w^1F^\circ$	3	55790.72		0.908
$3d^7(a^4F)4d$	$f^3G$	6 5 4 3 2	53169.21 53281.735 53769.020 54161.182 54375.719	—112.53 —487.285 —392.162 —214.537	1.323 1.221 1.142		$s^3G^\circ$	5 4 3	55907.22 55905.56 56097.85	1.66 —192.29	1.145 0.857
	$z^1P^\circ$	1	53229.94		1.266	$3d^6 4s(b^2H)4p$	$u^3H^\circ$	6 5 4	56334.01 56382.69 56423.33	—48.68 —40.64	1.166 1.029 0.859
$3d^7(a^4F)4d$	$e^3H$	7 6 5 4 3	53275.20: 53353.02: 53874.30: 54237.20 54491.08	—77.82 —521.28 —362.90 —253.88	1.30: 1.191 1.102 0.90: 0.484	$3d^6 4s(a^6D)5d$	1	5	56428.06		
	$9^\circ$	4	53328.87			$3d^6 4s(a^6D)5d$	2	4, 5	56452.04		
$3d^6 4s(b^4D)4p$	$t^3P^\circ$	3 2 1	53388.68: 54112.30 54271.11	—723.62 —158.81	1.70:	$3d^7(a^2D)4p$	$u^3F^\circ$	4 3 2	56592.76 56783.33 56858.65	—190.57 —75.32	1.148 1.077 0.687
	$y^1F^\circ$	3	53661.13		1.21:	$3d^6 4s(a^6D)5d$	3	4	56842.70		
$3d^7(a^2H)4p$	$y^1H^\circ$	5	53722.44		1.03:		$v^1G^\circ$	4	56951.27		1.053
$3d^7(a^4F)4d$	$e^3G$	5 4 3	53739.488 54066.57 54379.44	—327.08 —312.87	1.248 1.096 0.842	$3d^6 4s(b^2H)4p$	$x^3I^\circ$	7 6 5	57027.56: 57070.25 57104.26	—42.69 —34.01	1.145 1.028 0.832
$3d^7(a^4F)4d$	$f^3D$	3 2 1	53747.547 54066.821 54449.33	—319.274 —382.51	1.258		$t^3F^\circ$	4 3 2	57550.09 57641.06 57708.76	—90.97 —67.70	1.235 0.698
	$x^1F^\circ$	3	53763.28		1.079	$3d^6 4s(a^4D)4d$	$i^3D$	4 3 2 1 0	57697.59 57813.97 57974.16	—116.38 —160.19	1.384 1.415
$3d^6 4s(a^6D)6s$	$g^1D$	5 4 3 2 1	53800.90 54124.62 54413.74: 54611.72 54747.74:	—323.72 —289.12 —197.98 —136.02	1.586 1.65:	$3d^6 4s(a^6D)7s$	$h^1D$	5 4 3 2 1	57897.17		
	$e^3H$	6 5 4	53840.68: 54266.76: 54555.45:	—426.08 —288.69	1.225 1.109 0.871	$3d^6 4s(a^4D)4d$	$g^3G$	6 5 4 3 2	58001.88 58271.50: 58520.18: 58710.09: 58824.81	—269.62 —248.68 —189.91 —114.72	1.40:
$3d^6 4s(b^4D)4d$	$10^\circ(^6D^\circ?)$	3	53891.54		1.476		$r^3G^\circ$	5 4 3	59926.62: 60172.06 60364.76:	—245.44 —192.70	1.190 1.030 0.780
$3d^6 4s(a^4G)4p$	$t^3G^\circ$	5 4 3	53983.30 54237.46 54600.35	—254.16 —362.89	1.234 1.183 0.922	$3d^6 4s(a^4D)4d$	$t^3H^\circ$	6 5 4	60365.70: 60549.18 60757.68	—183.48 —208.50	1.163 1.040 0.805
	$11^\circ$	3	54004.82				$q^3G^\circ$	5 4 3	60677.23: 60754.71: 60806.72	—77.48 —52.01	
$3d^6 4s(b^4D)4d$	$12^\circ(^6F^\circ?)$	5	54013.78		1.356						
	$13^\circ$	4	54301.36			Fe II ( $a^6D_{4/2}$ )	Limit		63700		



## Fe I OBSERVED TERMS\*

Config. $1s^2 2s^2 2p^6 3s^2 3p^6 +$	Observed Terms	
$3d^6 4s^2$	$\left\{ \begin{array}{lllll} a^5P & \begin{array}{l} a^5D \\ b^3D \\ b^1D \end{array} & b^3F & \begin{array}{l} b^3G \\ b^1G \end{array} & a^3H \\ & & & & a^1I \end{array} \right.$	
$3d^6$	$c^3F$	
	$ns (n \geq 4)$	$np (n \geq 4)$
$3d^6 4s(a^6D)nx$	$\left\{ \begin{array}{l} e, g, h^7D \\ e^5D \end{array} \right.$	$\begin{array}{lll} z, x^7P^\circ & z^7D^\circ & z^7F^\circ \\ z, u^5P^\circ & z, t^5D^\circ & z, u^5F^\circ \end{array}$
$3d^7(a^4F)nx$	$\left\{ \begin{array}{l} a, e^5F \\ a, e^3F \end{array} \right.$	$\begin{array}{lll} y^5D^\circ & y^5F^\circ & z^5G^\circ \\ y^3D^\circ & y^3F^\circ & z^3G^\circ \end{array}$
$3d^6 4s(a^4D)nx$	$\left\{ \begin{array}{l} g^5D \\ e^3D \end{array} \right.$	$\begin{array}{lll} y^5P^\circ & x^5D^\circ & x^5F^\circ \\ z^3P^\circ & z^3D^\circ & z^3F^\circ \end{array}$
$3d^7(a^4P)nx$	$\left\{ \begin{array}{l} a^5P \\ b^3P \end{array} \right.$	$\begin{array}{lll} y^5S^\circ & v^5P^\circ & u^5D^\circ \\ y^3S^\circ & y^3P^\circ & w^3D^\circ \end{array}$
$3d^7(a^2G)nx$	$\left\{ \begin{array}{l} a^3G \\ a^1G \end{array} \right.$	$\begin{array}{lll} x^3F^\circ & v^3G^\circ & y^3H^\circ \\ z^1F^\circ & z^1G^\circ & z^1H^\circ \end{array}$
$3d^7(a^2P)nx$	$\left\{ \begin{array}{l} c^3P \\ a^1P \end{array} \right.$	$\begin{array}{lll} x^3S^\circ & v^3P^\circ & u^3D^\circ \\ & z^1P^\circ & y^1D^\circ \end{array}$
$3d^7(a^2H)nx$	$\left\{ \begin{array}{l} b^3H \\ a^1H \end{array} \right.$	$\begin{array}{lll} u^3G^\circ & w^3H^\circ & y^3I^\circ \\ y^1G^\circ & y^1H^\circ & z^1I^\circ \end{array}$
$3d^7(a^2D)nx$	$\left\{ \begin{array}{l} a^3D \\ a^1D \end{array} \right.$	$\begin{array}{lll} w^3P^\circ & t^3D^\circ & u^3F^\circ \\ & w^1D^\circ & \end{array}$
$3d^6 4s(b^4P)nx$	$\left\{ \right.$	$\begin{array}{lll} z^5S^\circ & x^5P^\circ & w^5D^\circ \\ z^3S^\circ & x^3P^\circ & x^3D^\circ \end{array}$
$3d^6 4s(a^4H)nx$	$\left\{ \right.$	$\begin{array}{lll} y^5G^\circ & z^5H^\circ & \\ y^3G^\circ & z^3H^\circ & z^3I^\circ \end{array}$
$3d^6 4s(b^4F)nx$	$\left\{ \right.$	$\begin{array}{lll} v^5D^\circ & w^5F^\circ & x^5G^\circ \\ v^3D^\circ & w^3F^\circ & x^3G^\circ \end{array}$
$3d^5 4s^2(a^6S)nx$	$\left\{ \right.$	$\begin{array}{l} y^7P^\circ \\ w^5P^\circ \end{array}$
$3d^6 4s(a^4G)nx$	$\left\{ \right.$	$\begin{array}{lll} v^5F^\circ & w^5G^\circ & \\ v^3F^\circ & t^3G^\circ & x^3H^\circ \end{array}$
$3d^6 4s(b^2H)nx$	$\left\{ \right.$	$\begin{array}{l} u^3H^\circ: x^3I^\circ \end{array}$
$3d^6 4s(b^4D)nx$	$\left\{ \right.$	$\begin{array}{l} t^5P^\circ \end{array}$
$3d^7(b^2F)nx$	$\left\{ \begin{array}{l} d^3F \\ a^1F \end{array} \right.$	
	$nd (n \geq 4)$	
$3d^6 4s(a^6D)nx$	$\left\{ \begin{array}{lllll} e^7S & e^7P & f^7D & e^7F & e^7G \\ e^5S & e^5P & f^5D & f^5F & e^5G \end{array} \right.$	
$3d^7(a^4F)nx$	$\left\{ \begin{array}{lllll} f^5P & h^5D & g^5F & f^5G & e^5H \\ e^3P & f^3D & f^3F & e^3G & e^3H \end{array} \right.$	
$3d^6 4s(a^4D)nx$	$\left\{ \begin{array}{ll} i^5D & g^5G \end{array} \right.$	

\*For predicted terms in the spectra of the Fe I isoelectronic sequence, see Vol. II, Introduction.

## Fe II

(Mn I sequence; 25 electrons)

 $Z=26$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^6 4s^1 {}^6D_{4\frac{1}{2}}$  $a {}^6D_{4\frac{1}{2}} 130524 \text{ cm}^{-1}$ 

I. P. 16.18 volts

The early work on this spectrum by Meggers, Kiess, and Walters, and Russell was greatly extended by Dobbie, who in 1938 published a list of some 1,300 classified lines based on his observations covering the range between 2150 Å and 6627 Å. The listed terms are chiefly from this paper, supplemented by additional terms by Edlén and L. C. Green. A correction of  $0.02 \text{ cm}^{-1}$  has been subtracted from all of Dobbie's values (1938) in order to start with the ground state zero. In the course of his work on Fe III, Edlén has extended the analysis of Fe II and communicated 33 new terms in advance of publication. L. C. Green has observed the spectrum in the ultraviolet from 896 Å to 2495 Å, classified more than 450 lines, and published 57 levels. The arbitrary numbers he assigned to the miscellaneous levels are repeated here. For some of these levels two  $J$ -values are listed, denoting that the observed combinations do not indicate which of the two is correct. Edlén has been able to improve the values of some levels found by Green.

Two differences in interpretation have been handled as follows: Green's revision of Dobbie's incomplete  $f {}^6D$  term as part of  $e {}^6F$  has been adopted; Dobbie's  $e {}^6P$  term, whose components are assigned numbers by Green, has been retained.

With four exceptions, the configurations are from Dobbie (1935 paper), Edlén, or Green. Russell in his investigation of the Fe I spectrum assigns  $b {}^2F$  to  $3d^7$  (instead of  $3d^6(a {}^1F)4s$ );  $c {}^2F$  to  $3d^6(a {}^1F)4s$ ; and  $d {}^2D$  to  $3d^7$ . The writer has tentatively suggested the configuration of  $e {}^4H$  as  $3d^6(a {}^3H)5s$ .

The limit from Dobbie's 1934 paper, 130978, is an average value based on the  ${}^4D$  and  ${}^6D$  terms from  $3d^6(a {}^5D)ns$  ( $n=4,5$ ). He used a Rydberg formula and corrected the results empirically to conform to a Ritz formula, as suggested by Russell. From a study of related spectra in which long series are known, Russell has suggested a further correction of  $-454 \text{ cm}^{-1}$ , which has been adopted here.

The  $g$ -values have been determined by Miss Weeks from films of the Zeeman effect of Fe I automatically recorded from plates taken with the Bitter magnet at the Massachusetts Institute of Technology. Harrison generously supplied this observational material, and Miss Weeks derived the observed  $g$ -values especially for inclusion here.

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## Fe II

## Fe II

Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>	Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>
$3d^6(a^5D)4s$	$a^6D$	$4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	0.00 384.77 667.64 862.63 977.03	—384.77 —282.87 —194.99 —114.40	1.58 1.58 1.655 1.862 3.31	$3d^6(a^1D)4s$	$c^2D$	$2\frac{1}{2}$ $1\frac{1}{2}$	38164.24 38214.50	—50.26	1.176 0.79
$3d^7$	$a^4F$	$4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$	1872.60 2430.08 2837.94 3117.48	—557.48 —407.86 —279.54	1.33 1.223 1.02 0.385	$3d^6(a^5D)4p$	$z^6D^o$	$4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	38458.99 38660.04 38858.96 39013.28 39109.34	—201.05 —198.92 —154.32 —96.06	1.542 1.584 1.653 1.86 3.35
$3d^6(a^5D)4s$	$a^4D$	$3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	7955.24 8391.92 8680.47 8846.76	—436.68 —288.55 —166.29	1.419 1.365 1.200 —0.05	$3d^6(a^5D)4p$	$z^6F^o$	$5\frac{1}{2}$ $4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	41968.11 42114.79 42237.05 42334.86 42401.33 42439.88	—146.68 —122.26 —97.81 —66.47 —38.55	1.43 1.399 1.304 1.04 —0.647
$3d^7$	$a^4P$	$2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	13474.43 13673.21 13904.87	—198.78 —231.66	1.609 1.737 2.67	$3d^6(a^5D)4p$	$z^6P^o$	$3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$	42658.23 43238.61 43620.98	—580.38 —382.37	1.702 1.869 2.398
$3d^7$	$a^2G$	$4\frac{1}{2}$ $3\frac{1}{2}$	15844.71 16369.39	—524.68		$3d^6(a^5D)4p$	$z^4F^o$	$4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$	44232.51 44753.82 45079.91 45289.84	—521.31 —326.09 —209.93	1.32 1.29 1.069 0.445
$3d^7$	$a^2P$	$1\frac{1}{2}$ $0\frac{1}{2}$	18360.65 18886.75	—526.10	1.28	$3d^6(a^5D)4p$	$z^4D^o$	$3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	44446.89 44784.78 45044.21 45206.49	—337.89 —259.43 —162.28	1.40 1.35 1.15 —0.021
$3d^7$	$a^2D$	$2\frac{1}{2}$ $1\frac{1}{2}$	20516.98 21308.08	—791.10	1.22	$3d^6(a^1F)4s$	$c^2F$	$3\frac{1}{2}$ $2\frac{1}{2}$	44915.07 44929.59	—14.52	
$3d^6(a^3P)4s$	$b^4P$	$2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	20830.52 21812.04 22409.82	—981.52 —597.78	1.583 1.720 2.68	$3d^6(a^5D)4p$	$z^4P^o$	$2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	46967.47 47389.82 47626.14	—422.35 —236.32	1.592 1.717 2.70
$3d^6(a^3H)4s$	$a^4H$	$6\frac{1}{2}$ $5\frac{1}{2}$ $4\frac{1}{2}$ $3\frac{1}{2}$	21251.55 21430.39 21581.64 21711.89	—178.84 —151.25 —130.25	1.20 1.119 0.951 0.661	$3d^7$	$d^2D$	$1\frac{1}{2}$ $2\frac{1}{2}$	47674.78 48039.23	364.45	
$3d^6(a^3F)4s$	$b^4F$	$4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$	22637.19 22810.33 22939.35 23031.30	—173.14 —129.02 —91.95	1.307 1.210 1.019 0.398	$3d^6(b^3P)4s$	$c^4P$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$	49101.09 49506.99 50212.93	405.90 705.94	
$3d^64s^2$	$a^6S$	$2\frac{1}{2}$	23317.60		1.996	$3d^6(b^3F)4s$	$c^4F$	$1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$ $4\frac{1}{2}$	50076.10 50142.93 50187.95 50157.61	66.83 45.02 —30.34	
$3d^6(a^3G)4s$	$a^4G$	$5\frac{1}{2}$ $4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$	25428.80 25805.32 25981.65 26055.40	—376.52 —176.33 —73.75	1.237 1.15 0.98 0.574	$3d^6(b^3P)4s$	$c^2P$	$0\frac{1}{2}$ $1\frac{1}{2}$	54063.53 54902.42	838.89	
$3d^6(a^3P)4s$	$b^2P$	$1\frac{1}{2}$ $0\frac{1}{2}$	25787.60 26932.74	—1145.14	1.33 0.67	$3d^54s(a^7S)4p$	$z^8P^o$	$4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$	54490.2		
$3d^6(a^3H)4s$	$b^2H$	$5\frac{1}{2}$ $4\frac{1}{2}$	26170.19 26352.80	—182.61	1.09 0.927	$3d^6(b^3F)4s$	$d^2F$	$2\frac{1}{2}$ $3\frac{1}{2}$	54870.62 54904.50	33.88	
$3d^6(a^3F)4s$	$a^2F$	$3\frac{1}{2}$ $2\frac{1}{2}$	27314.93 27620.39	—305.46	1.129 0.851	$3d^6(b^1G)4s$	$d^2G$	$4\frac{1}{2}$ $3\frac{1}{2}$	58631.65 58666.36	—34.71	
$3d^6(a^3G)4s$	$b^2G$	$4\frac{1}{2}$ $3\frac{1}{2}$	30388.55 30764.46	—375.91	1.10 0.898	$3d^6(a^3P)4p$	$z^4S^o$	$1\frac{1}{2}$	59663.45		1.89
$3d^6(a^3D)4s$	$b^4D$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$	31368.45 31364.47 31387.98 31483.20	—3.98 23.51 95.22	1.327 1.41	$3d^54s^2$	$c^4D$	$3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	60270.37 60445.28 60441.05 60384.46	—174.91 4.23 56.59	
$3d^7$	$b^2F$	$2\frac{1}{2}$ $3\frac{1}{2}$	31811.87 31999.12	187.25	0.86 1.124	$3d^6(a^3P)4p$	$y^4P^o$	$2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	60402.38 61332.82 61035.37	—930.44 297.45	1.58 1.74 2.613
$3d^6(a^1I)4s$	$a^2I$	$6\frac{1}{2}$ $5\frac{1}{2}$	32875.63 32909.87	—34.24	1.062 0.92	$3d^6(a^3H)4p$	$z^4G^o$	$5\frac{1}{2}$ $4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$	60625.47 60807.28 60956.82 61041.78	—181.81 —149.54 —84.96	1.24 1.155 0.969 0.799
$3d^6(a^1G)4s$	$c^2G$	$4\frac{1}{2}$ $3\frac{1}{2}$	33466.50 33501.32	—34.82	1.099 0.88	$3d^6(a^3H)4p$	$z^4H^o$	$6\frac{1}{2}$ $5\frac{1}{2}$ $4\frac{1}{2}$ $3\frac{1}{2}$	60837.59 60887.66 60989.48 61156.90	—50.07 —101.82 —167.42	0.720
$3d^6(a^3D)4s$	$b^2D$	$1\frac{1}{2}$ $2\frac{1}{2}$	36126.41 36252.96	126.55	0.799 1.179						
$3d^6(a^1S)4s$	$a^2S$	$0\frac{1}{2}$	37227.32		2.06						



## Fe II—Continued

## Fe II—Continued

Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g.</i>	Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g.</i>
$3d^6(a^3P)4p$	$z^2D^\circ$	$2\frac{1}{2}$ $1\frac{1}{2}$	61093.44 62125.66	-1032.22	1.01 1.019	$3d^6(a^1I)4p$	$z^2K^\circ$	$6\frac{1}{2}$ $7\frac{1}{2}$	70986.69 71432.75	446.06	1.05
$3d^6(a^3H)4p$	$z^4I^\circ$	$7\frac{1}{2}$ $6\frac{1}{2}$ $5\frac{1}{2}$ $4\frac{1}{2}$	61347.44 61527.59 61587.24 61512.67	-180.15 -59.65 74.57		$3d^6(a^3D)4p$	$w^4P^\circ$	$2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	71964.81 72043.21 72213.10	-78.40 -169.89	1.66
$3d^6(a^3P)4p$	$y^4D^\circ$	$3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	61726.09 62689.96 62962.26 62829.16	-963.87 -272.30 133.10	1.411 1.349 1.14	$3d^6(a^3D)4p$	$x^2H^\circ$	$4\frac{1}{2}$ $5\frac{1}{2}$	72130.44 72261.83	131.39	0.91 1.08
$3d^6(a^7S)4p$	$y^6P^\circ$	$1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$	61975.11 62049.17 62171.76	74.06 122.59	1.68	$3d^6(a^3D)4p$	$w^4F^\circ$	$1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$ $4\frac{1}{2}$	72169.15 72238.63 72352.17 72650.63	69.48 113.54 298.46	
$3d^6(a^3F)4p$	$y^4F^\circ$	$4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$	62158.19 62065.57 62151.61 62244.57	92.62 -86.04 -92.96	1.33 1.198 1.025 0.43	$3d^6(a^3D)4p$	$w^4D^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$	72429.74 72524.62 72619.61 72651.91	94.88 94.99 32.30	
$3d^6(a^3H)4p$	$z^2G^\circ$	$4\frac{1}{2}$ $3\frac{1}{2}$	62083.17 62322.50	-239.33	1.097	$3d^6(a^3D)4p?$	$x^2F^\circ$	$3\frac{1}{2}$ $2\frac{1}{2}$	73016.33 73054.97	-38.64	
$3d^6(a^3H)4p$	$z^2I^\circ$	$6\frac{1}{2}$ $5\frac{1}{2}$	62293.20 62662.30	-369.10	1.069 0.910	$3d^6(a^1G)4p$	$w^2G^\circ$	$4\frac{1}{2}$ $3\frac{1}{2}$	73091.70 73143.48	-51.78	0.91
$3d^6(a^3F)4p$	$x^4D^\circ$	$3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	62945.12 63273.03 63465.19 63559.56	-327.91 -192.16 -94.37	1.385 1.351 1.21 0.013	$3d^6(a^3D)4p$	$y^2P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	73187.46 73189.16	1.70	
$3d^6(a^3F)4p$	$y^4G^\circ$	$5\frac{1}{2}$ $4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$	63876.38 63948.84 64040.96 64087.50	-72.46 -92.12 -46.54	1.24 1.15 0.975 0.617	$3d^6(a^1I)4p$	$y^2I^\circ$	$6\frac{1}{2}$ $5\frac{1}{2}$	73966.94 73969.71	-2.77	
$3d^6(a^3F)4p$	$z^2F^\circ$	$3\frac{1}{2}$ $2\frac{1}{2}$	64286.44 64425.46	-139.02	1.135 0.82	$3d^6(a^3D)4p$	$x^2D^\circ$	$1\frac{1}{2}$ $2\frac{1}{2}$	74498.15 74606.97	108.82	
$3d^6(a^3P)4p$	$z^2P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	64806.52 64834.12	27.60	1.329	$3d^6(a^1S)4p$	$w^2F^\circ$	$3\frac{1}{2}$ $2\frac{1}{2}$	75600.93 75915.21	-314.28	1.125 0.844
$3d^6(a^3F)4p$	$y^2G^\circ$	$4\frac{1}{2}$ $3\frac{1}{2}$	64832.00 65109.71	-277.71	1.101 0.896	$3d^6(a^1D)4p$	$x^2P^\circ$	$1\frac{1}{2}$ $0\frac{1}{2}$	76129.58 76577.50	-447.92	1.34
$3d^6(a^3H)4p?$	$z^2H^\circ$	$5\frac{1}{2}$ $4\frac{1}{2}$	65363.66 65556.34	-192.68	1.066 0.913	$3d^6(a^5D)5s$	$v^2F^\circ$	$2\frac{1}{2}$ $3\frac{1}{2}$	77742.78 78137.53	394.75	1.13
$3d^6(a^3G)4p$	$x^4G^\circ$	$5\frac{1}{2}$ $4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$	65580.09 65696.11 65931.46 66078.34	-116.02 -235.35 -146.88	1.00 0.62	$3d^6(a^1D)4p$	$e^4D$	$4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	77861.47 78237.54 78525.27 78725.61 78843.72	-376.07 -287.73 -200.34 -118.11	
$3d^6(a^3G)4p$	$x^4F^\circ$	$4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$	66012.83 66377.37 66522.32 66612.74	-364.54 -144.95 -90.42	1.21 1.02	$3d^6(a^1D)4p$	$w^2D^\circ$	$1\frac{1}{2}$ $2\frac{1}{2}$	78487.25 78690.98	203.73	
$3d^6(a^3P)4p$	$z^2S^\circ$	$0\frac{1}{2}$	66248.67			$3d^6(a^1D)4p$	$w^2P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	78841.97 79243.73	401.76	
$3d^6(a^3G)4p$	$y^4H^\circ$	$6\frac{1}{2}$ $5\frac{1}{2}$ $4\frac{1}{2}$ $3\frac{1}{2}$	66411.70 66463.59 66589.17 66672.39	-51.89 -125.58 -83.22	1.13 0.959 0.69	$3d^54s(a^5S)4p$	$x^6P^\circ$	$1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$	79246.13 79285.10 79331.49	38.97 46.39	
$3d^6(a^3F)4p$	$y^2D^\circ$	$2\frac{1}{2}$ $1\frac{1}{2}$	67000.63 67273.86	-273.23	1.16 0.719	$3d^6(a^5D)5s$	$e^4D$	$3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	79439.30 79885.32 80177.87 80345.91	-446.02 -292.55 -168.04	
$3d^6(a^3G)4p?$	$y^2H^\circ$	$5\frac{1}{2}$ $4\frac{1}{2}$	67516.37 68000.82	-484.45	1.07 0.907	$3d^6(a^5D)4d$	$e^6F$	$5\frac{1}{2}$ $4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	82853.5 82978.9 83136.5 83308.4 83459.7 83558.5	-125.4 -157.6 -171.9 -151.3 -98.8	
$3d^54s(a^5S)4p$	$x^4P^\circ$	$2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	69102.69 69302.35 69427.27	-199.66 -124.92		$3d^6(a^1F)4p$	$v^2G^\circ$	$3\frac{1}{2}$ $4\frac{1}{2}$	83305.37 83871.31	565.94	
$3d^6(a^3G)4p?$	$y^2F^\circ$	$3\frac{1}{2}$ $2\frac{1}{2}$	69606.64 69650.54	-43.90	1.13 0.857	$3d^6(a^5D)4d?$	$30(^6D)$	$3\frac{1}{2}$	83713.3		
$3d^6(a^3G)4p$	$x^2G^\circ$	$4\frac{1}{2}$ $3\frac{1}{2}$	70314.74 70523.73	-208.99	1.11 0.87	$3d^6(a^5D)4d$	$e^6P$	$3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$	83726.24 84266.48 84326.91	-540.24 -60.43	

## Fe II—Continued

Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g.</i>
$3d^6(a^5D)4d?$	$32(^6D)$	$2\frac{1}{2}$	83812. 1		
$3d^6(a^1F)4p$	$v^2D^{\circ}$	$2\frac{1}{2}$ $1\frac{1}{2}$	83868. 65 84359. 90	—491. 25	
$3d^6(a^5D)4d?$	$33(^6D)$	$1\frac{1}{2}$	83989. 7		
$3d^6(a^5D)4d$	$e^6G$	$6\frac{1}{2}$ $5\frac{1}{2}$ $4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$	84035. 09 84296. 70 84527. 89 84710. 66 84844. 81 84938. 13	—261. 61 —231. 19 —182. 77 —134. 15 —93. 32	1. 33
$3d^6(a^5D)4d?$	$34(^6D)$	$\left\{ \begin{smallmatrix} 1\frac{1}{2} \\ 0\frac{1}{2} \end{smallmatrix} \right\}$	84131. 2		
$3d^6(a^5D)4d$	$f^4D$	$3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	84685. 16 84870. 84 85048. 56 85172. 77	—185. 68 —177. 72 —124. 21	
$3d^6(a^5D)4d$	$e^4G$	$5\frac{1}{2}$ $4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$	84863. 14 85184. 69 85462. 78 85679. 64	—321. 55 —278. 09 —216. 86	1. 27
$3d^6(a^5D)4d$	$e^4F$	$4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$	86124. 14 86416. 22 86599. 66 86710. 84	—292. 08 —183. 44 —111. 18	1. 29
$3d^6(b^3P)4p$	$v^4D^{\circ}$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$	86388. 98 86544. 14 86767. 87 86929. 92	155. 16 223. 73 162. 05	
$3d^6(a^1F)4p$	$u^2F^{\circ}$	$3\frac{1}{2}$ $2\frac{1}{2}$	86482. 75 86547. 55	—64. 80	
$3d^6(a^5D)5p$	$y^6F^{\circ}$	$5\frac{1}{2}$ $4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	87340. 4 87470. 8 87536. 9 87571. 8 87601. 9 87635. 2	—130. 4 —66. 1 —34. 9 —30. 1 —33. 3	
	$1^{\circ}(^6P^{\circ})$	$3\frac{1}{2}$	88208. 6		
	$2^{\circ}(^6P^{\circ})$	$3\frac{1}{2}$	89127. 7		
	$3^{\circ}(^6P^{\circ})$	$2\frac{1}{2}$	89443. 7		
	$4^{\circ}(^6P^{\circ})$	$1\frac{1}{2}$	89625. 0		
	$5^{\circ}$	$3\frac{1}{2}$	90300. 0		
	$6^{\circ}$	$\left\{ \begin{smallmatrix} 4\frac{1}{2} \\ 3\frac{1}{2} \end{smallmatrix} \right\}$	90385. 5		
	$8^{\circ}(^4P^{\circ})$	$\left\{ \begin{smallmatrix} 1\frac{1}{2} \\ 0\frac{1}{2} \end{smallmatrix} \right\}$	90828. 4		
	$9^{\circ}(^4P^{\circ})$	$1\frac{1}{2}$	90898. 2		
	$10^{\circ}(^4P^{\circ})$	$\left\{ \begin{smallmatrix} 2\frac{1}{2} \\ 1\frac{1}{2} \end{smallmatrix} \right\}$	90981. 5		
	$11^{\circ}$	$2\frac{1}{2}$	91067. 1		
	$w^6P^{\circ}$	$3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$	91167. 3 91574. 8 91843. 1	—407. 5 —268. 3	
$3d^6 4s(a^5G)4p$	$x^4H^{\circ}$	$3\frac{1}{2}$ $4\frac{1}{2}$ $5\frac{1}{2}$ $6\frac{1}{2}$	92089. 41 92116. 98 92166. 81 92250. 27	27. 57 49. 83 83. 46	
$3d^6 4s(a^5G)4p$	$v^4F^{\circ}$	$4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$	92171. 95 92282. 76 92330. 1 92358. 8	—110. 81 —47. 3 —28. 7	

## Fe II—Continued

Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g.</i>
$3d^6(b^3F)4p$	$u^2D^{\circ}$	$1\frac{1}{2}$ $2\frac{1}{2}$	92216. 42 92695. 62	479. 20	
$3d^6(b^3F)4p$	$u^2G^{\circ}$	$4\frac{1}{2}$ $3\frac{1}{2}$	92427. 22 92602. 94	—175. 72	
$3d^6(b^3F)4p$	$u^4F^{\circ}$	$1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$ $4\frac{1}{2}$	93328. 6 93395. 6 93487. 71 93484. 75	67. 0 92. 1 —2. 96	
$3d^6 4s(a^5G)4p$	$w^4G^{\circ}$	$2\frac{1}{2}$ $3\frac{1}{2}$ $4\frac{1}{2}$ $5\frac{1}{2}$	93988. 30 94073. 46 94148. 71 94190. 02	85. 16 75. 25 41. 31	
	$14^{\circ}$	$2\frac{1}{2}$	94210. 1		
	$15^{\circ}$	$3\frac{1}{2}$	94762. 3		
$3d^6 4s(a^3G)4p$	$v^2H^{\circ}$	$5\frac{1}{2}$ $4\frac{1}{2}$	96062. 18 96239. 1	—176. 9	
$3d^6(b^3F)4p$	$t^2F^{\circ}$	$2\frac{1}{2}$ $3\frac{1}{2}$	96279. 65 96357. 07	77. 42	
$3d^6(a^3H)5s$	$e^4H$	$6\frac{1}{2}$ $5\frac{1}{2}$ $4\frac{1}{2}$ $3\frac{1}{2}$	98129. 98 98294. 60 98445. 24 98568. 75	—164. 62 —150. 64 —123. 51	
$3d^6(a^3H)5s$	$e^2H$	$5\frac{1}{2}$ $4\frac{1}{2}$	99093. 29 99331. 95	—238. 66	
$3d^6(a^3F)5s$	$f^4F$	$4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$	99573. 11 99688. 20 99824. 04 99918. 30	—115. 09 —135. 84 —94. 26	
$3d^6(a^3F)5s$	$e^2F$	$3\frac{1}{2}$ $2\frac{1}{2}$	100492. 04 100749. 75	—257. 71	
$3d^6(a^3G)5s$	$f^4G$	$5\frac{1}{2}$ $4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$	102584. 81		
$3d^6(a^3G)5s$	$e^2G$	$4\frac{1}{2}$ $3\frac{1}{2}$	103608. 82 103983. 35	—374. 53	
	$16^{\circ}$	$3\frac{1}{2}$	106863. 2		
	$17^{\circ}$	$\left\{ \begin{smallmatrix} 3\frac{1}{2} \\ 2\frac{1}{2} \end{smallmatrix} \right\}$	107165. 6		
	$18^{\circ}$	$2\frac{1}{2}$	107196. 2		
	$20^{\circ}(^6D^{\circ})$	$3\frac{1}{2}$	107886. 6		
	$21^{\circ}(^6D^{\circ})$	$\left\{ \begin{smallmatrix} 4\frac{1}{2} \\ 3\frac{1}{2} \end{smallmatrix} \right\}$	107964. 7		
	$22^{\circ}(^6D^{\circ})$	$2\frac{1}{2}$	108130. 6		
	$23^{\circ}(^6D^{\circ})$	$1\frac{1}{2}$	108191. 6		
	$24^{\circ}$	$3\frac{1}{2}$	108239. 2		
	$25^{\circ}$	$1\frac{1}{2}$	108371. 7		
	$26^{\circ}$	$3\frac{1}{2}$	108373. 8		
$3d^6(a^1I)5s$	$e^2I$	$5\frac{1}{2}$ $6\frac{1}{2}$ $1\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$	108630. 24 108648. 64 108780. 0 109780. 0 111929. 0	18. 40	
Fe III( $a^5D_4$ )	Limit	-----	130524		



Config. 1s <sup>2</sup> 2s <sup>2</sup> 2p <sup>6</sup> 3s <sup>2</sup> 3p <sup>6</sup> +	Observed Terms			
	$ns$ ( $n \geq 4$ )	$np$ ( $n \geq 4$ )	$nd$ ( $n \geq 4$ )	
$3d^5 4s^2$	$\{ \begin{array}{l} a^6S \\ c^4D \end{array} \}$			
$3d^7$	$\{ \begin{array}{l} a^4P \\ a^2P \end{array} \}$ $\{ \begin{array}{l} a^4F \\ a^2D \\ d^2D \end{array} \}$ $\{ \begin{array}{l} a^2G \\ a^2H \end{array} \}$			
$3d^6(a^5D)nx$	$\{ \begin{array}{l} a, e^6D \\ a, e^4D \end{array} \}$	$\begin{array}{l} z^6P^o \\ z^4P^o \end{array}$ $\begin{array}{l} z^6D^o/z, y^6F^o \\ z^4D^o \\ z^4F^o \end{array}$	$\begin{array}{l} e^6P \\ f^4D \end{array}$ $e^6F$ $e^4F$ $e^4G$	
$3d^6(a^3P)nx$	$\{ \begin{array}{l} b^4P \\ b^2P \end{array} \}$	$\begin{array}{l} y^4P^o \\ z^2P^o \end{array}$ $\begin{array}{l} y^4D^o \\ z^2D^o \end{array}$		
$3d^6(a^3H)nx$	$\{ \begin{array}{l} a, e^4H \\ b, e^2H \end{array} \}$	$\begin{array}{l} z^4G^o \\ z^2G^o \end{array}$ $\begin{array}{l} z^4H^o \\ z^2H^o \end{array}$ $\begin{array}{l} z^4I^o \\ z^2I^o \end{array}$		
$3d^6(a^3F)nx$	$\{ \begin{array}{l} b, f^4F \\ a, e^2F \end{array} \}$	$\begin{array}{l} x^4D^o \\ y^2D^o \end{array}$ $\begin{array}{l} y^4F^o \\ z^2F^o \end{array}$ $\begin{array}{l} y^4G^o \\ y^2G^o \end{array}$		
$3d^6(a^3G)nx$	$\{ \begin{array}{l} a, f^4G \\ b, e^2G \end{array} \}$	$\begin{array}{l} x^4F^o \\ y^2F^o \end{array}$ $\begin{array}{l} x^4G^o \\ x^2G^o \end{array}$ $\begin{array}{l} y^4H^o \\ y^2H^o \end{array}$		
$3d^5 4s(a^1S)nx$	$\{ \}$	$\begin{array}{l} z^8P^o \\ y^6P^o \end{array}$		
$3d^6(a^1I)nx$	$\{ \begin{array}{l} b^4D \\ b^2D \end{array} \}$	$\begin{array}{l} w^4P^o \\ y^2P^o \end{array}$ $\begin{array}{l} w^4D^o \\ x^2D^o \end{array}$ $\begin{array}{l} w^4F^o \\ x^2F^o \end{array}$ $y^2I^o$ $z^2K^o$		
$3d^6(a^3D)nx$	$\{ \}$	$\begin{array}{l} c^2G \end{array}$		
$3d^6(a^1G)nx$	$\{ \}$			
$3d^6(a^1S)nx$	$a^2S$	$\begin{array}{l} x^2P^o \\ w^2P^o \end{array}$ $\begin{array}{l} w^2D^o \\ v^2F^o \end{array}$		
$3d^6(a^1D)nx$	$\{ \begin{array}{l} c^2D \end{array} \}$	$\begin{array}{l} x^2P^o \\ w^2P^o \end{array}$ $\begin{array}{l} x^2D^o \\ v^2F^o \end{array}$		
$3d^5 4s(a^5S)nx$	$\{ \}$	$\begin{array}{l} x^6P^o \\ x^4P^o \end{array}$		
$3d^6(a^1F)nx$	$\{ \begin{array}{l} c^2F \end{array} \}$	$\begin{array}{l} v^2D^o \\ v^4D^o \end{array}$ $\begin{array}{l} u^2F^o \\ v^2G^o \end{array}$		
$3d^6(b^3P)nx$	$\{ \begin{array}{l} c^4P \\ c^2P \end{array} \}$	$\begin{array}{l} u^4F^o \\ t^2F^o \end{array}$ $\begin{array}{l} u^2G^o \end{array}$		
$3d^6(b^3F)nx$	$\{ \begin{array}{l} c^4F \\ d^2F \end{array} \}$	$\begin{array}{l} v^4F^o \\ w^4G^o \end{array}$ $\begin{array}{l} x^4H^o \\ v^2H^o \end{array}$		
$3d^6(b^1G)nx$	$\{ \begin{array}{l} d^2G \end{array} \}$			
$3d^5 4s(a^6G)nx$				
$3d^5 4s(b^3G)nx$				

\*For predicted terms in the spectra of the Mn I isoelectronic sequence, see Vol. II, Introduction.



## Fe III

(Cr I sequence; 24 electrons)

 $Z=26$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^6 {}^5D_4$  $a {}^5D_4$  247200  $\text{cm}^{-1}$ 

I. P. 30.64 volts

The early work on this spectrum was by Bowen and L. C. Green, who found a few multiplets. Later Edlén and Swings published a detailed analysis which includes a remarkably complete array of terms from the  $3d^6$ ,  $3d^5 4s$ , and  $3d^5 4p$  configurations. Their observations extend from about 500 Å to 6500 Å and their final tables contain some 320 energy levels and approximately 1500 classified lines. A few revisions and one new level have been furnished by Glad and entered in page proof.

In the present work the prefixes  $a$ ,  $b$ , . . .  $z$ ,  $y$ , . . . have been adopted throughout the spectrum, but the notation by Edlén and Swings is given in the first column for convenience in cross reference. A correction of  $0.8 \text{ cm}^{-1}$  has, also, here been added to their published values of all the levels in order to place the ground state at zero.

The terms of all four multiplicities recognized in this spectrum (1, 3, 5, 7), are connected by observed intersystem combinations.

## REFERENCES

- B. Edlén and P. Swings, *Astroph. J.* **95**, 532 (1942). (I P) (T) (C L)  
S. Glad, unpublished material (Sept. 1951). (T)

## Fe III

## Fe III

Authors	Config.	Desig.	$J$	Level	Interval	Authors	Config.	Desig.	$J$	Level	Interval
$3d {}^5D_4$	$3d^6$	$a {}^5D$	4	0.0	—436.2	$4s {}^7S_3$	$3d^5(a {}^6S)4s$	$a {}^7S$	3	30088.84	
${}^5D_3$			3	436.2	—302.7	$3d {}^1I_6$	$3d^6$	$a {}^1I$	6	30356.2	
${}^5D_2$			2	738.9	—193.5	$3d {}^3D_1$	$3d^6$	$a {}^3D$	1	30725.8	—9.6
${}^5D_1$			1	932.4	—94.9	${}^3D_2$			2	30716.2	141.6
${}^5D_0$			0	1027.3		${}^3D_3$			3	30857.8	
$3d {}^3P_2$	$3d^6$	$a {}^3P$	2	19404.8	—1283.6	$3d {}^1G_4$	$3d^6$	$a {}^1G$	4	30886.4	
${}^3P_1$			1	20688.4	—520.1	$3d {}^1S_0$	$3d^6$	$a {}^1S$	0	34812.4	
${}^3P_0$			0	21208.5		$3d {}^1D_2$	$3d^6$	$a {}^1D$	2	35803.7	
$3d {}^3H_6$	$3d^6$	$a {}^3H$	6	20051.1	—249.7	$4s {}^6S_2$	$3d^5(a {}^6S)4s$	$a {}^6S$	2	40999.87	
${}^3H_5$			5	20300.8	—181.1	$3d {}^1F_3$	$3d^6$	$a {}^1F$	3	42896.9	
${}^3H_4$			4	20481.9		$3d' {}^3P_0$	$3d^6$	$b {}^3P$	0	49148	429
$3d {}^3F_4$	$3d^6$	$a {}^3F$	4	21462.2	—237.7	${}^3P_1$			1	49576.9	835.4
${}^3F_3$			3	21699.9	—157.3	${}^3P_2$			2	50412.3	
${}^3F_2$			2	21857.2							
$3d {}^3G_5$	$3d^6$	$a {}^3G$	5	24558.8	—382.1						
${}^3G_4$			4	24940.9	—201.5						
${}^3G_3$			3	25142.4							

## Fe III—Continued

## Fe III—Continued

Authors	Config.	Desig.	<i>J</i>	Level	Interval	Authors	Config.	Desig.	<i>J</i>	Level	Interval
$3d' \ ^3F_2$ $\ ^3F_3$ $\ ^3F_4$	$3d^6$	$b \ ^3F$	2 3 4	50184. 9 50295. 2 50276. 1	110. 3 —19. 1	$b \ ^3G_3$ $\ ^3G_4$ $\ ^3G_5$	$3d^5(a \ ^2G)4s$	$c \ ^3G$	3 4 5	89697. 52 89783. 59 89907. 85	86. 07 124. 26
$3d' \ ^1G_4$	$3d^6$	$b \ ^1G$	4	57221. 7		$b \ ^3F_2$ $\ ^3F_3$ $\ ^3F_4$	$3d^5(a \ ^4F)4s$	$d \ ^3F$	2 3 4	90423. 68 90483. 94 90472. 53	60. 26 —11. 41
$a \ ^5G_6$ $\ ^5G_5$ $\ ^5G_4$ $\ ^5G_3$ $\ ^5G_2$	$3d^5(a \ ^4G)4s$	$a \ ^5G$	6 5 4 3 2	63425. 17 63466. 39 63486. 78 63494. 00 63494. 56	—41. 22 —20. 39 —7. 22 —0. 56	$a \ ^1H_5$	$3d^5(a \ ^2H)4s$	$a \ ^1H$	5	92523. 91	
$a \ ^5P_3$ $\ ^5P_2$ $\ ^5P_1$	$3d^5(a \ ^4P)4s$	$a \ ^5P$	3 2 1	66464. 64 66522. 95 66591. 68	—58. 31 —68. 73	$c \ ^3F_4$ $\ ^3F_3$ $\ ^3F_2$	$3d^5(b \ ^2F)4s$	$e \ ^3F$	4 3 2	93388. 75 93392. 45 93412. 93	—3. 70 —20. 48
$a \ ^5D_4$ $\ ^5D_3$ $\ ^5D_2$ $\ ^5D_1$ $\ ^5D_0$	$3d^5(a \ ^4D)4s$	$b \ ^5D$	4 3 2 1 0	69695. 73 69836. 83 69837. 76 69788. 19 69747. 40	—141. 10 —0. 93 49. 57 40. 79	$a \ ^1G_4$	$3d^5(a \ ^2G)4s$	$c \ ^1G$	4	93512. 64	
$a \ ^3G_5$ $\ ^3G_4$ $\ ^3G_3$	$3d^5(a \ ^4G)4s$	$b \ ^3G$	5 4 3	70694. 03 70728. 75 70725. 01	—34. 72 3. 74	$b \ ^1F_2$	$3d^5(b \ ^2F)4s$	$c \ ^1F$	3	97041. 38	
$a \ ^3P_2$ $\ ^3P_1$ $\ ^3P_0$	$3d^5(a \ ^4P)4s$	$c \ ^3P$	2 1 0	73727. 64 73849. 10 73935. 96	—121. 46 —86. 86	$c \ ^3D_1$ $\ ^3D_2$ $\ ^3D_3$	$3d^5(b \ ^2D)4s$	$d \ ^3D$	1 2 3	105895. 35 105906. 23 105929. 16	10. 88 22. 93
$a \ ^3D_3$ $\ ^3D_2$ $\ ^3D_1$	$3d^5(a \ ^4D)4s$	$b \ ^3D$	3 2 1	76956. 79 77102. 43 77075. 30	—145. 64 27. 13	$b \ ^1D_2$	$3d^5(b \ ^2D)4s$	$c \ ^1D$	2	109570. 84	
$a \ ^3I_7$ $\ ^3I_6$ $\ ^3I_5$	$3d^5(a \ ^2I)4s$	$a \ ^3I$	7 6 5	79840. 12 79844. 74 79860. 42	—4. 62 —15. 68	$z \ ^5G_2$ $\ ^5G_3$ $\ ^5G_4$ $\ ^5G_5$ $\ ^5G_6$	$3d^5(a \ ^4G)4p$	$z \ ^5G^\circ$	2 3 4 5 6	113584. 20 113605. 37 113635. 34 113677. 01 113739. 62	21. 17 29. 97 41. 67 62. 61
$4p \ ^7P_2$ $\ ^7P_3$ $\ ^7P_4$	$3d^5(a \ ^6S)4p$	$z \ ^7P^\circ$	2 3 4	82001. 73 82333. 92 82846. 59	332. 19 512. 67	$c \ ^3G_5$ $\ ^3G_4$ $\ ^3G_3$	$3d^5(b \ ^2G)4s$	$d \ ^3G$	5 4 3	114325. 35 114339. 95 114351. 92	—14. 60 —11. 97
$b \ ^3D_3$ $\ ^3D_2$ $\ ^3D_1$	$3d^5(a \ ^2D)4s$	$c \ ^3D$	3 2 1	82382. 87 82410. 94 82494. 88	—28. 07 —83. 94	$z \ ^5H_3$ $\ ^5H_4$ $\ ^5H_5$ $\ ^5H_6$ $\ ^5H_7$	$3d^5(a \ ^4G)4p$	$z \ ^5H^\circ$	3 4 5 6 7	114948. 55 115110. 92 115289. 91 115474. 25 115642. 23	162. 37 178. 99 184. 34 167. 98
$a \ ^5F_5$ $\ ^5F_4$ $\ ^5F_3$ $\ ^5F_2$ $\ ^5F_1$	$3d^5(a \ ^4F)4s$	$a \ ^5F$	5 4 3 2 1	83138. 23 83161. 48 83237. 86 83358. 88 83646. 98	—23. 25 —76. 38 —121. 02 —288. 10	$z \ ^5F_5$ $\ ^5F_4$ $\ ^5F_3$ $\ ^5F_2$ $\ ^5F_1$	$3d^5(a \ ^4G)4p$	$z \ ^5F^\circ$	5 4 3 2 1	116316. 63 116467. 41 117068. 56 116975. 05 116937. 57	—150. 78 —601. 15 93. 51 37. 48
$a \ ^1I_6$	$3d^5(a \ ^2I)4s$	$b \ ^1I$	6	83429. 61		$z \ ^5D_0$ $\ ^5D_1$ $\ ^5D_2$ $\ ^5D_3$ $\ ^5D_4$	$3d^5(a \ ^4P)4p$	$z \ ^5D^\circ$	0 1 2 3 4	116364. 76 116380. 07 116419. 39 116475. 44 117521. 91	15. 31 39. 32 56. 05 1046. 47
$a \ ^3F_4$ $\ ^3F_3$ $\ ^3F_2$	$3d^5(a \ ^2F)4s$	$c \ ^3F$	4 3 2	84159. 55 84671. 87 84369. 92	—512. 32 301. 95	$z \ ^5S_2$	$3d^5(a \ ^4P)4p$	$z \ ^5S^\circ$	2	116898. 22	
$a \ ^1D_2$	$3d^5(a \ ^2D)4s$	$b \ ^1D$	2	86847. 11		$b \ ^1G_4$	$3d^5(b \ ^2G)4s$	$d \ ^1G$	4	117950. 32	
$a \ ^1F_3$	$3d^5(a \ ^2F)4s$	$b \ ^1F$	3	87901. 87		$z \ ^3F_2$ $\ ^3F_3$ $\ ^3F_4$	$3d^5(a \ ^4G)4p$	$z \ ^3F^\circ$	2 3 4	118163. 56 118246. 52 118350. 24	82. 96 103. 72
$a \ ^3H_4$ $\ ^3H_5$ $\ ^3H_6$	$3d^5(a \ ^2H)4s$	$b \ ^3H$	4 5 6	88663. 87 88694. 67 88923. 07	30. 80 228. 40	$z \ ^3H_6$ $\ ^3H_5$ $\ ^3H_4$	$3d^5(a \ ^4G)4p$	$z \ ^3H^\circ$	6 5 4	118355. 01 118557. 25 118686. 25	—202. 24 —129. 00
$4p \ ^5P_3$ $\ ^5P_2$ $\ ^5P_1$	$3d^5(a \ ^6S)4p$	$z \ ^5P^\circ$	3 2 1	89084. 79 89334. 59 89491. 44	—249. 80 —156. 85	$z \ ^5P_3$ $\ ^5P_2$ $\ ^5P_1$	$3d^5(a \ ^4P)4p$	$y \ ^5P^\circ$	3 2 1	118442. 92 118721. 60 118867. 87	—278. 68 —146. 27



## Fe III—Continued

Authors	Config.	Desig.	J	Level	Interval
$z^3P_2$ $^3P_1$ $^3P_0$	$3d^5(a^4P)4p$	$z^3P^\circ$	2 1 0	119697.64 119982.26 120179.95	—284.62 —197.69
$y^5F_1$ $^5F_2$ $^5F_3$ $^5F_4$ $^5F_5$	$3d^5(a^4D)4p$	$y^5F^\circ$	1 2 3 4 5	120697.10 120826.17 121008.78 121241.67 121468.82	129.07 182.61 232.89 227.15
$z^3G_3$ $^3G_4$ $^3G_5$	$3d^5(a^4G)4p$	$z^3G^\circ$	3 4 5	121919.74 121941.29 121949.62	21.55 8.33
$z^3D_3$ $^3D_2$ $^3D_1$	$3d^5(a^4P)4p$	$z^3D^\circ$	3 2 1	122346.61 122628.34 122843.03	—281.73 —214.69
$y^5D_4$ $^5D_3$ $^5D_2$ $^5D_1$ $^5D_0$	$3d^5(a^4D)4p$	$y^5D^\circ$	4 3 2 1 0	122944.15 122829.55 122898.84 122921.37 123455.92	114.60 —69.29 —22.53 —534.55
$y^5P_1$ $^5P_2$ $^5P_3$	$3d^5(a^4D)4p$	$x^5P^\circ$	1 2 3	123552.95 123697.18 123750.39	144.23 53.21
$y^3D_3$ $^3D_2$ $^3D_1$	$3d^5(a^4D)4p$	$y^3D^\circ$	3 2 1	124854.04 124903.92 124954.88	—49.88 —50.96
$y^3F_4$ $^3F_3$ $^3F_2$	$3d^5(a^4D)4p$	$y^3F^\circ$	4 3 2	125443.58 125637.98 125672.83	—194.40 —34.85
$z^3S_1$	$3d^5(a^4P)4p$	$z^3S^\circ$	1	126390.57	
$y^3P_0$ $^3P_1$ $^3P_2$	$3d^5(a^4D)4p$	$y^3P^\circ$	0 1 2	128371.53 128605.65 128917.51	234.12 311.86
$z^3I_7$ $^3I_6$ $^3I_5$	$3d^5(a^2I)4p$	$z^3I^\circ$	7 6 5	130040.56 129854.80 130256.27	185.76 —401.47
$z^3K_6$ $^3K_7$ $^3K_8$	$3d^5(a^2I)4p$	$z^3K^\circ$	6 7 8	130756.84 131035.07 130852.25	278.23 —182.82
$z^1D_2$	$3d^5(a^2D)4p$	$z^1D^\circ$	2	131445.03	
$z^1H_5$	$3d^5(a^2I)4p$	$z^1H^\circ$	5	131710.79	
$z^1K_7$	$3d^5(a^2I)4p$	$z^1K^\circ$	7	131991.58	
$x^3F_2$ $^3F_3$ $^3F_4$	$3d^5(a^2D)4p$	$x^3F^\circ$	2 3 4	132104.94 132079.91 132785.36	—25.03 705.45
$y^3H_6$ $^3H_5$ $^3H_4$	$3d^5(a^2I)4p$	$y^3H^\circ$	6 5 4	132262.66 132564.71 132659.17	—302.05 —94.46
$x^3P_2$ $^3P_1$ $^3P_0$	$3d^5(a^2D)4p$	$x^3P^\circ$	2 1 0	134265.42 134549.4 135088.1	—284.0 —538.7
$z^1G_4$	$3d^5(a^2F)4p$	$z^1G^\circ$	4	134360.40	

## Fe III—Continued

Authors	Config.	Desig.	J	Level	Interval
$y^3G_3$ $^3G_4$ $^3G_5$	$3d^5(a^2F)4p$	$y^3G^\circ$	3 4 5	134549.00 135554.41 135735.31	1005.41 180.90
$y^5G_2$ $^5G_3$ $^5G_4$ $^5G_5$ $^5G_6$	$3d^5(a^4F)4p$	$y^5G^\circ$	2 3 4 5 6	134937.84 135096.84 135239.74 135316.42 135739.47	159.00 142.90 76.68 423.05
$x^3D_3$ $^3D_2$ $^3D_1$	$3d^5(a^2D)4p$	$x^3D^\circ$	3 2 1	134976.22 135279.0 135217.1	—302.8 61.9
$z^1I_6$	$3d^5(a^2I)4p$	$z^1I^\circ$	6	135582.08	
$w^3D_3$ $^3D_2$ $^3D_1$	$3d^5(a^2F)4p$	$w^3D^\circ$	3 2 1	135705.7 136793.8 136464.9	—1088.1 328.9
$x^5F_5$ $^5F_4$ $^5F_3$ $^5F_2$ $^5F_1$	$3d^5(a^4F)4p$	$x^5F^\circ$	5 4 3 2 1	136185.17 135990.62 136008.74 136117.94 136235.84	194.55 —18.12 —109.20 —117.90
$z^1F_3$	$3d^5(a^2D)4p$	$z^1F^\circ$	3	136200.13	
$w^3F_2$ $^3F_3$ $^3F_4$	$3d^5(a^2F)4p$	$w^3F^\circ$	2 3 4	136532.45 136797.05 136612.78	264.60 —184.27
$x^5D_4$ $^5D_3$ $^5D_2$ $^5D_1$ $^5D_0$	$3d^5(a^4F)4p$	$x^5D^\circ$	4 3 2 1 0	137209.73 137423.00 137544.60 137561.1 137573.2	—213.27 —121.60 —16.5 —12.1
$x^3H_4$ $^3H_5$ $^3H_6$	$3d^5(a^2G)4p$	$x^3H^\circ$	4 5 6	137527.92 137763.70 138264.47	235.78 500.77
$x^3G_5$ $^3G_4$ $^3G_3$	$3d^5(a^2H)4p$	$x^3G^\circ$	5 4 3	138054.59 138103.12 138187.93	—48.53 —84.81
$z^1P_1$	$3d^5(a^2D)4p$	$z^1P^\circ$	1	138691.81	
$w^3G_5$ $^3G_4$ $^3G_3$	$3d^5(a^4F)4p$	$w^3G^\circ$	5 4 3	139463.36 139625.17 139680.47	—161.81 —55.30
$y^3I_5$ $^3I_6$ $^3I_7$	$3d^5(a^2H)4p$	$y^3I^\circ$	5 6 7	139509.44 139846.18 140196.33	336.74 350.15
$y^1D_2$	$3d^5(a^2F)4p$	$y^1D^\circ$	2	139764.48	
$y^1G_4$	$3d^5(a^2G)4p$	$y^1G^\circ$	4	139827.17	
$y^1F_3$	$3d^5(a^2F)4p$	$y^1F^\circ$	3	140453.10	
$v^3F_2$ $^3F_3$ $^3F_4$	$3d^5(a^2G)4p$	$v^3F^\circ$	2 3 4	140750.98 140693.36 141002.99	—57.62 309.63
$v^3D_3$ $^3D_2$ $^3D_1$	$3d^5(a^4F)4p$	$v^3D^\circ$	3 2 1	141466.53 141399.04 141469.45	67.49 —70.41
$y^1I_6$	$3d^5(a^2H)4p$	$y^1I^\circ$	6	141539.55	



## Fe III—Continued

## Fe III—Continued

Authors	Config.	Desig.	<i>J</i>	Level	Interval	Authors	Config.	Desig.	<i>J</i>	Level	Interval
$u^3F_4$ $^3F_3$ $^3F_2$	$3d^5(a^4F)4p$	$u^3F^\circ$	4 3 2	142047.0 142312.90 142535.07	—265.9 —222.17	$v^1F_3$	$3d^5(b^2D)4p$	$v^1F^\circ$	3	159493.0	
$w^3H_4$ $^3H_5$ $^3H_6$	$3d^5(a^2H)4p$	$w^3H^\circ$	4 5 6	142855.59 142908.48 143320.85	52.89 412.37	$v^3P_2$ $^3P_1$ $^3P_0$	$3d^5(b^2D)4p$	$v^3P^\circ$	2 1 0	160037.9	
$v^3G_5$ $^3G_4$ $^3G_3$	$3d^5(a^2G)4p$	$v^3G^\circ$	5 4 3	143883.74 144085.97 144116.64	—202.23 —30.67	$w^1D_2$	$3d^5(b^2D)4p$	$w^1D^\circ$	2	162084.8?	
$t^3F_4$ $^3F_4$ $^3F_2$	$3d^5(b^2F)4p$	$t^3F^\circ$	4 3 2	144332.21 144570.53 144501.74	—238.32 68.79	$v^3H_4$ $^3H_5$ $^3H_6$	$3d^5(b^2G)4p$	$v^3H^\circ$	4 5 6	165719.1 165939.6 166187?	220.5 247
$y^1H_5$	$3d^5(a^2G)4p$	$y^1H^\circ$	5	144586.83		$5p^1P_2$ $^1P_3$ $^1P_4$	$3d^5(a^6S)5p$	$y^1P^\circ$	2 3 4	166144.66 166252.74 166421.35	108.08 168.61
$x^1H_5$	$3d^5(a^2H)4p$	$x^1H^\circ$	5	144843.24		$r^3F_4$ $^3F_3$ $^3F_2$	$3d^5(b^2G)4p$	$r^3F^\circ$	4 3 2	166222.2 166498 167002	—276 —504
$x^1G_4$	$3d^5(a^2H)4p$	$x^1G^\circ$	4	144968.50		$t^3G_3$ $^3G_4$ $^3G_5$	$3d^5(b^2G)4p$	$t^3G^\circ$	3 4 5	167085.0 167207.3 167298.9	122.3 91.6
$x^1F_3$	$3d^5(a^2G)4p$	$x^1F^\circ$	3	145038.61		$5p^3P_3$ $^3P_2$ $^3P_1$	$3d^5(a^6S)5p$	$w^3P^\circ$	3 2 1	168329.65 168421.01 168477.36	—91.36 —56.35
$x^1D_2$	$3d^5(b^2F)4p$	$x^1D^\circ$	2	145618.39		$w^1H_5$	$3d^5(b^2G)4p$	$w^1H^\circ$	5	168780.1	
$u^3G_3$ $^3G_4$ $^3G_5$	$3d^5(b^2F)4p$	$u^3G^\circ$	3 4 5	146891.0 147161.36 147406.14	270.4 244.78	$v^1G_4$	$3d^5(b^2G)4p$	$v^1G^\circ$	4	169277.6?	
$4d^7D_1$ $^7D_2$ $^7D_3$ $^7D_4$ $^7D_5$	$3d^5(a^6S)4d$	$e^7D$	1 2 3 4 5	147281.72 147291.20 147305.97 147326.84 147354.70	9.48 14.77 20.87 27.86	$u^1F_3$	$3d^5(b^2G)4p$	$u^1F^\circ$	3	170310.6?	
$u^3D_1$ $^3D_2$ $^3D_3$	$3d^5(b^2F)4p$	$u^3D^\circ$	1 2 3	147556.45 147614.65 147635.95	58.20 21.30	$4f^7F_0$ $^7F_1$ $^7F_2$ $^7F_3$ $^7F_4$ $^7F_5$ $^7F_6$	$3d^5(a^6S)4f$	$z^7F^\circ$	0 1 2 3 4 5 6	184247.3 184316.6 184374.7 184416.9 184447.7	69.3 58.1 42.2 30.8
$w^3P_0$ $^3P_1$ $^3P_2$	$3d^5(a^2S)4p$	$w^3P^\circ$	0 1 2	148655 148915.3 149525.63	260 610.3	$4f^5F$	$3d^5(a^6S)4f$	$w^5F^\circ$	1 to 5	184781±	
$w^1G_4$	$3d^5(b^2F)4p$	$w^1G^\circ$	4	149013.36		$5d^7D_1$ $^7D_2$ $^7D_3$ $^7D_4$ $^7D_5$	$3d^5(a^6S)5d$	$f^7D$	1 2 3 4 5	190393.30 190397.74 190404.34 190413.59 190425.76	4.44 6.60 9.25 12.17
$5s^7S_3$	$3d^5(a^6S)5s$	$e^7S$	3	149284.94		$6s^7S_3$	$3d^5(a^6S)6s$	$f^7S$	3	190918.28	
$w^1F_3$	$3d^5(b^2F)4p$	$w^1F^\circ$	3	150654.9		$6s^5S_2$	$3d^5(a^6S)6s$	$f^5S$	2	192006.99	
$4d^5D_0$ $^5D_1$ $^5D_2$ $^5D_3$ $^5D_4$	$3d^5(a^6S)4d$	$e^5D$	0 1 2 3 4	151537.83 151536.62 151534.82 151534.05 151537.70	—1.21 —1.80 —0.77 3.65	$5d^5D_0$ $^5D_1$ $^5D_2$ $^5D_3$ $^5D_4$	$3d^5(a^6S)5d$	$f^5D$	0 1 2 3 4	193595.3 193599.8 193606.1 193610.3 193610.8	4.5 6.3 4.2 0.5
$y^1P_1$	$3d^5(a^2S)4p$	$y^1P^\circ$	1	151637.3?		$5g^7G$	$3d^5(a^6S)5g$	$e^7G$	1 to 7	207641	
$5s^5S_2$	$3d^5(a^6S)5s$	$e^5S$	2	151757.61		$5g^6G$	$3d^5(a^6S)5g$	$e^6G$	2 to 6	207643±	
$s^3F_2$ $^3F_3$ $^3F_4$	$3d^5(b^2D)4p$	$s^3F^\circ$	2 3 4	157684.3 157982.0 158562.7	297.7 580.7						
$t^3D_1$ $^3D_2$ $^3D_3$	$3d^5(b^2D)4p$	$t^3D^\circ$	1 2 3	158257.3 158416.8 158729.3	159.5 312.5						
							Fe IV ( $^6S_{24}$ )	Limit	-----	247200	

September 1951.



## Fe IV

(V I sequence; 23 electrons)

 $Z=26$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 {}^6S_{2\frac{1}{2}}$  $a {}^6S_{2\frac{1}{2}}$   $\text{cm}^{-1}$ 

I. P. volts

The analysis of the Fe IV spectrum is conspicuously incomplete. In 1931 Miss Gilroy published 11 terms, and 71 classified lines between 574 Å and 1825 Å. Later, Kruger and Gilroy reported that the three lines from the ground term, having the transition  $3d^5 {}^6S-4p {}^6P^\circ$ , were near 526 Å, rather than between 574 Å and 587 Å as was stated in the earlier paper. Consequently, the relative term values published in 1931 need revision.

By analogy with Fe III, Edlén has estimated the positions of the lowest terms. These are entered in brackets in the table. The term  $4p {}^6P^\circ$  has been taken from the observed wave numbers of the combination with the ground state.

## REFERENCES

H. T. Gilroy, Phys. Rev. **38**, 2217 (1931). (T) (C L)P. G. Kruger and H. T. Gilroy, Phys. Rev. **48**, 720 (1935). (T) (C L)

B. Edlén, letter; Actualités Scientifiques et Industrielles, No. 895, Part I (Hermann et Cie, Paris, 1941) (T)

## Fe IV

Config.	Desig.	$J$	Level	Interval
$3d^5$	$3d^5 {}^6S$	$2\frac{1}{2}$	0	
$3d^5$	$3d^5 {}^4G$	$\left\{ \begin{array}{c} 2\frac{1}{2} \\ \text{to} \\ 5\frac{1}{2} \end{array} \right\}$	[32000]	
$3d^5$	$3d^5 {}^4P$	$\left\{ \begin{array}{c} 0\frac{1}{2} \\ \text{to} \\ 2\frac{1}{2} \end{array} \right\}$	[35100]	
$3d^5$	$3d^5 {}^4D$	$\left\{ \begin{array}{c} 0\frac{1}{2} \\ \text{to} \\ 3\frac{1}{2} \end{array} \right\}$	[38500]	
$3d^5$	$3d^5 {}^4F$	$\left\{ \begin{array}{c} 0\frac{1}{2} \\ \text{to} \\ 4\frac{1}{2} \end{array} \right\}$	[52100]	
$3d^4({}^6D)4p$	$4p {}^6P^\circ$	$\begin{array}{c} 1\frac{1}{2} \\ 2\frac{1}{2} \\ 3\frac{1}{2} \end{array}$	$\begin{array}{c} 189897 \\ 190013 \\ 190230 \end{array}$	$\begin{array}{c} 116 \\ 217 \end{array}$

January 1950.



## Fe v

(Ti I sequence; 22 electrons)

Z=26

Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^4 {}^5D_0$  $a {}^5D_0$  cm<sup>-1</sup>

I. P. volts

The analysis is from Bowen who has extended White's early work and published 145 classified lines; 98 in the range from 364 Å to 432 Å, and 47 in the interval between 1302 Å and 1554 Å.

Intersystem combinations connecting the triplet and quintet systems of terms have been observed.

No series have been found and the spectrum needs further study. Bowen remarks that some ambiguity exists as to the assignment of some levels of the  $z {}^5D^o$ ,  $z {}^5F^o$  and  $z {}^3D^o$  terms because of the overlapping of these terms. He states also that the term here labeled  $x {}^3G^o$  may possibly be the  ${}^3H^o$  term from the same limit,  $a {}^2H$ .

## REFERENCE

I. S. Bowen, Phys. Rev. **52**, 1153 (1937). (T) (C L)

## Fe v

## Fe v

Config.	Desig.	J	Level	Interval	Config.	Desig.	J	Level	Interval
$3d^4$	$a {}^5D$	0	0		$3d^3(a {}^4F)4p$	$z {}^5D^o$	0		
		1	145	145			1	257746	
		2	419	274			2	258134	388
		3	804	385			3	258685	551
		4	1285	481			4	259349	664
$3d^4$	$a {}^3P$	0	24054		$3d^3(a {}^4F)4p$	$z {}^5F^o$	1	258887	
		1	24973	919			2	259380	493
		2	26466	1493			3	259959	579
$3d^4$	$a {}^3H$	4	24937				4	260528	569
		5	25229	292			5	261054	526
		6	25527	298	$3d^3(a {}^4F)4p$	$z {}^3D^o$	1	259994	
$3d^4$	$a {}^3F$	2	26765				2	260419	425
		3	26846	81			3	261182	763
		4	26973	127	$3d^3(a {}^4F)4p$	$z {}^3G^o$	3	263911	
$3d^4$	$a {}^3G$	3	29820				4	264445	534
		4	30150	330			5	265117	672
		5	30429	279	$3d^3(a {}^4F)4p$	$z {}^3F^o$	2	266625	
$3d^3(a {}^4F)4s$	$a {}^5F$	1	186437				3	267248	623
		2	186736	299			4	267932	684
		3	187162	426	$3d^3(a {}^4P)4p$	$z {}^5P^o$	1	273643	
		4	187725	563			2	274136	493
		5	188401	676			3	274928	792
$3d^3(a {}^4F)4s$	$b {}^3F$	2	195212		$3d^3(a {}^2G)4p$	$y {}^3G^o$	3	278800	
		3	195942	730			4	279507	707
		4	196845	903			5	280039	532
$3d^3(a {}^4F)4p$	$z {}^5G^o$	2	254805		$3d^3(a {}^2H)4p$	$x {}^3G^o$	5	292291	
		3	255406	601			4	292437	-146
		4	256179	773			3	292518	-81
		5	257142	963					
		6	258301	1159					

January 1949.

## Fe v OBSERVED TERMS\*

Config. $1s^2 2s^2 2p^6 3s^2 3p^4 +$	Observed Terms	
$3d^4$	$\left\{ \begin{array}{ccccc} a^3P & a^5D & a^3F & a^3G & a^3H \end{array} \right.$	
	$ns (n \geq 4)$	$np (n \geq 4)$
$3d^3(a^4F)nx$	$\left\{ \begin{array}{c} a^5F \\ b^3F \end{array} \right.$	$\begin{array}{ccc} z^5D^\circ & z^5F^\circ & z^5G^\circ \\ z^3D^\circ & z^3F^\circ & z^3G^\circ \end{array}$
$3d^3(a^4P)nx$		$z^5P^\circ$
$3d^3(a^2G)nx$		$y^3G^\circ$
$3d^3(a^2H)nx$		$x^3G^\circ$

\*For predicted terms in the spectra of the Ti I isoelectronic sequence, see Vol. I, p. xxxvii.

## Fe VI

(Sc I sequence; 21 electrons)

$Z=26$

Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^3 {}^4F_{1/2}$

$a^4F_{1/2}$

$\text{cm}^{-1}$

I. P.

volts

The analysis is incomplete, but Bowen has classified about 100 lines in the region between 276 Å and 318 Å. Intersystem combinations connecting the doublet and quartet systems of terms have been observed.

## REFERENCES

- I. S. Bowen, Phys. Rev. **47**, 924 (1935). (T) (C L)  
 S. Pasternack, Astroph. J. **92**, 140 (1940). (T)

Fe VI

Fe VI

Config.	Desig.	<i>J</i>	Level	Interval	Config.	Desig.	<i>J</i>	Level	Interval
$3d^3$	$a\ ^4F$	$1\frac{1}{2}$	0	510 675 809	$3d^2(a\ ^3F)4p$	$z\ ^5F^\circ$	$2\frac{1}{2}$	$342570$	1030
		$2\frac{1}{2}$	510				$3\frac{1}{2}$	$343600$	
		$3\frac{1}{2}$	1185						
		$4\frac{1}{2}$	1994						
$3d^3$	$a\ ^4P$	$0\frac{1}{2}$	18734	203 664	$3d^2(a\ ^3F)4p$	$z\ ^4D^\circ$	$0\frac{1}{2}$	$343619$	-409 1060 1149
		$1\frac{1}{2}$	18937				$1\frac{1}{2}$	$343210$	
		$2\frac{1}{2}$	19601				$2\frac{1}{2}$	$344270$	
							$3\frac{1}{2}$	$345419$	
$3d^3$	$a\ ^2G$	$3\frac{1}{2}$	20609	696	$3d^2(a\ ^3F)4p$	$z\ ^2D^\circ$	$1\frac{1}{2}$	$344656$	1252
		$4\frac{1}{2}$	21305				$2\frac{1}{2}$	$345908$	
$3d^3$	$a\ ^2P$	$1\frac{1}{2}$	26204	-279	$3d^2(a\ ^3F)4p$	$z\ ^2G^\circ$	$3\frac{1}{2}$	$343962$	1054
		$0\frac{1}{2}$	26483				$4\frac{1}{2}$	$350016$	
$3d^3$	$a\ ^2D$	$2\frac{1}{2}$	28469	-138	$3d^2(a\ ^3P)4p$	$z\ ^4S^\circ$	$1\frac{1}{2}$	$355652$	
		$1\frac{1}{2}$	28607						
$3d^3$	$a\ ^2H$	$4\frac{1}{2}$	28723	473	$3d^2(a\ ^3P)4p$	$y\ ^4D^\circ$	$0\frac{1}{2}$	$359104$	680 921 1560
		$5\frac{1}{2}$	29196				$1\frac{1}{2}$	$359784$	
							$2\frac{1}{2}$	$360705$	
							$3\frac{1}{2}$	$362265$	
$3d^2(a\ ^3F)4p$	$z\ ^4G^\circ$	$2\frac{1}{2}$	$338256$	1221 1452 1794	$3d^2(a\ ^3P)4p$	$z\ ^4P^\circ$	$0\frac{1}{2}$	$363944$	446 1102
		$3\frac{1}{2}$	$339477$				$1\frac{1}{2}$	$364390$	
		$4\frac{1}{2}$	$340929$				$2\frac{1}{2}$	$365492$	
		$5\frac{1}{2}$	$342723$						
$3d^2(a\ ^3F)4p$	$z\ ^4F^\circ$	$1\frac{1}{2}$	$339538$	803 1020 1065	$3d^2(a\ ^1G)4p$	$y\ ^2G^\circ$	$3\frac{1}{2}$	$365077$	185
		$2\frac{1}{2}$	$340341$				$4\frac{1}{2}$	$365262$	
		$3\frac{1}{2}$	$341361$						
		$4\frac{1}{2}$	$342426$						
$3d^2(a\ ^3F)4p$	$z\ ^4F^\circ$	$1\frac{1}{2}$	$339538$	803 1020 1065	$3d^2(a\ ^1G)4p$	$z\ ^2H^\circ$	$4\frac{1}{2}$	$372096$	1606
		$2\frac{1}{2}$	$340341$				$5\frac{1}{2}$	$373702$	
		$3\frac{1}{2}$	$341361$						
		$4\frac{1}{2}$	$342426$						

December 1948.

Fe VI OBSERVED TERMS\*

Config. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6+$	Observed Terms
$3d^3$	$\left\{ \begin{array}{cccccc} a\ ^4P & & & a\ ^4F & & \\ a\ ^2P & a\ ^2D & & & a\ ^2G & a\ ^2H \end{array} \right.$
	$np\ (n\geq 4)$
	$\left\{ \begin{array}{cccc} z\ ^4D^\circ & z\ ^4F^\circ & z\ ^4G^\circ & \\ z\ ^2D^\circ & z\ ^2F^\circ & z\ ^2G^\circ & \end{array} \right.$
$3d^2(a\ ^3F)nx$	
$3d^2(a\ ^3P)nx$	$z\ ^4S^\circ\quad z\ ^4P^\circ\quad y\ ^4D^\circ$
$3d^2(a\ ^1G)nx$	$y\ ^2G^\circ\quad z\ ^2H^\circ$

\*For predicted terms in the spectra of the Sc I isoelectronic sequence, see Vol. I, p. xxxvi.



## Fe VII

(Ca I sequence; 20 electrons)

 $Z=26$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^2 {}^3F_2$  $a {}^3F_2$        $\text{cm}^{-1}$ 

I. P.      volts

The early analysis by Cady, who classified 33 lines between 231 Å and 245 Å, has been revised and extended by Edlén. The present term list is from Edlén's manuscript, kindly furnished by him for inclusion here in advance of publication.

The prefix "y" is assigned to the  ${}^1P^\circ$  and  ${}^3D^\circ$  terms from the  $4f$  configuration on the assumption that the similar terms from the  $4p$  configuration, which have not yet been found, will be lower and should, therefore, be assigned the prefix "z".

## REFERENCES

- W. M. Cady, Phys. Rev. **43**, 324 (1933). (T) (C L)  
 I. S. Bowen and B. Edlén, Nature **143**, 374 (1939). (T) (C L)  
 B. Edlén, unpublished material (Feb. 1949). (T)

## Fe VII

## Fe VII

Config.	Desig.	$J$	Level	Interval	Config.	Desig.	$J$	Level	Interval
$3d^2$	$a {}^3F$	2 3 4	0 1047 2327	1047 1280	$3d({}^2D)4f$	$y {}^3F^\circ$	2 3 4	660022 660360 661176	338 816
$3d^2$	$a {}^1D$	2	17475		$3d({}^2D)4f$	$z {}^3G^\circ$	3 4 5	663104 663953 664483	849 530
$3d^2$	$a {}^3P$	0 1 2	20037 20428 21275	391 847	$3d({}^2D)4f$	$y {}^1D^\circ$	2	663882	
$3d^2$	$a {}^1G$	4	28915		$3d({}^2D)4f$	$y {}^1F^\circ$	3	665425	
$3d({}^2D)4p$	$z {}^1D^\circ$	2	425388		$3d({}^2D)4f$	$y {}^3D^\circ$	1 2 3	665843 665925 666663	82 738
$3d({}^2D)4p$	$z {}^3F^\circ$	2 3 4	431606 433870	2264	$3d({}^2D)4f$	$y {}^3P^\circ$	3 1 0	667903 668265 668497	—362 —232
$3d({}^2D)4p$	$z {}^3P^\circ$	0 1 2	437010 436963 437567	—47 604	$3d({}^2D)4f$	$z {}^1H^\circ$	5	669978	
$3d({}^2D)4p$	$z {}^1F^\circ$	3	439812		$3d({}^2D)4f$	$y {}^1P^\circ$	1	671470	
$3d({}^2D)4f$	$z {}^1G^\circ$	4	659923						

March 1949.

## Fe VII OBSERVED TERMS\*

Config. $1s^2 2s^2 2p^6 3s^2 3p^6 +$	Observed Terms				
$3d^2$	$\left\{ \begin{array}{cccc} a {}^3P & & a {}^3F & & \\ & a {}^1D & & a {}^1G & \end{array} \right.$				
	$np \ (n \geq 4)$		$nf \ (n \geq 4)$		
$3d({}^2D)nz$	$\left\{ \begin{array}{ccc} z {}^3P^\circ & & z {}^3F^\circ \\ & z {}^1D^\circ & z {}^1F^\circ \end{array} \right.$		$y {}^3P^\circ$ $y {}^3D^\circ$ $y {}^3F^\circ$ $z {}^3G^\circ$ $y {}^1P^\circ$ $y {}^1D^\circ$ $y {}^1F^\circ$ $z {}^1G^\circ$ $z {}^1H^\circ$		

\*For predicted terms in the spectra of the Ca I isoelectronic sequence, see Vol. I, p. xxxv.

**Fe VIII**

(K I sequence; 19 electrons)

 $Z=26$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^2 D_{1/2}$  $3d^2 D_{1/2}$  1219360  $\text{cm}^{-1}$ 

I. P. 151 volts

The analysis is by Kruger and Weissberg, who have classified 15 lines in the interval 93 Å to 370 Å.

## REFERENCE

P. G. Kruger and S. G. Weissberg, Phys. Rev. **52**, 316 (1937). (I P) (T) (C L)**Fe VIII**

Config.	Desig.	$J$	Level	Interval
$3p^6(^1S)3d$	$3d^2D$	$1\frac{1}{2}$ $2\frac{1}{2}$	0 1875	1875
$3p^6(^1S)4p$	$4p^2P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	510084 513447	3363
$3p^6(^1S)4f$	$4f^2F^\circ$	$2\frac{1}{2}$ $3\frac{1}{2}$	763714 763821	107
$3p^6(^1S)5s$	$5s^2S$	$0\frac{1}{2}$	783402	
$3p^6(^1S)5f$	$5f^2F^\circ$	$2\frac{1}{2}$ $3\frac{1}{2}$	927024 927084	60
$3p^6(^1S)6s$	$6s^2S$	$0\frac{1}{2}$	960135	
$3p^6(^1S)6f$	$6f^2F^\circ$	$2\frac{1}{2}$ $3\frac{1}{2}$	1016828 1016877	49
$3p^6(^1S)7f$	$7f^2F^\circ$	$2\frac{1}{2}$ $3\frac{1}{2}$	1072765 1072875	110
-----	-----	---	-----	
Fe IX ( $^1S_0$ )	<b>Limit</b>	---	1219360	

May 1948.

**Fe IX**

(A I sequence; 18 electrons)

 $Z=26$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 ^1S_0$  $3p^6 ^1S_0$  1893000  $\text{cm}^{-1}$ 

I. P. 235 volts

Two lines, at 103 Å and 105 Å, respectively, are classified as combinations with the ground term. The tabular values have been rounded off in the last places. Apparently the limit and the 5s-level are extrapolated from isoelectronic data, as indicated by brackets in the table.

For convenience, the Paschen notation has been added by the writer in column one under the heading "A I". As for A I, the  $jl$ -coupling notation in the general form suggested by Racah is here introduced, although  $LS$ -designations indicated in column two under the heading "Authors" are perhaps preferable for the terms thus far identified.

## REFERENCES

P. G. Kruger, S. G. Weissberg and L. W. Phillips, Phys. Rev. **51**, 1090 (1937). (I P) (T) (C L)  
G. Racah, Phys. Rev. **61**, 537 (L) (1942).

## Fe IX

A I	Authors	Config.	Desig.	<i>J</i>	Level
$1p_0$	$3p^6\ ^1S$	$3p^6$	$3p^6\ ^1S$	0	0
$1s_4$	$3p^5\ 4s\ ^3P^o$	$3p^5(^2P_{1/2})4s$	$4s\ [1\frac{1}{2}]^o$	2 1	950200
$1s_2$	$3p^5\ 4s\ ^1P^o$	$3p^5(^2P_{3/2})4s$	$4s'\ [0\frac{1}{2}]^o$	0 1	965400
$2s_4$	$3p^5\ 5s\ ^3P^o$	$3p^5(^2P_{1/2})5s$	$5s\ [1\frac{1}{2}]^o$	2 1	[1355000]
		-----	-----	---	-----
		Fe X ( $^3P_{1/2}$ )	<i>Limit</i>	---	[1893000]

May 1948.

## Fe X

(Cl I sequence; 17 electrons)

 $Z=26$ Ground state  $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5\ ^2P_{1/2}^o$  $3p^5\ ^2P_{1/2}^o\ 2114000\ \text{cm}^{-1}$ 

I. P. 262 volts

Edlén has classified eight lines in the region between 94 Å and 97 Å, as combinations from the ground term. He has confirmed Grotrian's suggestion that the strong coronal line at 6374.51 Å (wave number  $15683.2\ \text{cm}^{-1}$ ) may be due to the forbidden transition  $3p^5\ ^2P_{1/2}^o - 3p^5\ ^2P_{3/2}^o$ .

He has extrapolated the value of the limit along the isoelectronic sequence, as indicated by brackets in the table.

Edlén's unit,  $10^3\ \text{cm}^{-1}$ , has here been changed to  $\text{cm}^{-1}$ .

## REFERENCES

B. Edlén, Zeit. Phys. **104**, 407 (1937). (I P) (T) (C L)W. Grotrian, Naturwiss. **27**, 214 (1939).B. Edlén, Zeit. Astroph. **22**, 30 (1942). (T) (C L)

## Fe X

Config.	Desig.	<i>J</i>	Level	Interval
$3s^2\ 3p^5$	$3p^5\ ^3P^o$	$1\frac{1}{2}$ $0\frac{1}{2}$	$0$ $15683$	—15683
$3s^2\ 3p^4(^3P)4s$	$4s\ ^4P$	$2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	1022100 1029630	—7530
$3s^2\ 3p^4(^3P)4s$	$4s\ ^3P$	$1\frac{1}{2}$ $0\frac{1}{2}$	1040350 1048900	—8550
$3s^2\ 3p^4(^1D)4s$	$4s'\ ^3D$	$2\frac{1}{2}$ $1\frac{1}{2}$	1063690 1064190	—500
-----	-----	---	-----	
Fe XI ( $^3P_2$ )	<i>Limit</i>	---	[2114000]	

January 1950.



Fe XI

(S I sequence; 16 electrons)

Z=26

Ground state  $1s^2 2s^2 2p^6 3s^2 3p^4 \text{}^3\text{P}_2$

$3p^4 \text{}^3\text{P}_2$  2342000  $\text{cm}^{-1}$

I. P. 290 volts

Edlén has classified 12 lines in the region from 86 Å to 90 Å. He has extrapolated the value of the limit from isoelectronic sequence data and also the value of  $3p^4 \text{}^1\text{S}_0$ , entered in brackets in the table.

Following Grotrian's suggestion, Edlén has tentatively identified two coronal lines as due to the following forbidden transitions:

I. Å.	Int.	Wave No.	Desig.
3986.9	0.7	25075	$3p^4 \text{}^3\text{P}_1 - 3p^4 \text{}^1\text{D}_2$
7891.94	13	12667.7	$3p^4 \text{}^3\text{P}_2 - 3p^4 \text{}^3\text{P}_1$

The singlet and triplet terms are connected by the intersystem combination furnished by the coronal line at 3986 Å.

Edlén's unit,  $10^3 \text{ cm}^{-1}$ , has here been changed to  $\text{cm}^{-1}$ .

REFERENCES

B. Edlén, Zeit. Phys. **104**, 188 (1937). (I P) (T) (C L)  
W. Grotrian, Naturwiss. **27**, 214 (1939).  
B. Edlén, Zeit. Astroph. **22**, 30 (1942). (C L)  
B. Edlén, letter (January 1950). (T)

Fe XI

Config.	Desig.	J	Level	Interval
$3s^2 3p^4$	$3p^4 \text{}^3\text{P}$	2	0	-12668 -1772
		1	12668	
		0	14440	
$3s^2 3p^4$	$3p^4 \text{}^1\text{D}$	2	37743	450 3350
$3s^2 3p^4$	$3p^4 \text{}^1\text{S}$	0	[80300]	
$3s^2 3p^3(^4\text{S}^\circ)4s$	$4s \text{}^3\text{S}^\circ$	1	1121270	
$3s^2 3p^3(^2\text{D}^\circ)4s$	$4s' \text{}^3\text{D}^\circ$	1	1148650	
		2	1149100	
		3	1152450	
$3s^2 3p^3(^2\text{D}^\circ)4s$	$4s' \text{}^1\text{D}^\circ$	2	1160020	
$3s^2 3p^3(^2\text{P}^\circ)4s$	$4s'' \text{}^1\text{P}^\circ$	1	1193640	
-----	-----	---	-----	
Fe XII ( $^4\text{S}_{1/2}$ )	Limit	---	[2342000]	

January 1950.

**Fe XIII**

(Si I sequence; 14 electrons)

 $Z=26$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^2 {}^3P_0$  $3p^2 {}^3P_0$        $\text{cm}^{-1}$ 

I. P. 355 volts

In his classical work on the identification of the coronal lines Edlén suggests that three strong coronal lines may be attributed to [Fe XIII] as follows:

I. A.	Int.	Wave No.	Desig.
3388. 1	16	29507	$3p^2 {}^3P_2 - 3p^2 {}^1D_2$
10746. 80	55	9302. 5	$3p^2 {}^3P_0 - 3p^2 {}^3P_1$
10797. 95	35	9258. 5	$3p^2 {}^3P_1 - 3p^2 {}^3P_2$

The coronal wave numbers are in satisfactory agreement with the theoretical values predicted from isoelectronic sequence data. The term values in the table have been calculated from the coronal wave numbers, with the exception of  $3p^2 {}^1S$  for which Edlén's estimated value is entered in brackets. Edlén's unit,  $10^3 \text{ cm}^{-1}$ , has here been changed to  $\text{cm}^{-1}$ .

## REFERENCE

B. Edlén, Zeit. Astroph. **22**, 40 (1942). (I P) (T) (C L)**Fe XIII**

Config.	Desig.	$J$	Level	Interval
$3s^2 3p^2$	$3p^2 {}^3P$	0	0. 0	9302. 5 9258. 5
		1	9302. 5	
		2	18561. 0	
$3s^2 3p^2$	$3p^2 {}^1D$	2	48068	
$3s^2 3p^2$	$3p^2 {}^1S$	0	[82000]	

October 1947.

**Fe XIV**

(Al I sequence; 13 electrons)

 $Z=26$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^2 P_{1/2}^{\circ}$  $3p^2 P_{1/2}^{\circ}$  cm<sup>-1</sup>

I. P. 390 volts

Astrophysically, the spectrum of Fe XIV is one of the most significant, although only two lines have been classified in the laboratory spectrum. In his classical papers on the identification of the coronal lines Edlén has suggested that the conspicuous coronal line at 5302.86 Å, wave number 18852.5 cm<sup>-1</sup> and intensity 100, may be due to the forbidden transition that corresponds to the interval of the ground term of Fe XIV, i. e.,  $3p^2 P_{0/2}^{\circ} - 3p^2 P_{1/2}^{\circ}$ .

He also classifies two lines as follows:

I. A.	Int.	Wave No.	Desig.
58. 963	2	1695980	} $3p^2 P^{\circ} - 4d^2 D$
59. 579	3	1678440	

His unit, 10<sup>3</sup> cm<sup>-1</sup>, is here changed to cm<sup>-1</sup>.

## REFERENCES

B. Edlén, Zeit. Phys. **103**, 540 (1936). (C L)

B. Edlén, Zeit. Astroph. **22**, 47 (1942). (I P) (T) (C L)

December 1947.

**Fe XV**

(Mg I sequence; 12 electrons)

 $Z=26$ Ground state  $1s^2 2s^2 2p^6 3s^2 {}^1S_0$  $3s^2 {}^1S_0$  3684000 cm<sup>-1</sup>

I. P. 457 volts

Edlén has classified eight lines in the region between 55 Å and 70 Å. No singlet combinations have been observed and the triplet terms are not all connected by observed combinations. He has determined the relative positions of the terms and also the ionization potential by extrapolation along the isoelectronic sequence. Estimated values are denoted by brackets in the table.

Edlén's unit, 10<sup>3</sup> cm<sup>-1</sup>, has here been changed to cm<sup>-1</sup>.

## REFERENCE

B. Edlén, Zeit. Phys. **103**, 536 (1936). (I P) (T) (C L)



**Fe xv**

Config.	Desig.	<i>J</i>	Level	Interval
$3s^2$	$3s^2\ ^1S$	0	0	
$3s(^2S)3p$	$3p\ ^3P^\circ$	0 1 2	$[235690] + x$ $241490 + x$ $255610 + x$	5800 14120
$3s(^2S)3d$	$3d\ ^3D$	1 2 3	$687570 + x$	
$3s(^2S)4p$	$4p\ ^1P^\circ$	1	$[1889970]$	
$3s(^2S)4d$	$4d\ ^3D$	1 2 3	$2033120 + x$ $2033830 + x$ $2034970 + x$	710 1140
$3s(^2S)4f$	$4f\ ^3F^\circ$	2 3 4	$2115040 + x$	
$3s(^2S)5f$	$5f\ ^3F^\circ$	2 3 4	$2682780 + x$	
-----	-----	---	-----	
Fe xvi ( $^2S_{1/2}$ )	<i>Limit</i>	---	$[3684000]$	

August 1947.

**Fe xvi**

(Na I sequence; 11 electrons)

 $Z=26$ Ground state  $1s^2\ 2s^2\ 2p^6\ 3s\ ^2S_{1/2}$  $3s\ ^2S_{1/2}\ 3947840\ \text{cm}^{-1}$ 

I. P. 489 volts

Edlén has classified 13 lines in the interval 39 Å to 66 Å, and extrapolated the absolute value of the ground term from isoelectronic sequence data. His unit,  $10^3\ \text{cm}^{-1}$ , has here been changed to  $\text{cm}^{-1}$ .

## REFERENCE

B. Edlén, Zeit. Phys. **100**, 621 (1936). (I P) (T) (C L)

Fe xvi

Config.	Desig.	<i>J</i>	Level	Interval
3 <i>s</i>	3 <i>s</i> <sup>2</sup> S	0½	0	
3 <i>p</i>	3 <i>p</i> <sup>2</sup> P°	0½ 1½	276500 297470	20970
3 <i>d</i>	3 <i>d</i> <sup>2</sup> D	1½ 2½	676930 679770	2840
4 <i>s</i>	4 <i>s</i> <sup>2</sup> S	0½	1866860	
4 <i>p</i>	4 <i>p</i> <sup>2</sup> P°	0½ 1½	1978040 1986100	8060
4 <i>d</i>	4 <i>d</i> <sup>2</sup> D	1½ 2½	2123500 2124690	1190
4 <i>f</i>	4 <i>f</i> <sup>2</sup> F°	2½ 3½	2186070 2186570	500
5 <i>d</i>	5 <i>d</i> <sup>2</sup> D	1½ 2½	2787360 2787940	580
5 <i>f</i>	5 <i>f</i> <sup>2</sup> F°	2½ 3½	2820050 2820270	220
-----	-----	---	-----	
Fe xvii ( <sup>1</sup> S <sub>0</sub> )	<i>Limit</i>	---	[3947840]	

June 1947.

Fe xvii

(Ne I sequence; 10 electrons)

*Z*=26

Ground state 1*s*<sup>2</sup> 2*s*<sup>2</sup> 2*p*<sup>6</sup> <sup>1</sup>S<sub>0</sub>

2*p*<sup>6</sup> <sup>1</sup>S<sub>0</sub> 10211700 cm<sup>-1</sup>

I. P. 1266 volts

Tyrén has classified nine lines in the region 12 Å to 17 Å, as combinations with the ground term. His absolute term values have been derived by extrapolation along the Ne I iso-electronic sequence.

By analogy with Ne I, the *jl*-coupling notation in the general form suggested by Racah is introduced.

The unit adopted by Tyrén, 10<sup>3</sup> cm<sup>-1</sup>, has here been changed to cm<sup>-1</sup>.

REFERENCES

F. Tyrén, Zeit. Phys. **111**, 314 (1938). (I P) (T) (C L)  
G. Racah, Phys. Rev. **61**, 537 (L) (1942).

## Fe xvii

## Fe xvii

Author	Config.	Desig.	<i>J</i>	Level	Author	Config.	Desig.	<i>J</i>	Level
$2p\ ^1S_0$	$2s^2\ 2p^6$	$2p^6\ ^1S$	0	0	$3p'\ ^3P_1$	$2s\ 2p^6(^2S)3p$	$3p\ ^3P^{\circ}$	$\begin{smallmatrix} 2 \\ 1 \\ 0 \end{smallmatrix}$	7201000
$3s\ ^3P_1$	$2s^2\ 2p^5(^2P_{1/2})3s$	$3s\ [1\frac{1}{2}]^{\circ}$	$\begin{smallmatrix} 2 \\ 1 \end{smallmatrix}$	5864800	$3p'\ ^1P_1$	$2s\ 2p^6(^2S)3p$	$3p\ ^1P^{\circ}$	1	7235900
$3s\ ^1P_1$	$2s^2\ 2p^5(^2P_{3/2})3s$	$3s'\ [0\frac{1}{2}]^{\circ}$	$\begin{smallmatrix} 0 \\ 1 \end{smallmatrix}$	5961600	$4d\ ^1P_1$	$2s^2\ 2p^5(^2P_{1/2})4d$	$4d\ [1\frac{1}{2}]^{\circ}$	1	8155000
$3d\ ^3P_1$	$2s^2\ 2p^5(^2P_{1/2})3d$	$3d\ [0\frac{1}{2}]^{\circ}$	$\begin{smallmatrix} 0 \\ 1 \end{smallmatrix}$	6471200	$4d\ ^3D_1$	$2s^2\ 2p^5(^2P_{3/2})4d$	$4d'\ [1\frac{1}{2}]^{\circ}$	1	8250000
$3d\ ^1P_1$	"	$3d\ [1\frac{1}{2}]^{\circ}$	1	6552700		Fe xviii ( $^2P_{1/2}$ )	Limit	-----	[10211700]
$3d\ ^3D_1$	$2s^2\ 2p^5(^2P_{3/2})3d$	$3d'\ [1\frac{1}{2}]^{\circ}$	1	6661300		Fe xviii ( $^2P_{3/2}$ )	Limit	-----	[10313800]

March 1947.

## Fe xvii OBSERVED LEVELS\*

Config. $1s^2+$	Observed Terms		
$2s^2\ 2p^6$	$2p^6\ ^1S$		
	$ns\ (n \geq 3)$	$np\ (n \geq 3)$	$nd\ (n \geq 3)$
$2s^2\ 2p^5(^3P^{\circ})nx$	$\begin{Bmatrix} 3s\ ^3P^{\circ} \\ 3s\ ^1P^{\circ} \end{Bmatrix}$		$\begin{matrix} 3d\ ^3P^{\circ} \\ 3, 4d\ ^1P^{\circ} \end{matrix} \quad 3, 4d\ ^3D^{\circ}$
$2s\ 2p^6(^2S)nx$	$\begin{Bmatrix} \end{Bmatrix}$	$\begin{matrix} 3p\ ^3P^{\circ} \\ 3p\ ^1P^{\circ} \end{matrix}$	
jl—Coupling Notation			
Config. $1s^2+$	Observed Pairs		
	$ns\ (n \geq 3)$		$nd\ (n \geq 3)$
$2s^2\ 2p^5(^2P_{1/2})nx$	$3s\ [1\frac{1}{2}]^{\circ}$		$\begin{matrix} 3d\ [0\frac{1}{2}]^{\circ} \\ 3, 4d\ [1\frac{1}{2}]^{\circ} \end{matrix}$
$2s^2\ 2p^5(^2P_{3/2})nx'$	$3s'\ [0\frac{1}{2}]^{\circ}$		$3, 4d'\ [1\frac{1}{2}]^{\circ}$

\*For predicted levels in the spectra of the Ne I isoelectronic sequence, see Vol. I, p. xxxi.



## COBALT

## Co I

27 electrons

Z=27

Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^7 4s^2 {}^4F_{4/2}$  $a {}^4F_{4/2}$  63438  $\text{cm}^{-1}$ I. P.  $7.86 \pm 0.02$  volts

The number of terms known in this complex spectrum is 99; in addition, there are 43 miscellaneous levels which are not yet grouped into terms. Combinations among these give 2725 classified lines in the range between 1814 Å and 11894 Å, and include 768 multiplets. The terms of all multiplicities are connected by observed intersystem combinations.

In 1936 Catalán and Antunes published a detailed analysis, classifying 2076 lines. The terms in the table are from the 1940 paper by Russell, King, and Moore. Their analysis was begun without knowledge that Catalán and Antunes were investigating the spectrum. It was continued because further observations in the infrared and ultraviolet, together with extensive data on the Zeeman effect, made it possible to revise and extend the earlier work.

Some of the electron configurations of the low even terms were assigned on the basis of the theoretical results by Marvin. Racah suggests that two of these assignments should be interchanged, as follows:

Term	R K M	Racah
$a {}^4P$	$3d^8 4s$	$3d^7 4s^2$
$b {}^4P$	$3d^7 4s^2$	$3d^8 4s$

This change was subsequently confirmed by Shenstone, and is adopted in the table. Further changes suggested by Shenstone by analogy with Ni II and Cu III have also been adopted, namely, the configuration assignments published in the 1940 reference below have been interchanged for the following pairs of terms:  $y {}^2H^\circ$ ,  $x {}^2H^\circ$ ;  $y {}^4S^\circ$ ,  $x {}^4S^\circ$ .

Roth and Bartunek observed Zeeman patterns of 151 lines of Co I between 3200 Å and 6500 Å. Later and more extensive observations by R. B. King and A. S. King are in good general agreement with their results. The two-place entries in the table are from the Kings' observations. Those given to three places are from unpublished material by Miss Weeks, who derived them from the films made at the Massachusetts Institute of Technology and furnished by G. R. Harrison.

The limit has been determined by estimating the Rydberg denominators by comparison with neighboring elements. Russell's value is  $63536 \text{ cm}^{-1}$ , while that of Catalán and Antunes, using the same method, is  $63339 \text{ cm}^{-1}$ . The mean of these two values,  $63438 \text{ cm}^{-1}$ , is given here.

Russell has remarked that the convergence of the components of selected terms of Co I to the components of the limit terms in Co II is of interest: "Catalán and Antunes have shown that among the terms which have  $d^8 {}^3F$  as limit, the quartet and doublet components of lowest  $J$  go to  ${}^3F_2$ , those of next higher  $J$  to  ${}^3F_3$ , leaving two high  $J$  quartet components for  ${}^3F_4$ ." This "inverted" convergence was found by Russell for the limit  $d^9 {}^2D$  in Ni II (see text for Ni II).

## REFERENCES

- H. H. Marvin, Phys. Rev. **47**, 521 (1935).  
 F. L. Roth and P. F. Bartunek, Phys. Rev. **47**, 526 (1935). (C L) (Z E)  
 M. A. Catalán and M. T. Antunes, Anal. Soc. Esp. de Física y Química (Madrid) **34**, 103-145, 207-297 (1936). (I P) (T) (C L)  
 H. N. Russell, R. B. King, and C. E. Moore, Phys. Rev. **58**, 407 (1940). (I P) (T) (C L) (Z E)  
 G. Racah, Phys. Rev. **61**, 537 (1942).  
 M. T. Antunes, Phys. Rev. **62**, 362 (1942).  
 A. G. Shenstone, private communication (April 1950).  
 J. E. Mack, Rev. Mod. Phys. **22**, No. 1, 64 (1950). (Summary hfs)  
 D. W. Weeks, unpublished material (March 1951). (Z E)

## Co I

## Co I

Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>	Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>
$3d^7 4s^2$	$a^4F$	$4\frac{1}{2}$	0.00	—816.00	1.32	$3d^7 4s(b^2F)4p$	$z^2F^\circ$	$3\frac{1}{2}$	31871.15	—910.56	1.177
		$3\frac{1}{2}$	816.00	—590.84	1.237			$2\frac{1}{2}$	32781.71		0.870
		$2\frac{1}{2}$	1406.84	—402.49	1.028	$3d^8(a^2F)4p$	$y^4D^\circ$	$3\frac{1}{2}$	32027.50	—627.00	1.395
		$1\frac{1}{2}$	1809.33		0.402			$2\frac{1}{2}$	32654.60	—496.18	1.366
$3d^8(a^2F)4s$	$b^4F$	$4\frac{1}{2}$	3482.82	—659.84	1.336			$1\frac{1}{2}$	33150.68	—298.50	1.195
		$3\frac{1}{2}$	4142.66	—547.52	1.239			$0\frac{1}{2}$	33449.18		0.012
		$2\frac{1}{2}$	4690.18		1.031	$3d^8(a^2F)4p$	$y^4G^\circ$	$5\frac{1}{2}$	32430.59	—34.14	1.287
		$1\frac{1}{2}$	5075.83	—385.65	0.404			$4\frac{1}{2}$	32464.73	—708.63	1.154
$3d^8(a^2F)4s$	$a^2F$	$3\frac{1}{2}$	7442.41	—1018.40	1.147			$3\frac{1}{2}$	33173.36	—501.02	1.039
		$2\frac{1}{2}$	8460.81		0.862			$2\frac{1}{2}$	33674.38		0.704
$3d^7 4s^2$	$a^4P$	$2\frac{1}{2}$	13795.52	—240.76	1.604	$3d^8(a^2F)4p$	$y^4F^\circ$	$4\frac{1}{2}$	32841.99	—624.88	1.313
		$1\frac{1}{2}$	14036.28	—363.00	1.722			$3\frac{1}{2}$	33466.87	—479.03	1.155
		$0\frac{1}{2}$	14399.28		2.651			$2\frac{1}{2}$	33945.90	—250.31	0.900
$3d^8(3P)4s$	$b^4P$	$2\frac{1}{2}$	15184.04	—590.00	1.515	$3d^8(a^2F)4p$	$y^2G^\circ$	$4\frac{1}{2}$	33439.72	—693.87	1.165
		$1\frac{1}{2}$	15774.04	—421.64	1.476			$3\frac{1}{2}$	34133.59		0.917
		$0\frac{1}{2}$	16195.68		2.682	$3d^7 4s(b^2F)4p$	$z^2D^\circ$	$2\frac{1}{2}$	33462.83	—889.59	1.186
$3d^7 4s^2$	$a^2G$	$4\frac{1}{2}$	16467.90	—765.78	1.109			$1\frac{1}{2}$	34352.42		0.787
		$3\frac{1}{2}$	17233.68		0.883	$3d^8(a^2F)4p$	$y^2F^\circ$	$3\frac{1}{2}$	35450.56	—879.30	1.145
$3d^8(1D)4s$	$a^2D$	$1\frac{1}{2}$	16470.60	307.56	1.101			$2\frac{1}{2}$	36329.86		0.892
		$2\frac{1}{2}$	16778.16		1.296	$3d^8(a^2F)4p$	$y^2D^\circ$	$2\frac{1}{2}$	36092.44	—782.69	1.186
$3d^8(3P)4s$	$a^2P$	$1\frac{1}{2}$	18389.57	—385.44	1.300			$1\frac{1}{2}$	36875.13		0.794
		$0\frac{1}{2}$	18775.01		0.695	$3d^7 4s(b^2F)4p$	$x^4D^\circ$	$3\frac{1}{2}$	39649.16	—696.79	1.428
$3d^7 4s^2$	$b^2P$	$1\frac{1}{2}$	20500.71	—715.19	1.284			$2\frac{1}{2}$	40345.95	—481.82	1.370
		$0\frac{1}{2}$	21215.90		0.680			$1\frac{1}{2}$	40827.77	—274.03	1.240
$3d^7 4s^2$	$a^2H$	$5\frac{1}{2}$	21780.47	—694.89	1.100			$0\frac{1}{2}$	41101.80		0.026
		$4\frac{1}{2}$	22475.36		0.921	$3d^7 4s(a^2P)4p$	$z^4S^\circ$	$1\frac{1}{2}$	40621.62		2.017
$3d^8(1G)4s$	$b^2D$	$2\frac{1}{2}$	21920.09	—1232.48	1.180			$1^\circ$	$3\frac{1}{2}$	41041.43	1.40
		$1\frac{1}{2}$	23152.57		0.955			$2^\circ$	$2\frac{1}{2}$	41104.96	1.863
$3d^7 4s^2$	$b^2G$	$4\frac{1}{2}$	23184.23	—23.53	1.098	$3d^7 4s(b^2F)4p$	$x^4F^\circ$	$4\frac{1}{2}$	41225.76	—692.65	1.319
		$3\frac{1}{2}$	23207.76		0.883			$3\frac{1}{2}$	41918.41	—515.82	1.248
$3d^7 4s(a^2F)4p$	$z^2F^\circ$	$5\frac{1}{2}$	23611.78	—243.84	1.466			$2\frac{1}{2}$	42434.23	—362.44	1.024
		$4\frac{1}{2}$	23855.62	—470.49	1.481			$1\frac{1}{2}$	42796.67		0.406
		$3\frac{1}{2}$	24326.11	—407.17	1.436	$3d^7 4s(b^2F)4p$	$x^4G^\circ$	$5\frac{1}{2}$	41528.53	—740.79	1.291
		$2\frac{1}{2}$	24733.28	—307.88	1.336			$4\frac{1}{2}$	42269.32	—542.12	1.169
		$1\frac{1}{2}$	25041.16	—191.63	1.118			$3\frac{1}{2}$	42811.44	—388.21	1.004
		$0\frac{1}{2}$	25232.79		—0.622			$2\frac{1}{2}$	43199.65		0.649
$3d^7 4s(a^2F)4p$	$z^2D^\circ$	$4\frac{1}{2}$	24627.79	—641.46	1.569	$3d^7 4s(a^2P)4p$	$z^4P^\circ$	$2\frac{1}{2}$	41968.89	—13.77	1.627
		$3\frac{1}{2}$	25269.25	—470.68	1.550			$1\frac{1}{2}$	41982.66	12.76	1.732
		$2\frac{1}{2}$	25739.93	—323.18	1.612			$0\frac{1}{2}$	41969.90		2.51
		$1\frac{1}{2}$	26063.11	—187.38	1.812	$3d^8(1D)4p$	$z^2P^\circ$	$0\frac{1}{2}$	43130.24	407.47	0.727
		$0\frac{1}{2}$	26260.49		3.286			$1\frac{1}{2}$	43537.71		1.120
		$6\frac{1}{2}$	25138.88	—429.80	1.40			$3\frac{1}{2}$	42988.12		
$3d^7 4s(a^2F)4p$	$z^2G^\circ$	$5\frac{1}{2}$	25568.68	—368.91	1.354			$4\frac{1}{2}$	43295.32	—552.66	1.295
		$4\frac{1}{2}$	25937.59	—294.46	1.281	$3d^7 4s(3G)4p$	$w^4F^\circ$	$3\frac{1}{2}$	43847.98	—353.94	1.197
		$3\frac{1}{2}$	26232.05	—217.97	1.150			$2\frac{1}{2}$	44201.92	—353.79	0.950
		$2\frac{1}{2}$	26450.02	—147.62	0.876			$1\frac{1}{2}$	44555.71		0.415
		$1\frac{1}{2}$	26597.64		0.006			$4\frac{1}{2}$	43295.32	—552.66	1.295
		$2\frac{1}{2}$	26597.64		0.006	$3d^7 4s(3G)4p$	$x^2F^\circ$	$2\frac{1}{2}$	43425.71	129.51	1.229
$3d^8$	$c^2D$	$2\frac{1}{2}$	27497.06	—973.45	1.200			$3\frac{1}{2}$	43555.22		1.119
		$1\frac{1}{2}$	28470.51		0.907			$1\frac{1}{2}$	43911.36	10.53	1.127
$3d^7 4s(a^2F)4p$	$z^4F^\circ$	$4\frac{1}{2}$	28345.86	—431.41	1.330		$w^4G^\circ$	$5\frac{1}{2}$	43952.06	—231.28	1.279
		$3\frac{1}{2}$	28777.27	—439.10	1.247			$4\frac{1}{2}$	44183.34	—211.13	1.163
		$2\frac{1}{2}$	29216.37	—346.80	1.033			$3\frac{1}{2}$	44394.47	—174.00	1.004
		$1\frac{1}{2}$	29563.17		0.410			$2\frac{1}{2}$	44568.47		0.676
$3d^7 4s(a^2F)4p$	$z^4G^\circ$	$5\frac{1}{2}$	28845.22	—424.51	1.276	$3d^7 4s(3G)4p$	$4^\circ$	$3\frac{1}{2}$	43969.90		1.081
		$4\frac{1}{2}$	29269.73	—465.45	1.175						
		$3\frac{1}{2}$	29735.18	—367.78	0.995						
		$2\frac{1}{2}$	30102.96		0.577						
$3d^7 4s(a^2F)4p$	$z^4D^\circ$	$3\frac{1}{2}$	29294.52	—654.24	1.425						
		$2\frac{1}{2}$	29948.76	—494.87	1.359						
		$1\frac{1}{2}$	30443.63	—299.02	1.192						
		$0\frac{1}{2}$	30742.65		—0.006						
$3d^7 4s(b^2F)4p$	$z^2G^\circ$	$4\frac{1}{2}$	31699.69	—1033.38	1.126						
		$3\frac{1}{2}$	32733.07		0.899						



## Co I—Continued

Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>
	5°	1½	44381. 32:		
3d <sup>7</sup> 4s(³P)4p:	<i>z</i> ²S°	0½	44454. 51		2. 10
3d <sup>8</sup> (³P)4p	<i>y</i> ⁴P°	2½	44480. 14	—177. 89	1. 557
		1½	44658. 03	—199. 54	1. 674
		0½	44857. 57		2. 371
3d <sup>8</sup> (a ³F)5s	<i>e</i> ⁴F	4½	44782. 13	—323. 46	1. 33
		3½	45105. 59	—770. 99	1. 21
		2½	45876. 58	—498. 59	1. 01
		1½	46375. 17		0. 44
3d <sup>7</sup> 4s(³G)4p	<i>z</i> ²H°	4½	45111. 48	428. 80	0. 897
		5½	45540. 28		1. 097
3d <sup>7</sup> 4s(a ⁵F)5s	<i>e</i> ⁶F	5½	45676. 00	—547. 01	1. 475
		4½	46223. 01	—483. 82	1. 443
		3½	46706. 83	—383. 82	1. 396
		2½	47090. 65	—274. 08	1. 301
		1½	47364. 73	—163. 71	1. 054
		0½	47528. 44		—0. 666
3d <sup>8</sup> (³P)4p:	<i>w</i> ²D°	2½	45688. 15	—766. 80	1. 219
		1½	46454. 95		0. 869
3d <sup>7</sup> 4s(³G)4p	<i>x</i> ²G°	3½	45766. 63	265. 47	0. 898
		4½	46032. 10		1. 131
3d <sup>7</sup> 4s(³P)4p	<i>x</i> ⁴P°	0½	45957. 29	—52. 61	2. 522
		1½	45904. 68	98. 15	1. 674
		2½	46002. 83		1. 543
3d <sup>8</sup> (a ³F)5s	<i>e</i> ²F	3½	45924. 98	—821. 02	1. 14
		2½	46746. 00		0. 49:
3d <sup>8</sup> (³P)4p	<i>v</i> ⁴D°	3½	45971. 19	—358. 44	1. 424
		2½	46329. 63	69. 61	1. 365
		1½	46260. 02	—242. 13	1. 508
		0½	46502. 15		0. 161
3d <sup>7</sup> 4s(³P)4p:	<i>v</i> ²D°	1½	46186. 41	485. 53	1. 218
		2½	46671. 94		1. 233
3d <sup>7</sup> 4s(³P)4p	<i>y</i> ⁴S°	1½	46562. 87		1. 273
3d <sup>7</sup> 4s(³P)4p:	<i>y</i> ²P°	1½	46685. 43	—405. 71	1. 352
		0½	47091. 14		0. 656
	<i>u</i> ⁴D°	3½	46872. 74	—521. 19	1. 332
		2½	47393. 93	—218. 25	1. 324
		1½	47612. 18	—293. 08	1. 122
		0½	47905. 26		0. 016
3d <sup>8</sup> (¹D)4p:	<i>w</i> ²F°	2½	47128. 96	96. 15	0. 858
		3½	47225. 11		1. 229
3d <sup>7</sup> 4s(a ⁵F)5s	<i>f</i> ⁴F	4½	47524. 47	—677. 13	1. 328
		3½	48201. 60	—516. 97	1. 226
		2½	48718. 57	—359. 86	1. 041
		1½	49078. 43		0. 401
	6°	3½?	47839. 15		
3d <sup>8</sup> (³P)4p:	<i>y</i> ²S°	0½	47977. 94		2. 093
3d <sup>7</sup> 4s(³P)4p:	<i>x</i> ²S°	0½	48026. 34		1. 699
3d <sup>8</sup> (³P)4p:	<i>x</i> ²P°	0½	48160. 43:	173. 94	1. 204
		1½	48334. 37		1. 436
3d <sup>7</sup> 4s(³P)4p	<i>t</i> ⁴D°	3½	48217. 32	—226. 44	1. 211
		2½	48443. 76	—102. 31	1. 340
		1½	48546. 07	—25. 70	1. 050
		0½	48571. 77		0. 452
	<i>v</i> ²F°	3½	48317. 17	—298. 39	1. 173
		2½	48615. 56:		0. 619
3d <sup>8</sup> (³P)4p	<i>x</i> ⁴S°	1½	48753. 72		1. 728
	7°	2½	48828. 87		

## Co I—Continued

Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>
	<i>w</i> ²S°	0½	48837. 72		1. 50:
	8°	1½	48851. 58:		
3d <sup>7</sup> 4s(³P)4p:	<i>w</i> ²P°	1½	49025. 42	—729. 31	1. 099
		0½	49754. 73		1. 365
	9°	{ 4½ 3½ }	49197. 74:		
	10°	3½	49484. 05		1. 260
	11°	2½	49847. 08		1. 079
	12°	1½	50105. 05		0. 569
3d <sup>8</sup> (¹G)4p	<i>y</i> ²H°	4½	50210. 80	165. 11	0. 899
		5½	50375. 91		1. 091
3d <sup>8</sup> (¹G)4p	<i>u</i> ²F°	3½	50578. 73	—133. 72	1. 125
		2½	50712. 45		0. 905
3d <sup>7</sup> 4s(³H)4p:	<i>w</i> ²G°	4½	50593. 38	—17. 84	1. 10
		3½	50611. 22		0. 82
3d <sup>7</sup> 4s(³H)4p	<i>x</i> ²H°	5½	50703. 08	—199. 53	1. 110
		4½	50902. 61		0. 941
	13°	{ 4½ 3½ }	50738. 20		
3d <sup>7</sup> 4s(³D)4p:	<i>s</i> ⁴D°	3½	50741. 66	—397. 72	1. 458
		2½	51139. 38	—707. 89	
		1½	51847. 27	—416. 74	
		0½	52264. 01:		
	14°	2½	50806. 55		1. 136
	<i>v</i> ²P°	1½	50925. 11	—20. 36	1. 340
		0½	50945. 47		0. 732
3d <sup>8</sup> (a³F)4d	<i>e</i> ⁴P	2½	51042. 26	—991. 00	1. 59
		1½	52033. 26	—882. 66	1. 40
		0½	52915. 92:		
3d <sup>8</sup> (a³F)4d	<i>e</i> ⁴D	3½	51052. 98	—507. 78	1. 402
		2½	51560. 76	—703. 73	1. 354
		1½	52264. 49:	—370. 13	
		0½	52634. 62		1. 58:
3d <sup>8</sup> (a³F)4d	<i>e</i> ⁴H	6½	51142. 53	—31. 75	1. 224
		5½	51174. 28	—946. 93	1. 147
		4½	52121. 21	—595. 49	0. 96
		3½	52716. 70		0. 896
3d <sup>7</sup> 4s(³D)4p:	<i>w</i> ⁴P°	2½	51160. 03	—854. 42	1. 578
		1½	52014. 45	—340. 67	1. 616
		0½	52355. 12		2. 304
3d <sup>8</sup> (a³F)4d	<i>g</i> ⁴F	4½	51170. 14	—29. 44	1. 337
		3½	51199. 58	—870. 42	1. 16
		2½	52070. 00	—632. 76	1. 08
		1½	52702. 76		0. 76:
	15°	3½	51184. 63		
3d <sup>8</sup> (a³F)4d	<i>e</i> ²P	1½	51200. 60	—840. 54	1. 368
		0½	52041. 14:		0. 48:
3d <sup>8</sup> (a³F)4d	<i>e</i> ⁴G	5½	51203. 75	—64. 18	1. 21
		4½	51267. 93	—894. 09	1. 083
		3½	52162. 02	—610. 28	1. 13
		2½	52772. 30		0. 74
	16°	2½	51863. 18		
	<i>t</i> ²F°	3½	51896. 75:	—899. 38	1. 15:
		2½	52796. 13		0. 883
	17°	2½	51989. 31:		



## Co I—Continued

## Co I—Continued

Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>	Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>
$3d^3(a^3F)4d$	$f^2F$	$3\frac{1}{2}$ $2\frac{1}{2}$	52095. 00 52970. 62	—875. 62	1. 11 1. 13	$3d^7 4s(a^5F)4d$	$e^6P$	$3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$	53789. 12 54445. 61 54949. 97	—656. 49 —504. 36	1. 635 1. 594 2. 134
$3d^3(a^3F)4d$	$e^2H$	$5\frac{1}{2}$ $4\frac{1}{2}$	52113. 91 52775. 47	—661. 56	1. 13 0. 97	$3d^7 4s(a^5F)4d$	$e^6H$	$7\frac{1}{2}$ $6\frac{1}{2}$ $5\frac{1}{2}$ $4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$	53822. 08 54452. 38 54947. 68 55312. 96 55520. 64 55555. 34	—630. 30 —495. 30 —365. 28 —207. 68 —34. 70	1. 34 1. 289 1. 22 1. 108 0. 922
$3d^3(a^3F)4d$	$e^2G$	$4\frac{1}{2}$ $3\frac{1}{2}$	52156. 46 52856. 68	—700. 22	1. 12 0. 92						
$3d^3(a^3F)4d$	$e^2D$	$2\frac{1}{2}$ $1\frac{1}{2}$	52460. 10 53343. 27	—883. 17	0. 92 0. 80	$3d^7 4s(a^5F)4d$	$f^4P$	$2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	53936. 68		1. 46
	18°	$3\frac{1}{2}$	52476. 64								
	19°	$1\frac{1}{2}$	52498. 17								
	20°	{ $2\frac{1}{2}$ $1\frac{1}{2}$ }	52526. 04				23°	$1\frac{1}{2}$	54165. 35		1. 353
							24°	$3\frac{1}{2}$	54398. 60		
$3d^7 4s(b^3F)5s$	$g^2F$	$3\frac{1}{2}$ $2\frac{1}{2}$	52763. 68 53704. 14	—940. 46	0. 933 0. 923		1	$2\frac{1}{2}$	54561. 74		1. 323
$3d^7 4s(b^3F)5s$	$h^4F$	$4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$	52864. 41 53694. 57 54258. 75 54426. 64	—830. 16 —564. 18 —167. 89	1. 307 1. 28: 0. 986 0. 422		$v^4F^o$	$4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$	54791. 2 55314. 04: 55684. 7 55622. 84	—522. 8 —370. 7 61. 9	
	21°	{ $4\frac{1}{2}$ $3\frac{1}{2}$ }	53065. 96:				25°	$4\frac{1}{2}$	54874. 08		
	$u^2D^o$	$1\frac{1}{2}$ $2\frac{1}{2}$	53074. 92 53195. 98	121. 06	0. 823 1. 206		26°	$3\frac{1}{2}$	54932. 32		
	$s^2F^o$	$3\frac{1}{2}$ $2\frac{1}{2}$	53103. 78 53146. 91:	—43. 13	1. 136		27°	$2\frac{1}{2}$	55061. 49		1. 539
$3d^3(^1G)4p$	$v^2G^o$	$4\frac{1}{2}$ $3\frac{1}{2}$	53276. 02 53373. 53	—97. 51	1. 124 0. 888		2	$1\frac{1}{2}$	55078. 76		1. 46:
	22°	$3\frac{1}{2}$	53463. 10				28°	$3\frac{1}{2}$	55120. 30:		
$3d^7 4s(a^5F)4d$	$f^4G$	$5\frac{1}{2}$ $4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$	53511. 83 54158. 17 54514. 67 55165. 63:	—646. 34 —356. 50 —650. 96	1. 274 1. 25: 1. 23:		3	$3\frac{1}{2}$	55223. 14		1. 14
$3d^7 4s(a^5F)4d$	$f^4H$	$6\frac{1}{2}$ $5\frac{1}{2}$ $4\frac{1}{2}$ $3\frac{1}{2}$	53618. 08 54315. 67 54860. 93 55268. 75	—697. 59 —545. 26 —407. 82	1. 227 1. 168 1. 10: 0. 857		29°	$2\frac{1}{2}$	55387. 11:		1. 170
$3d^7 4s(a^5F)4d$	$f^6F$	$5\frac{1}{2}$ $4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	53660. 37 54356. 45 54896. 57 55283. 02 55577. 28:	—696. 08 —540. 12 —386. 45 —294. 26	1. 421 1. 403 1. 27 1. 17 1. 07		30°	$2\frac{1}{2}$	55508. 78		
$3d^7 4s(a^5F)4d$	$f^4D$	$3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	53702. 13 54282. 73:	—580. 60	1. 377		4	$2\frac{1}{2}$	55598. 74		
$3d^7 4s(a^5F)4d$	$e^6D$	$4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	53725. 20 54352. 30 54946. 90 55407. 10:	—627. 10 —594. 60 —460. 20	1. 387 1. 48 1. 47: 2. 14	$3d^3(^3P)5s$	$g^4P$	$2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	56545. 51:		1. 31:
$3d^7 4s(a^5F)4d$	$e^6G$	$6\frac{1}{2}$ $5\frac{1}{2}$ $4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$	53728. 36: 54367. 43 54682. 91 54989. 62: 55449. 97 55389. 73	—639. 07 —315. 48 —306. 71 —460. 35 60. 24	1. 35 1. 320 1. 23 1. 23 1. 199		$g^4H$	$6\frac{1}{2}$ $5\frac{1}{2}$ $4\frac{1}{2}$ $3\frac{1}{2}$	57922. 06 58441. 03 58673. 73 59314. 82:	—518. 97 —232. 70 —641. 09	0. 920
$3d^7 4s(a^5F)4d$	$i^4F$	$4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$	53788. 78 54477. 07 54904. 99	—688. 29 —427. 92	1. 316 0. 85		36°	{ $4\frac{1}{2}$ $3\frac{1}{2}$ }	58187. 39		
							37°	{ $3\frac{1}{2}$ $2\frac{1}{2}$ }	59388. 89		
						Co II ( $a^3F_4$ )	Limit	-----	63438		

March 1951.

675475 O - 63 - 8

Co I OBSERVED TERMS\*

Config. $1s^2 2s^2 2p^6 3s^2 3p^6 +$	Observed Terms			
	$a^4P$ $b^2P$ $c^2D$	$a^4F$ $a^2G$ $a^2H$		
	$ns (n \geq 4)$	$np (n \geq 4)$	$nd (n \geq 4)$	
$3d^7 4s^2$				
$3d^8$				
$3d^8(a^3F)nx$	$\{$ $b, e^4F$ $a, e^2F$ $\}$	$y^4D^\circ$ $y^2D^\circ$	$y^4G^\circ$ $y^2G^\circ$	$e^4P$ $e^2P$ $e^4D$ $e^2D$
$3d^7 4s(a^5F)nx$	$\{$ $e^6F$ $f^4F$ $\}$	$z^6D^\circ$ $z^4D^\circ$	$z^6G^\circ$ $z^4G^\circ$	$e^6P$ $f^4P$ $e^6D$ $f^4D$
$3d^7 4s(b^3F)nx$	$\{$ $h^4F$ $g^2F$ $\}$	$x^4D^\circ$ $z^2D^\circ$	$x^4G^\circ$ $z^2G^\circ$	$e^4P$ $f^2P$ $e^4D$ $f^2D$
$3d^7 4s(a^6P)nx$		$z^4S^\circ$ $z^2P^\circ$		
$3d^8(3P)nx$	$\{$ $b, g^4P$ $a^2P$ $\}$	$x^4S^\circ$ $y^2S^\circ$ $y^4P^\circ$ $x^2P^\circ$	$v^4D^\circ$ $w^2D^\circ$	
$3d^8(1D)nx$		$z^2P^\circ$	$w^2F^\circ$	
$3d^8(1G)nx$			$u^2G^\circ$ $y^2H^\circ$	
$3d^7 4s(3G)nx$			$w^4F^\circ$ $x^2F^\circ$	$w^4G^\circ$ $x^2G^\circ$
$3d^7 4s(3P)nx$		$y^4S^\circ$ $z^2S^\circ$ $x^4P^\circ$ $y^2P^\circ$	$t^4D^\circ$ $v^2D^\circ$	
$3d^7 4s(3P)nx$		$x^2S^\circ$ $w^2P^\circ$		
$3d^7 4s(3H)nx$			$w^2G^\circ$ $x^2H^\circ$	
$3d^7 4s(3D)nx$		$w^4P^\circ$ $s^4D^\circ$		

\*For predicted terms of the Co I isoelectronic sequence, see Vol. II, Introduction.

Limits with prefixes "a", "b" are known in Co II. The remaining limit terms are arranged in the order of their appearance in the term table.

## Co II

(Fe I sequence; 26 electrons)

 $Z=27$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^8 {}^3F_4$  $a {}^3F_4$  137572  $\text{cm}^{-1}$ 

I. P. 17.05 volts

In 1930 Findlay published 15 terms and 194 classified lines in the range between 1940.64 Å and 3621.22 Å. With the aid of observed Zeeman patterns he revised and extended the early work by Meggers, using Meggers' line list and some additional observations of his own. From a Rydberg formula he determined an ionization potential based on the  $ns {}^5F$  series ( $n=4,5$ ). Russell has recently improved this value by applying a revised Ritz correction to the Rydberg series. The revised value of the limit is quoted here.

A set of plates taken by Kiess at the National Bureau of Standards for wave lengths greater than 2000 Å, and a set taken in Shenstone's laboratory at Princeton for the region of wave length less than 2000 Å, have made it possible to study the spectrum further. With this material Hager has recently extended the analysis especially for inclusion here. He has provisionally submitted in manuscript 10 additional terms and nearly 100 newly classified lines from his own measurements combined with the earlier ones. His line list extends from 1226.970 Å to 5192.947 Å. This work is now in progress and will doubtless be extended appreciably in the near future. He has suggested one change in Findlay's paper, namely, that the level at 63616.0 be designated  ${}^3D_2^\circ$  instead of  ${}^3P_2^\circ$ .

All  $g$ -values in the table except those for the  $4p {}^5P^\circ$  term, for  $z {}^5D_0^\circ$ , and for the changed level, have been determined by Miss Weeks from films taken at the Massachusetts Institute of Technology. Her manuscript was submitted in advance of publication.

The triplet and quintet systems of terms are connected by observed intersystem combinations.

## REFERENCES

- J. H. Findlay, Phys. Rev. **36**, 5 (1930). (I P) (T) (C L) (Z E)  
 H. N. Russell, J. Opt. Soc. Am. **40**, 618 (1950). (I P)  
 D. W. Weeks, unpublished material (March 1950). (Z E)  
 N. E. Hager, Jr., unpublished material (April 1951). (T) (C L)



## Co II

## Co II

Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>	Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>
$3d^8$	$a^3F$	4	0. 0			$3d^7(a^4F)4p$	$z^3G^\circ$	5	48555. 9		1. 19
		3	950. 3	−950. 3				4	49348. 2	−792. 3	1. 111
		2	1597. 2	−646. 9				3	50035. 9	−687. 7	0. 811
$3d^7(a^4F)4s$	$a^5F$	5	3350. 5		1. 406	$3d^7(a^4F)4p$	$z^3F^\circ$	4	49697. 5		1. 197
		4	4028. 9	−678. 4	1. 34			3	50381. 6	−684. 1	1. 059
		3	4560. 8	−531. 9	1. 26			2	50913. 8	−532. 2	0. 689
		2	4950. 0	−389. 2	0. 990	$3d^7(a^4F)4p$	$z^3D^\circ$	3	51512. 2		1. 33
		1	5204. 5	−254. 5	0. 008			2	52229. 6	−717. 4	1. 167
				1	52684. 5			−454. 9	0. 524		
$3d^7(a^4F)4s$	$b^3F$	4	9812. 7		1. 257	$3d^7(a^4P)4p$	$z^5S^\circ$	2	56010. 6		2. 00
		3	10708. 1	−895. 4	1. 087						
		2	11321. 5	−613. 4	0. 683						
$3d^8$	$a^3P$	2	13261. 1			$3d^7(a^4P)4p$	$y^5D^\circ$	4	61388. 1		1. 442
		1	13404. 6	−143. 5				3	61240. 8	147. 3	1. 504
		0	13593. 5	−188. 9				2	61260. 1	−19. 3	1. 490
$3d^7(a^4P)4s$	$a^5P$	3	17771. 5		1. 671	$3d^7(a^4P)4p$	$z^3S^\circ$	1	61348. 5?	−88. 4	
		2	18031. 5	−260. 0	1. 82			0	61457. 9	−109. 4	0. 000
		1	18338. 5	−307. 0	2. 50						
$3d^7(a^4P)4s$	$b^3P$	2	24074. 6			$3d^7(a^4P)4p$	$z^5P^\circ$	3	63344. 1		1. 67
		1	24267. 8	−193. 2				2	63366. 9	−22. 8	1. 86
		0	24411. 5	−143. 7				1	63665. 0	−298. 1	2. 62
$3d^7(a^2P)4s$	$c^3P$	2	24886. 5			$3d^7(a^4P)4p$	$y^3D^\circ$	3	63587. 0		
		1						2	63616. 0	−29. 0	1. 33
		0						1	63865. 2	−249. 2	
$3d^6 4s^2$	$a^3D$	3	27484. 3			$3d^6 4s(a^6D)4p$	$x^5D^\circ$	4	80299. 2		
		2	28111. 9	−627. 6				3	80542. 8	−243. 6	
		1	27585. 3	526. 6				2	80788. 7	−245. 9	
								1	80971. 4	−182. 7	
								0	81066. 7?	−195. 3	
$3d^6 4s^2$	$a^5D$	4	40694. 9			$3d^6 4s(a^6D)4p$	$y^5F^\circ$	5	81970. 9		
		3	41313. 9	−619. 0				4	82343. 9	−373. 0	
		2	41737. 8	−423. 9				3	82628. 2	−284. 3	
		1	42008. 6	−270. 8				2			
		0						1			
$3d^7(a^4F)4p$	$z^5F^\circ$	5	45197. 8		1. 396	$3d^7(a^4F)5s$	$e^5F$	5	84012. 3		
		4	45378. 8	−181. 0	1. 407			4	84584. 8	−572. 5	1. 34
		3	45972. 1	−593. 3	1. 303			3	85165. 3	−580. 5	1. 242
		2	46452. 6	−480. 5	1. 058			2	85593. 9	−428. 6	
		1	46786. 3	−333. 7	0. 06			1	85874. 1	−280. 2	
$3d^7(a^4F)4p$	$z^5D^\circ$	4	46320. 8		1. 442	$3d^6 4s(a^6D)4p$	$y^5P^\circ$	3	85044. 3		
		3	47039. 0	−718. 2	1. 43			2	85712. 6	−668. 3	
		2	47537. 1	−498. 1	1. 43			1	86134. 4	−421. 8	
		1	47848. 5	−311. 4	1. 42						
		0	47995. 1	−146. 6	0/0						
$3d^7(a^4F)4p$	$z^5G^\circ$	6	47078. 2		1. 350	$3d^7(a^4F)5s$	$e^3F$	4	85479. 2		1. 217
		5	47345. 7	−267. 5	1. 260			3	86343. 8	−864. 6	1. 08
		4	47807. 2	−461. 5	1. 154			2	86937. 7	−593. 9	0. 472
		3	48150. 7	−343. 5	0. 92						
		2	48388. 1	−237. 4	0. 35						
Co III ( $^4F_{4/2}$ )						Limit	-----	137572			

May 1951.

## Co II OBSERVED TERMS\*

Config. $1s^2 2s^2 2p^6 3s^2 3p^6 +$	Observed Terms	
$3d^8$ $3d^6 4s^2$	$a^3P$ $a^5D$ $a^3F$	
	$ns (n \geq 4)$	$np (n \geq 4)$
$3d^7(a^4F)nx$	$\left\{ \begin{array}{l} a, e^5F \\ b, e^3F \end{array} \right.$	$\begin{array}{ccc} z^5D^\circ & z^5F^\circ & z^5G^\circ \\ z^3D^\circ & z^3F^\circ & z^3G^\circ \end{array}$
$3d^7(a^4P)nx$	$\left\{ \begin{array}{l} a^5P \\ b^3P \end{array} \right.$	$\begin{array}{ccc} z^5S^\circ & z^5P^\circ & y^5D^\circ \\ z^3S^\circ & & y^3D^\circ \end{array}$
$3d^6 4s(a^6D)nx$		$y^5P^\circ \quad x^5D^\circ \quad y^5F^\circ$
$3d^7(a^2P)nx$	$c^3P$	

\*For predicted terms in the spectra of the Fe I isoelectronic sequence, see Vol. II, Introduction.

## Co III

(Mn I sequence; 25 electrons)

$Z=27$

Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^7 {}^4F_{4/2}$

$a {}^4F_{4/2}$  270200  $\text{cm}^{-1}$

I. P. 33.49 volts

The analysis has been done by Shenstone especially for inclusion here. He has submitted, in manuscript form, the terms listed below. His observations extend from 650 Å to 2250 Å. There are at present more than 350 classified lines. Observed intersystem combinations connect the quartet and sextet systems of terms. His value of the ionization potential, determined from the  $ns {}^6D$  series ( $n=4, 5$ ) on the assumption that the Ritz correction,  $\alpha$ , is the same for Co III as for Fe III, is 268963  $\text{cm}^{-1}$ . From a study of isoelectronic data Catalán has derived an improved value, which is quoted here.

## REFERENCES

- A. G. Shenstone, unpublished material (November 1951). (I P) (T) (C L)  
M. A. Catalán, unpublished material (April 1952). (I P)

## Co III

## Co III

Config.	Desig.	<i>J</i>	Level	Interval	Config.	Desig.	<i>J</i>	Level	Interval
$3d^7$	$a^4F$	$4\frac{1}{2}$	0. 0		$3d^6(^5D)4p$	$z^6F^\circ$	$5\frac{1}{2}$	103245. 0	
		$3\frac{1}{2}$	841. 2	—841. 2			$4\frac{1}{2}$	103386. 7	—141. 7
		$2\frac{1}{2}$	1451. 3	—610. 1			$3\frac{1}{2}$	103501. 7	—115. 0
		$1\frac{1}{2}$	1866. 8	—415. 5			$2\frac{1}{2}$	103593. 7	—92. 0
$3d^7$	$a^4P$	$2\frac{1}{2}$	15201. 9		$3d^6(^5D)4p$	$z^6P^\circ$	$2\frac{1}{2}$	103655. 7	—62. 0
		$1\frac{1}{2}$	15428. 2	—226. 3			$1\frac{1}{2}$	103690. 8	—35. 1
		$0\frac{1}{2}$	15811. 4	—383. 2			$3\frac{1}{2}$	105008. 7	
							$2\frac{1}{2}$	105965. 1	—956. 4
$3d^7$	$a^2G$	$4\frac{1}{2}$	16977. 7		$3d^6(^5D)4p$	$z^4D^\circ$	$1\frac{1}{2}$	106591. 9	—626. 8
		$3\frac{1}{2}$	17766. 2	—788. 5			$3\frac{1}{2}$	106489. 1	
$3d^7$	$a^2H$	$5\frac{1}{2}$	22720. 3		$3d^6(^5D)4p$	$z^4D^\circ$	$2\frac{1}{2}$	106954. 7	—465. 6
		$4\frac{1}{2}$	23434. 3	—714. 0			$1\frac{1}{2}$	107297. 0	—342. 3
$3d^7$	$a^2D$	$2\frac{1}{2}$	23058. 8?		$3d^6(^5D)4p$	$z^4F^\circ$	$0\frac{1}{2}$	107507. 6	—210. 6
		$1\frac{1}{2}$					$4\frac{1}{2}$	106764. 9	
$3d^6(^5D)4s$	$a^6D$	$3\frac{1}{2}$	46438. 3		$3d^6(^5D)4p$	$z^4F^\circ$	$3\frac{1}{2}$	107530. 1	—765. 2
		$2\frac{1}{2}$	47003. 1	—564. 8			$2\frac{1}{2}$	107530. 1	—522. 8
		$2\frac{1}{2}$	47415. 4	—412. 3			$1\frac{1}{2}$	108052. 9	—350. 5
		$1\frac{1}{2}$	47698. 6	—283. 2			$2\frac{1}{2}$	110371. 2	
		$0\frac{1}{2}$	47864. 8	—166. 2			$1\frac{1}{2}$	110961. 5	—590. 3
$3d^6(^5D)4s$	$a^4D$	$3\frac{1}{2}$	55729. 2		$3d^6(^5D)4p$	$z^4P^\circ$	$0\frac{1}{2}$	111283. 1	—321. 6
		$2\frac{1}{2}$	56373. 8	—644. 6			$2\frac{1}{2}$	124597. 1?	
		$1\frac{1}{2}$	56794. 8	—421. 0			$1\frac{1}{2}$		
		$0\frac{1}{2}$	57036. 8	—242. 0			$0\frac{1}{2}$		
$3d^6(^3P)4s$	$b^4P$	$2\frac{1}{2}$	70933. 7		$3d^6(^3P)4p$	$y^4P^\circ$	$2\frac{1}{2}$		
		$1\frac{1}{2}$	72341. 6	—1407. 9			$1\frac{1}{2}$		
		$0\frac{1}{2}$	73214. 7	—873. 1			$0\frac{1}{2}$		
$3d^6(^3H)4s$	$a^4H$	$6\frac{1}{2}$	71623. 1		$3d^6(^3H)4p$	$z^4G^\circ$	$5\frac{1}{2}$	124766. 1	
		$5\frac{1}{2}$	71873. 7	—250. 6			$4\frac{1}{2}$	125012. 4	—246. 3
		$4\frac{1}{2}$	72083. 3	—209. 6			$3\frac{1}{2}$	125227. 0	—214. 6
		$3\frac{1}{2}$	72270. 1	—186. 8			$2\frac{1}{2}$	125368. 9	—141. 9
$3d^6(^3F)4s$	$b^4F$	$4\frac{1}{2}$	73286. 0		$3d^6(^3H)4p$	$z^4H^\circ$	$6\frac{1}{2}$	125276. 2	
		$3\frac{1}{2}$	73540. 2	—254. 2			$5\frac{1}{2}$	125296. 2	—20. 0
		$2\frac{1}{2}$	73726. 6	—186. 4			$4\frac{1}{2}$	125421. 5	—125. 3
		$1\frac{1}{2}$	73861. 3	—134. 7			$3\frac{1}{2}$	125690. 4	—268. 9
$3d^6(^3G)4s$	$a^4G$	$5\frac{1}{2}$	76518. 7		$3d^6(^3P)4p$	$z^2D^\circ$	$1\frac{1}{2}$	125769. 8?	
		$4\frac{1}{2}$	77121. 4	—602. 7			$2\frac{1}{2}$		
		$3\frac{1}{2}$	77383. 1	—261. 7			$1\frac{1}{2}$		
		$2\frac{1}{2}$	77472. 0	—88. 9			$0\frac{1}{2}$		
$3d^6(^3H)4s$	$b^2H$	$5\frac{1}{2}$	77411. 5		$3d^6(^3H)4p$	$z^4I^\circ$	$7\frac{1}{2}$	126119. 0	
		$4\frac{1}{2}$	77622. 9	—211. 4			$6\frac{1}{2}$	126475. 4	—356. 4
$3d^6(^3F)4s$	$a^2F$	$3\frac{1}{2}$	78927. 6		$3d^6(^3P)4p$	$y^4D^\circ$	$5\frac{1}{2}$	126501. 2	—25. 8
		$2\frac{1}{2}$	79425. 0	—497. 4			$4\frac{1}{2}$	126239. 4	261. 8
$3d^6(^3G)4s$	$b^2G$	$4\frac{1}{2}$	82363. 2		$3d^6(^3P)4p$	$y^4D^\circ$	$3\frac{1}{2}$	126549. 4	—1535. 8
		$3\frac{1}{2}$	82920. 4	—557. 2			$2\frac{1}{2}$	128085. 2	—337. 9
$3d^6(^1I)4s$	$a^2I$	$6\frac{1}{2}$	85474. 1		$3d^6(^3F)4p$	$y^4F^\circ$	$1\frac{1}{2}$	126987. 4	—116. 7
		$5\frac{1}{2}$	85517. 3	—43. 2			$2\frac{1}{2}$	126870. 7	21. 4
$3d^6(^1G)4s$	$c^2G$	$4\frac{1}{2}$	86283. 7		$3d^6(^3H)4p$	$z^2G^\circ$	$3\frac{1}{2}$	126892. 1	106. 0
		$3\frac{1}{2}$	86326. 9	—43. 2			$4\frac{1}{2}$	126998. 1	
$3d^6(^5D)4p$	$z^6D^\circ$	$4\frac{1}{2}$	98290. 3		$3d^6(^3H)4p$	$z^2G^\circ$	$4\frac{1}{2}$	127050. 8	
		$3\frac{1}{2}$	98545. 6	—255. 3			$3\frac{1}{2}$	127317. 6	—266. 8
		$2\frac{1}{2}$	98823. 2	—277. 6			$6\frac{1}{2}$	127672. 8	
		$1\frac{1}{2}$	99043. 5	—220. 3			$5\frac{1}{2}$	128258. 9	—586. 1
		$0\frac{1}{2}$	99182. 2	—138. 7					
$3d^6(^5D)4p$	$z^6D^\circ$	$4\frac{1}{2}$	98290. 3		$3d^6(^3F)4p$	$x^4D^\circ$	$3\frac{1}{2}$	128017. 8	
		$3\frac{1}{2}$	98545. 6	—255. 3			$2\frac{1}{2}$	128525. 0	—507. 2
		$2\frac{1}{2}$	98823. 2	—277. 6			$1\frac{1}{2}$	128804. 7	—279. 7
		$1\frac{1}{2}$	99043. 5	—220. 3			$0\frac{1}{2}$	128936. 9	—132. 2
		$0\frac{1}{2}$	99182. 2	—138. 7					



## Co III—Continued

## Co III—Continued

Config.	Desig.	<i>J</i>	Level	Interval	Config.	Desig.	<i>J</i>	Level	Interval
$3d^6(^3F)4p$	$y\ ^4G^\circ$	$5\frac{1}{2}$	129556.0	—36.3	$3d^6(^3G)4p$	$x\ ^2G^\circ$	$4\frac{1}{2}$	137661.3	—151.0
		$4\frac{1}{2}$	129592.3	—114.6			$3\frac{1}{2}$	137812.3	
		$3\frac{1}{2}$	129706.9	—40.0	$3d^6(^1I)4p$	$x\ ^2H^\circ$	$4\frac{1}{2}$	138920.7	216.8
		$2\frac{1}{2}$	129746.9				$5\frac{1}{2}$	139137.5	
$3d^6(^3F)4p$	$z\ ^2F^\circ$	$3\frac{1}{2}$	130183.9	—223.4	$3d^6(^1G)4p$	$w\ ^2G^\circ$	$4\frac{1}{2}$	140358.3	—24.6
		$2\frac{1}{2}$	130407.3				$3\frac{1}{2}$	140382.9	
$3d^6(^3F)4p$	$y\ ^2G^\circ$	$4\frac{1}{2}$	130802.0	—477.4	$3d^6(^1G)4p$	$x\ ^2F^\circ$	$3\frac{1}{2}$	140646.3	—141.0
		$3\frac{1}{2}$	131279.4				$2\frac{1}{2}$	140787.3	
$3d^6(^3H)4p$	$z\ ^2H^\circ$	$5\frac{1}{2}$	131054.2	—483.9	$3d^6(^1G)4p$	$w\ ^2H^\circ$	$5\frac{1}{2}$	141190.8	—156.4
		$4\frac{1}{2}$	131538.1				$4\frac{1}{2}$	141347.2	
$3d^6(^3G)4p$	$x\ ^4G^\circ$	$5\frac{1}{2}$	131098.1	—483.5	$3d^6(^1I)4p$	$y\ ^2I^\circ$	$6\frac{1}{2}$	141868.8	—5.0
		$4\frac{1}{2}$					$5\frac{1}{2}$	141873.8	
		$3\frac{1}{2}$			$3d^6(^3P')4p$	$z\ ^4S^\circ$	$1\frac{1}{2}$	155702.4	
		$2\frac{1}{2}$					$0\frac{1}{2}$	156291.4	
$3d^6(^3G)4p$	$x\ ^4F^\circ$	$4\frac{1}{2}$	131887.1	—390.1	$3d^6(^5D)5s$	$e\ ^6D$	$4\frac{1}{2}$	169527.7	
		$3\frac{1}{2}$	132277.2	—211.8			$3\frac{1}{2}$		
		$2\frac{1}{2}$	132489.0	—103.3			$2\frac{1}{2}$		
		$1\frac{1}{2}$	132592.3				$1\frac{1}{2}$		
$3d^6(^3G)4p$	$y\ ^4H^\circ$	$6\frac{1}{2}$	132376.6	—130.0			$0\frac{1}{2}$		
		$5\frac{1}{2}$	132506.6	—80.5					
		$4\frac{1}{2}$	132587.1	—36.4					
		$3\frac{1}{2}$	132623.5						
$3d^6(^3G)4p$	$y\ ^2H^\circ$	$5\frac{1}{2}$	134696.0	—708.0					
		$4\frac{1}{2}$	135404.0						
$3d^6(^3G)4p$	$y\ ^2F^\circ$	$2\frac{1}{2}$	136129.3	160.8					
		$3\frac{1}{2}$	136290.1						
					Co IV ( $^5D_4$ )	Limit		270200	

November 1951.

## Co III OBSERVED TERMS\*

Config. $1s^2 2s^2 2p^6 3s^2 3p^6 +$	Observed Terms	
$3d^7$	$\{ a\ ^4P \quad a\ ^3D \quad a\ ^4F \quad a\ ^2G \quad a\ ^2H$	
	$ns\ (n \geq 4)$	$np\ (n \geq 4)$
$3d^6(^5D)nx$	$\{ \quad a, e\ ^6D$ $\quad a\ ^4D$	$z\ ^6P^\circ \quad z\ ^6D^\circ \quad z\ ^6F^\circ$ $z\ ^4P^\circ \quad z\ ^4D^\circ \quad z\ ^4F^\circ$
$3d^6(^3P)nx$	$\{ b\ ^4P$	$y\ ^4P^\circ \quad y\ ^4D^\circ$ $\quad z\ ^2D^\circ$
$3d^6(^3H)nx$	$\{ \quad \quad \quad a\ ^4H$ $\quad \quad \quad b\ ^2H$	$z\ ^4G^\circ \quad z\ ^4H^\circ \quad z\ ^4I^\circ$ $z\ ^2G^\circ \quad z\ ^2H^\circ \quad z\ ^2I^\circ$
$3d^6(^3F)nx$	$\{ \quad \quad b\ ^4F$ $\quad \quad a\ ^2F$	$x\ ^4D^\circ \quad y\ ^4F^\circ \quad y\ ^4G^\circ$ $\quad \quad z\ ^2F^\circ \quad y\ ^2G^\circ$
$3d^6(^3G)nx$	$\{ \quad \quad \quad a\ ^4G$ $\quad \quad \quad b\ ^2G$	$x\ ^4F^\circ \quad x\ ^4G^\circ \quad y\ ^4H^\circ$ $y\ ^2F^\circ \quad x\ ^2G^\circ \quad y\ ^2H^\circ$
$3d^6(^1I)nx$	$\quad \quad \quad \quad \quad a\ ^2I$	$x\ ^2H^\circ \quad y\ ^2I^\circ$
$3d^6(^1G)nx$	$\quad \quad \quad c\ ^2G$	$x\ ^2F^\circ \quad w\ ^2G^\circ \quad w\ ^2H^\circ$
$3d^6(^3P')nx$		$z\ ^4S^\circ \quad x\ ^4P^\circ$

\*For predicted terms in the spectra of the Mn I isoelectronic sequence, see Vol. II, Introduction.

Co IV

(Cr I sequence; 24 electrons)

Z=27

Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^6 \ ^5D_4$

$a \ ^5D_4$ 

cm<sup>-1</sup>

I. P.

volts

From a study of isoelectronic sequence data, and especially by analogy with Fe III, Morell, in 1928, classified 9 lines between 1349 Å and 1863 Å as combinations between  $3d^5(^6S)4s \ ^7,^5S$  and  $3d^5(^6S)4p \ ^7,^5P^o$ . The present detailed analysis of Fe III indicates the urgent need of further investigation of the Co IV spectrum.

REFERENCE

L. Morell, Thesis (unpublished) Cornell University (1928). (T) (C L)  
January 1950.

Co V

(V I sequence; 23 electrons)

Z=27

Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 \ ^6S_{5/2}$

$a \ ^6S_{5/2}$ 

cm<sup>-1</sup>

I. P.

volts

This spectrum is very incompletely known. In 1931 Miss Gilroy published 9 terms, and 57 classified lines between 412 Å and 1488 Å. Later, Kruger and Gilroy reported that the three lines from the ground term having the transition  $3d^5 \ ^6S-4p \ ^6P^o$  were near 355 Å, rather than near 414 Å, as was stated in the earlier paper. Consequently, the relative term values as published in 1931 need revision. The accepted classifications are as follows:

Int.	I. A.	Wave No.	Desig.
20	355. 523	281275	$3d^5 \ ^6S_{5/2}-4p \ ^6P_{3/2}^o$
18	355. 876	280996	$3d^5 \ ^6S_{5/2}-4p \ ^6P_{2/2}^o$
12	356. 060	280851	$3d^5 \ ^6S_{5/2}-4p \ ^6P_{1/2}^o$

REFERENCES

H. T. Gilroy, Phys. Rev. **38**, 2217 (1931). (T) (C L)  
P. G. Kruger and H. T. Gilroy, Phys. Rev. **48**, 720 (1935). (T) (C L)  
January 1950.

## Co VI

(Ti I sequence; 22 electrons)

 $Z=27$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^4 {}^5D_0$  $a {}^5D_0$        $\text{cm}^{-1}$ 

I. P.      volts

The analysis is by Bowen who has classified 103 lines in the range between 266 Å and 306 Å. Intersystem combinations connecting the triplet and quintet systems of terms have been observed, but no series are known.

Phillips and Kruger find the line measured by Bowen at 278.184 Å as double, and classify the weaker component as  $a {}^5D_3 - z {}^5F_4^{\circ}$ . This places  $z {}^5F_4^{\circ}$  at  $360588 \text{ cm}^{-1}$ , which is  $102 \text{ cm}^{-1}$  lower than Bowen's value. Further study of this spectrum is needed.

## REFERENCES

I. S. Bowen, Phys. Rev. **53**, 889 (1938). (T) (C L)L. W. Phillips and P. G. Kruger, Phys. Rev. **54**, 839 (1938). (T) (C L)

## Co VI

## Co VI

Config.	Desig.	$J$	Level	Interval	Config.	Desig.	$J$	Level	Interval
$3d^4$	$a {}^3D$	0	0		$3d^3(a {}^4F)4p$	$z {}^5F^{\circ}$	1	358366	
		1	208	208			2	359036	670
		2	586	378			3	359826	790
		3	1129	543			4	360690	864
		4	1789	660			5	361263	573
$3d^4$	$a {}^3P$	0	27167		$3d^3(a {}^4F)4p$	$z {}^3D^{\circ}$	1	359903	
		1	28458	1291			2	360462	559
		2	30504	2046			3	361495	1033
$3d^4$	$a {}^3H$	4	28381		$3d^3(a {}^4F)4p$	$z {}^3G^{\circ}$	3	364343	
		5	28804	423			4	365083	740
		6	29233	429			5	366026	943
$3d^4$	$a {}^3F$	2	30545		$3d^3(a {}^4F)4p$	$z {}^3F^{\circ}$	2	367560	
		3	30635	90			3	368414	854
		4	30816	181			4	369316	902
$3d^4$	$a {}^3G$	3	34024		$3d^3(a {}^4P)4p$	$z {}^5P^{\circ}$	1	374556	
		4	34473	449			2	375250	694
		5	34852	379			3	376363	1113
$3d^3(a {}^4F)4p$	$z {}^5D^{\circ}$	0			$3d^3(a {}^2G)4p$	$y {}^3G^{\circ}$	3	380634	
		1	356754				4	381656	1022
		2	357279	525			5	382477	821
		3	358021	742	$3d^3(a {}^2H)4p$	$x {}^3G^{\circ}$	5	396229	-191
		4	358928	907			4	396420	-159
							3	396579	

January 1949.



### Co VI OBSERVED TERMS\*

Config $1s^2 2s^2 2p^6 3s^2 3p^6 +$	Observed Terms
$3d^4$	$\left\{ \begin{array}{ccccc} a^5D & & & & \\ a^3P & & a^3F & a^3G & a^3H \end{array} \right.$
	$np \ (n \geq 4)$
$3d^3(a^4F)nx$	$\left\{ \begin{array}{ccc} z^5D^\circ & z^5F^\circ & \\ z^3D^\circ & z^3F^\circ & z^3G^\circ \end{array} \right.$
$3d^3(a^4P)nx$	$z^5P^\circ$
$3d^3(a^3G)nx$	$y^3G^\circ$
$3d^3(a^3H)nx$	$x^3G^\circ$

\*For predicted terms in the spectra of the Ti I isoelectronic sequence, see Vol. I, p. xxxvii.

## Co VII

(Sc 1 sequence; 21 electrons)

 $Z=27$ 

Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^3 {}^4F_{1/2}$

 $a\ ^4F_{1\frac{1}{2}}$  $\text{cm}^{-1}$ 

I. P.

volts

The analysis is by Anderson and Mack who have classified 133 lines in the region between 415 Å and 484 Å. They have been unable to locate with certainty the  $^2P$  term having the configuration  $3d^3$ , but they suggest tentatively for this term two possible pairs of levels whose reality is not yet established, as follows:

$J$	Level	
$1\frac{1}{2}$	28876?	29244?
$0\frac{1}{2}$	29324?	29712?

Intersystem combinations connecting the doublet and quartet systems of terms have been observed.

## REFERENCE

E. E. Anderson and J. E. Mack, Phys. Rev. **59**, 717 (1941). (T) (C L)

## Co VII

## Co VII

Config.	Desig.	<i>J</i>	Level	Interval	Config.	Desig.	<i>J</i>	Level	Interval
$3d^3$	$a\ ^4F$	$1\frac{1}{2}$	0		$3d^3(a\ ^1F)4p$	$z\ ^4D^\circ$	$0\frac{1}{2}$	451559	-344
		$2\frac{1}{2}$	698	698			$1\frac{1}{2}$	451215	1351
		$3\frac{1}{2}$	1610	912			$2\frac{1}{2}$	452566	1591
		$4\frac{1}{2}$	2723	1113			$3\frac{1}{2}$	454157	
$3d^3$	$a\ ^4P$	$0\frac{1}{2}$	21096		$3d^3(a\ ^1F)4p$	$z\ ^2D^\circ$	$1\frac{1}{2}$	452709	
		$1\frac{1}{2}$	21304	208			$2\frac{1}{2}$	454482?	1773
		$2\frac{1}{2}$	22187	883	$3d^3(a\ ^1F)4p$	$z\ ^2G^\circ$	$3\frac{1}{2}$	459170	
$3d^3$	$a\ ^2G$	$3\frac{1}{2}$	24151	912			$4\frac{1}{2}$	460587	1417
		$4\frac{1}{2}$	25063		$3d^3(a\ ^1P)4p$	$z\ ^4S^\circ$	$1\frac{1}{2}$	465290	
$3d^3$	$a\ ^2D$	$2\frac{1}{2}$	31348				$0\frac{1}{2}$	469358?	
		$1\frac{1}{2}$	31555?	-207	$3d^3(a\ ^1P)4p$	$y\ ^4D^\circ$	$1\frac{1}{2}$	470375	1017
$3d^3$	$a\ ^2H$	$4\frac{1}{2}$	33251				$2\frac{1}{2}$	471880	1505
		$5\frac{1}{2}$	33873	622			$3\frac{1}{2}$	474067	2187
$3d^3(a\ ^1F)4p$	$z\ ^4G^\circ$	$2\frac{1}{2}$	445761		$3d^3(a\ ^1P)4p$	$z\ ^4P^\circ$	$0\frac{1}{2}$	474575	
		$3\frac{1}{2}$	447314	1553			$1\frac{1}{2}$	475156	581
		$4\frac{1}{2}$	449305	1991			$2\frac{1}{2}$	476592	1436
		$5\frac{1}{2}$	451810?	2505	$3d^3(a\ ^1G)4p$	$y\ ^2G^\circ$	$3\frac{1}{2}$	476054	
$3d^3(a\ ^1F)4p$	$z\ ^4F^\circ$	$1\frac{1}{2}$	446966	1085			$4\frac{1}{2}$	476288	234
		$2\frac{1}{2}$	448051	1389	$3d^3(a\ ^1G)4p$	$z\ ^2H^\circ$	$4\frac{1}{2}$	485616	
		$3\frac{1}{2}$	449440	1549			$5\frac{1}{2}$	487584	1968
		$4\frac{1}{2}$	450989						
$3d^3(a\ ^1F)4p$	$z\ ^2F^\circ$	$2\frac{1}{2}$	450865						
		$3\frac{1}{2}$	452009	1144					

December 1948.

## Co VII OBSERVED TERMS\*

Config. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6 +$	Observed Terms
$3d^3$	$\left\{ \begin{array}{ccccc} a\ ^4P & & a\ ^4F & & \\ & a\ ^2D & & a\ ^2G & a\ ^2H \end{array} \right.$
	$np\ (n \geq 4)$
$3d^3(a\ ^1F)nx$	$\left\{ \begin{array}{ccc} z\ ^4D^\circ & z\ ^4F^\circ & z\ ^4G^\circ \\ z\ ^2D^\circ & z\ ^2F^\circ & z\ ^2G^\circ \end{array} \right.$
$3d^3(a\ ^1P)nx$	$z\ ^4S^\circ\quad z\ ^4P^\circ\quad y\ ^4D^\circ$
$3d^3(a\ ^1G)nx$	$y\ ^2G^\circ\quad z\ ^2H^\circ$

\*For predicted terms in the spectra of the Sc I isoelectronic sequence, see Vol. I, p. xxxvi.

Co VIII

(Ca I sequence; 20 electrons)

Z=27

Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^2 \text{}^3F_2$

$a^3F_2$ 

cm<sup>-1</sup>

I. P.

volts

Although 27 lines between 181 Å and 192 Å were reported as classified in 1933, later study of the spectra of this sequence by Edlén indicates that the early interpretation is incorrect.

REFERENCES

W. M. Cady, Phys. Rev. **43**, 325 (1933). (T) (C L)  
B. Edlén, letter (Feb. 1949).  
February 1949.

Co XI

(Cl I sequence; 17 electrons)

Z=27

Ground state  $1s^2 2s^2 2p^6 3s^2 3p^5 \text{}^2P^{\circ}_{1\frac{1}{2}}$

$3p^5 \text{}^2P^{\circ}_{1\frac{1}{2}}$  2462000 cm<sup>-1</sup>

I. P. 305 volts

Edlén has classified six lines in the region between 81 Å and 84 Å, as combinations from the ground term. He has estimated the value of the limit by extrapolation along the isoelectronic sequence, as indicated by brackets in the table.  
His unit, 10<sup>3</sup> cm<sup>-1</sup>, has here been changed to cm<sup>-1</sup>

REFERENCE

B. Edlén, Zeit. Phys. **104**, 407 (1937). (I P) (T) (C L)

Co XI

Config.	Desig.	J	Level	Interval
$3s^2 3p^5$	$3p^5 \text{}^2P^{\circ}$	$1\frac{1}{2}$ $0\frac{1}{2}$	$\overset{0}{19280}$	—19280
$3s^2 3p^4(^3P)4s$	$4s \text{}^4P$	$2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	1189920	
$3s^2 3p^4(^3P)4s$	$4s \text{}^2P$	$1\frac{1}{2}$ $0\frac{1}{2}$	1202070 1211730	—9660
$3s^2 3p^4(^1D)4s$	$4s' \text{}^3D$	$2\frac{1}{2}$ $1\frac{1}{2}$	1226890 1227610	—720
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Co XII ( $\text{}^3P_2$ )	Limit	---	[2462000]	

January 1948.



## Co XIV

(Si I sequence; 14 electrons)

 $Z=27$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^2 {}^3P_0$  $3p^2 {}^3P_0$        $\text{cm}^{-1}$ 

I. P.      volts

This spectrum has not been analyzed, but Edlén has predicted the interval between the two lowest levels ( $3p^2 {}^3P_0$ — $3p^2 {}^3P_1$ ) to be 8448 Å, or  $11834 \text{ cm}^{-1}$ .

## REFERENCE

B. Edlén, Zeit. Astroph. **22**, 58 (1942). (C L)

October 1947.

## Co XV

(Al I sequence; 13 electrons)

 $Z=27$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p {}^2P_{0\frac{1}{2}}^\circ$  $3p {}^2P_{0\frac{1}{2}}^\circ$        $\text{cm}^{-1}$ 

I. P.      volts

This spectrum has not been analyzed, but Edlén has classified 2 lines as follows:

I. A.	Int.	Wave No.	Desig.
52. 583	1	1901750	} $3p {}^2P^\circ - 4d {}^2D$
53. 173	2	1880650	

His unit,  $10^3 \text{ cm}^{-1}$ , is here changed to  $\text{cm}^{-1}$ .

## REFERENCE

B. Edlén, Zeit. Phys. **103**, 540 (1936). (C L)

December 1947.

Co XVI

(Mg I sequence; 12 electrons)

$Z=27$

Ground state  $1s^2 2s^2 2p^6 3s^2 \ ^1S_0$

$3s^2 \ ^1S_0$  4133000  $\text{cm}^{-1}$

I. P. 512 volts

Edlén has classified 8 lines in the region between 49 Å and 61 Å. No singlet combinations have been observed and the triplet terms are not connected by observed combinations. He has determined the relative positions of the terms and also the ionization potential by extrapolation along the isoelectronic sequence. Estimated values are denoted by brackets in the table.  
Edlén's unit,  $10^3 \text{ cm}^{-1}$ , has here been changed to  $\text{cm}^{-1}$ .

REFERENCE

B. Edlén, Zeit. Phys. **103**, 536 (1936). (I P) (T) (C L)

Co XVI

Config.	Desig.	<i>J</i>	Level	Interval
$3s^2$	$3s^2 \ ^1S$	0	0	
$3s(^2S)3p$	$3p \ ^1P^\circ$	0 1 2	$[258310] + x$ $275590 + x$	17280
$3s(^2S)3d$	$3d \ ^1D$	1 2 3	$734890 + x$	
$3s(^2S)4p$	$4p \ ^1P^\circ$	1	$[2106020]$	
$3s(^2S)4d$	$4d \ ^1D$	1 2 3	$2259150 + x$ $2259990 + x$ $2261410 + x$	840 1420
$3s(^2S)4f$	$4f \ ^1F^\circ$	2 3 4	$2348260 + x$	
-----	-----	---	-----	
Co XVII ( $^2S_{0\frac{1}{2}}$ )	Limit	---	[4133000]	

August 1947.

## Co xvii

(Na I sequence; 11 electrons)

 $Z=27$ Ground state  $1s^2 2s^2 2p^6 3s^2 S_{0\frac{1}{2}}$  $3s^2 S_{0\frac{1}{2}}$  4410480  $\text{cm}^{-1}$ 

I. P. 547 volts

Edlén has classified 10 lines in the interval 41 Å to 58 Å, and extrapolated the absolute value of the ground term from isoelectronic sequence data. His unit,  $10^3 \text{ cm}^{-1}$ , has here been changed to  $\text{cm}^{-1}$ .

## REFERENCE

B. Edlén, Zeit. Phys. **100**, 621 (1936). (I P) (T) (C L)

## Co xvii

Config.	Desig.	$J$	Level	Interval
$3s$	$3s^2 S$	$0\frac{1}{2}$	0	
$3p$	$3p^2 P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	293550 318930	25380
$3d$	$3d^2 D$	$1\frac{1}{2}$ $2\frac{1}{2}$	721600 725230	3630
$4s$	$4s^2 S$	$0\frac{1}{2}$	2078910	
$4p$	$4p^2 P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	2196500 2206580	10080
$4d$	$4d^2 D$	$1\frac{1}{2}$ $2\frac{1}{2}$	2352650 2354220	1570
$4f$	$4f^2 F^\circ$	$2\frac{1}{2}$ $3\frac{1}{2}$	2421500 2422130	630
$5f$	$5f^2 F^\circ$	$2\frac{1}{2}$ $3\frac{1}{2}$	3137080	
-----	-----	-----	-----	
Co xviii ( $1S_0$ )	Limit	-----	[4410480]	

June 1947.



Co XVIII

(Ne I sequence; 10 electrons)

Z=27

Ground state  $1s^2 2s^2 2p^6 \ ^1S_0$

$2p^6 \ ^1S_0$  11316400  $\text{cm}^{-1}$

I P. 1403 volts

Tyrén has classified seven lines in the region 12 Å to 15 Å, as combinations with the ground term. His absolute term values have been derived by extrapolation along the Ne I isoelectronic sequence.

By analogy with Ne I the  $j\bar{l}$ -coupling notation in the general form suggested by Racah is introduced.

The unit adopted by Tyrén,  $10^3 \text{ cm}^{-1}$ , has here been changed to  $\text{cm}^{-1}$ .

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Co XVIII					Co XVIII				
Author	Config.	Desig.	J	Level	Author	Config.	Desig.	J	Level
$2p \ ^1S_0$	$2s^2 2p^6$	$2p^6 \ ^1S$	0	0	$3d \ ^3D_1$	$2s^2 2p^5(^2P_{3/2})3d$	$3d'[1\frac{1}{2}]^\circ$	1	7337300
$3s \ ^3P_1$	$2s^2 2p^5(^2P_{1/2})3s$	$3s \ [1\frac{1}{2}]^\circ$	$\begin{smallmatrix} 2 \\ 1 \end{smallmatrix}$	6477900	$3p' \ ^3P_1$	$2s 2p^6(^2S)3p$	$3p \ ^3P^\circ$	$\begin{smallmatrix} 2 \\ 1 \\ 0 \end{smallmatrix}$	7898300
$3s \ ^1P_1$	$2s^2 2p^5(^2P_{3/2})3s$	$3s' \ [0\frac{1}{2}]^\circ$	$\begin{smallmatrix} 0 \\ 1 \end{smallmatrix}$	6592400	$3p' \ ^1P_1$	$2s 2p^6(^2S)3p$	$3p \ ^1P^\circ$	1	7937100
$3d \ ^3P_1$	$2s^2 2p^5(^2P_{1/2})3d$	$3d \ [0\frac{1}{2}]^\circ$	$\begin{smallmatrix} 0 \\ 1 \end{smallmatrix}$	7124500		Co XIX( $^2P_{1/2}$ )	Limit	-----	[11316400]
$3d \ ^1P_1$	"	$3d \ [1\frac{1}{2}]^\circ$	1	7214000		Co XIX( $^2P_{3/2}$ )	Limit	-----	11437600

April 1947.

## NICKEL

## Ni I

28 electrons

 $Z=28$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^8 4s^2 {}^3F_4$  $\alpha {}^3F_4$  61579  $\text{cm}^{-1}$ 

I. P. 7.633 volts

The analysis is by Russell, who revised and extended the earlier work on this spectrum and published 1071 classified lines in the interval between 1963 Å and 18040 Å. Subsequently, Meggers and Kiess observed the infrared region and classified 39 lines between 8580 Å and 10979 Å. Eighty-one terms are known, and observed intersystem combinations connect the terms of all three multiplicities.

Burns and Sullivan have made accurate measurements with the interferometer, of Ni I lines observed in the vacuum arc between 2173 Å and 8968 Å. Their observations confirm in detail Russell's analysis, as well as the great majority of Ni I lines identified in the solar spectrum from predicted wavelengths. They have "measured by interference some four hundred Ni I lines not hitherto observed". From these accurate wavelengths they have derived many improved values of the known energy levels. Their results are recorded in the table except for the levels  $f {}^3P_1$ ,  $e {}^5G_4$ , and  $g {}^5F_5$ , for which the writer has derived the values quoted here. For all remaining levels, Russell's values are given.

Loyarte and Williams have observed the absorption spectrum of nickel and suggested the following rearrangement of nine levels given by Russell:

Loyarte and Williams	Russell	Level	Obs. $g$
$z {}^3D_3$	$1 {}^3D_3$	40361. 24	
$z {}^3D_2$	$y {}^3P_2^o$	42653. 58	
$z {}^3D_1$	$w {}^3D_1^o$	45122. 37	0. 57
$y {}^3\bar{F}_4$	$x {}^3F_4^o$	42584. 87	1. 35
$y {}^3\bar{F}_3$	$x {}^3F_3^o?$	43654. 82	1. 24
$y {}^3\bar{F}_2$	$x {}^1D_2^o$	43933. 39	1. 48
$x {}^3\bar{F}_4$	$x {}^3D_3^o$	42620. 94	
$x {}^3\bar{F}_3$	$w {}^3D_3^o$	42767. 79	1. 22
$x {}^3\bar{F}_2$	$x {}^3D_2^o$	42954. 77	0. 840

The observed  $g$ -value for the level at 43933 fits neither designation. The observed combinations confirm  $J=3$  for the level at 42620. The intensity behavior in the multiplets supports Russell's assignments, and his interpretation is quoted in the table.

The observed  $g$ -values are chiefly from the paper by Lindsley, but some are from the two other papers quoted for Zeeman effect. A theoretical discussion of some of the configuration assignments is given by Marvin.

## Ni I—Continued

Russell derives the limit  $61579 \text{ cm}^{-1}$  from the  $^3D$  and  $^1D$  terms of the  $3d^9(a^2D)ns$  series [ $n=4,5,6$ ], by using a Ritz formula. He remarks that the  $^3D_3$  and  $^3D_2$  levels evidently converge to the lower component,  $a^2D_{3/2}$ , of the ground term of Ni II; while  $^3D_1$  and  $^1D_2$  converge to  $a^2D_{1/2}$ , which lies  $1507 \text{ cm}^{-1}$  higher. He notes that "The correlation of the term components and their limits is of the inverted type pointed out by Shenstone . . . All the terms arising from the  $a^2D$  limit of Ni II show the same inverted convergence."

In "normal" convergence only *one* level converges to that component of the limit term having the larger  $J$ -value. The *shifting* that occurs when *two* levels converge to this component, etc., as in this case, is referred to as "inverted" convergence.

Racah has pointed out that for levels from the  $3d^9 nx$  configuration, the  $jl$ -coupling notation is preferable, as for the inert gases. This notation can be worked out for Ni I from the auxiliary table given in the text for Cu II.

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## Ni I

## Ni I

Config.	Desig.	$J$	Level	Interval	Obs. $g$	Config.	Desig.	$J$	Level	Interval	Obs. $g$
$3d^8 4s^2$	$a^3F$	4	0.000	—1332.153 —884.366	1.250	$3d^9(a^2D)4p$	$z^3P^\circ$	2	28569.210	—931.480 —691.578	1.485
		3	1332.153		1.083			1	29500.690		1.426
		2	2216.519		0.671			0	30192.268		
$3d^9(a^2D)4s$	$a^3D$	3	204.786	—675.027 —833.267	1.332	$3d^9(a^2D)4p$	$z^3F^\circ$	4	29481.020	160.238 —1298.658	1.287
		2	879.813		1.149			3	29320.782		1.086
		1	1713.080		0.497			2	30619.440		0.740
$3d^9(a^2D)4s$	$a^1D$	2	3409.925		1.014	$3d^9(a^2D)4p$	$z^3D^\circ$	3	29668.918	—219.587 —1024.333	1.300
								2	29888.505		1.044
								1	30912.838		0.552
$3d^8 4s^2$	$b^1D$	2	13521.352		1.143	$3d^8 4s(a^2F)4p$	$z^3G^\circ$	5	30922.763	—57.026 —806.421	1.21
$3d^{10}$	$a^1S$	0	14728.847					4	30979.789		1.052
$3d^8 4s^2$	$a^3P$	2	15609.861	—124.157 —283.299	1.356			3	31786.210		0.761
		1	15734.018		1.497	$3d^9(a^2D)4p$	$z^1F^\circ$	3	31031.042		1.048
		0	16017.317			$3d^9(a^2D)4p$	$z^1D^\circ$	2	31441.665		1.060
$3d^8 4s^2$	$a^1G$	4	22102.349		0.99	$3d^8 4s(a^2F)4p$	$y^3F^\circ$	4	32973.414	—138.954 —498.548	1.22
								3	33112.368		1.193
								2	33610.916		0.79
$3d^8 4s(a^4F)4p$	$z^5D^\circ$	4	25753.578	—912.325 —748.990 —528.650 —269.454	1.51	$3d^9(a^2D)4p$	$z^1P^\circ$	1	32982.280		1.005
		3	26665.903		1.50						
		2	27414.893		1.49						
		1	27943.543		1.486						
		0	28212.997								
$3d^8 4s(a^4F)4p$	$z^5G^\circ$	6	27260.891	—319.520 —487.680 —509.955 —435.182	1.32	$3d^8 4s(a^2F)4p$	$y^3D^\circ$	3	33500.854	—662.440 —245.280	1.198
		5	27580.411		1.28			2	34163.294		1.19
		4	28068.091		1.171			1	34408.574		0.511
		3	28578.046		0.945						
		2	29013.228		0.364						
$3d^8 4s(a^4F)4p$	$z^5F^\circ$	5	28542.113	—542.365 —748.332 —330.330 —228.912	1.38	$3d^8 4s(a^2F)4p$	$y^1D^\circ$	2	36600.805		1.013
		4	29084.478		1.288						
		3	29832.810		1.208						
		2	30163.140		0.985						
		1	30392.052		0.006						
							$1^\circ$	3	40361.254		
							$2^\circ$	2	40484.282		



## Ni I—Continued

## Ni I—Continued

Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>	Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>
$3d^3 4s(b^2D)4p$	$x^3F^\circ$	4 3 2	42585.296 43654.974?	-1069.678	1.35 1.24	$3d^3(a^2D)4d$	$f^3D$	3 2 1	49271.578 49327.845 50716.927	-56.267 -1389.082	1.32 0.45
$3d^3(a^2D)5s$	$e^3D$	3 2 1	42605.964 42790.027 44112.192	-184.063 -1322.165	1.34 1.085	$3d^3(a^2D)5p$	$u^3D^\circ$	3 2 1	49327.56 49185.146 50851.22	142.41 -1666.07	
$3d^3 4s(b^2D)4p$	$x^3D^\circ$	3 2 1	42621.048 42954.234	-333.186	0.840	$3d^3(a^2D)4d$	$e^3F$	4 3 2	49332.643 49313.851 50834.435	18.792 -1520.584	
$3d^3 4s(b^2D)4p$	$y^3P^\circ$	2 1 0	42653.723 42656.317	-2.594	1.32	$3d^3(a^2D)5p$	$w^1F^\circ$	3	50142.8		
						$3d^3(a^2D)5p$	$x^1P^\circ$	1	50458.187		
$3d^3 4s(a^4F)4p$	$w^3D^\circ$	3 2 1	42767.900 44475.158 45122.460	-1707.258 -647.302	1.22 1.16 0.57	$3d^3 4s(a^4F)5s$	$f^3F$	4 3 2	50466.172 51306.085 52040.568	-839.913 -734.483	1.27 1.08
$3d^3 4s(a^4F)4p$	$y^3G^\circ$	5 4 3	43089.636 44314.980 45281.152	-1225.344 -966.172	1.23 1.18 0.78	$3d^3(a^2D)4d$	$e^1P$	1	50536.742		1.54
						$3d^3(a^2D)5p$	$w^1D^\circ$	2	50689.490		
$3d^3 4s(a^4F)4p$	$w^3F^\circ$	4 3 2	43258.792 44565.10 45418.858	-1306.31 -853.76	1.25 1.04 0.68	$3d^3(a^2D)4d$	$e^1G$	4	50706.310		1.02
						$3d^3(a^2D)4d$	$f^1D$	2	50754.137		
$3d^3 4s(b^2D)4p$	$y^1P^\circ$	1	43464.019		1.39	$3d^3 4s(a^2G)4p$	$u^3F^\circ$	4 3 2	50789.5 51124.8 51343.80	-335.3 -219.0	
$3d^3 4s(b^2D)4p$	$x^1D^\circ$	2	43933.428		1.48						
$3d^3 4s(b^2D)4p$	$x^1F^\circ$	3	44206.185			$3d^3(a^2D)4d$	$e^1F$	3	50832.039		
$3d^3(a^2D)5s$	$e^1D$	2	44262.619		1.09	$3d^3(a^2D)4d$	$e^1S$	0	51457.285		
	$3^\circ$		44336.10			$3d^3(a^2D)6s$	$g^3D$	3 2 1	52197.482 52271.716 53703.899	-74.234 -1432.183	
$3d^3 4s(a^4P)4p$	$x^3P^\circ$	2 1 0	46522.965 47208.228 47686.625?	-685.263 -478.397		$3d^3(a^2D)6s$	$g^1D$	2	53754.036		
$3d^3 4s(a^4P)4p$	$v^3D^\circ$	3 2 1	47030.148 47139.392 47424.830	-109.244 -285.438	1.331 1.209 0.726	$3d^3 4s(a^2F)5s$	$g^3F$	4 3 2	54237.136 54251.353 55873.78	-14.217 -1622.43	1.27
	$4^\circ$	2	47328.85			$3d^3(a^2D)5d$	$f^3S$	1	54574.64		
$3d^3 4s(a^4F)5s$	$e^5F$	5 4 3 2 1	48466.530 49086.030 49777.619 50346.477 50744.593	-619.500 -691.589 -568.858 -398.116	1.40 1.33 1.23 0.95 0.07	$3d^3(a^2D)5d$	$f^3G$	5 4 3	54659.759 54667.928 56172.704	-8.169 -1504.776	1.03
						$3d^3(a^2D)5d$	$h^3D$	3 2 1	54699.852 54732.425?	-32.573	
$3d^3(a^2D)5p$	$v^3F^\circ$	4 3 2	48715.2 48671.9 50039.18	43.3 -1367.3		$3d^3(a^2D)5d$	$h^3F$	4 3 2	54761.346 54772.940 56274.516	-11.594 -1501.576	
$3d^3(a^2D)5p$	$w^3P^\circ$	2 1 0	48735.308 49403.42 50138.53	-668.11 -735.11		$3d^3 4s(a^2F)5s$	$f^1F$	3	55576.905		
	$5^\circ$	2, 1	48817.6			$3d^3(a^2D)5d$	$f^1G$	4	56183.51		
$3d^3(a^2D)4d$	$e^3S$	1	48953.344		1.92	$3d^3(a^2D)5d$	$g^1F$	3	56262.92		
	$6^\circ$	3	49032.589			$3d^3 4s(a^4F)4d$	$e^3H$	6 5 4	56624.668 57677.649 58518.11	-1052.981 -840.46	
$3d^3(a^2D)4d$	$e^3G$	5 4 3	49158.529 49174.811 50677.599	-16.282 -1502.788	1.20 1.05 0.77	$3d^3 4s(a^4F)4d$	$f^3P$	2 1 0	56710.889 57767.52 58448.79	-1056.63 -681.27	
$3d^3(a^2D)4d$	$e^3P$	2 1 0	49159.060 49171.187 50276.354	-12.127 -1105.167	1.43 1.00	$3d^3 4s(a^4F)4d$	$i^3F$	4 3 2	56766.523 57968.08 58629.84	-1201.56 -661.76	

## Ni I—Continued

Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>
$3d^8 4s(a^4F)4d$	$g^3G$	5 4 3	56801.654 57789.611 58530.35	—987.957 —740.74	
$3d^8 4s(a^4F)4d$	$e^5P$	3 2 1	56821.553 57586.7 58525.507	—765.1 —938.8	
$3d^8 4s(a^4F)4d$	$e^5D$	4 3 2 1 0	56857.933 57743.596	—885.663	
$3d^8 4s(a^4F)4d$	$e^5H$	7 6 5 4 3	56885.249 57762.106 58520.923 59039.693 59188.78	—876.857 —758.817 —518.770 —149.09	1.26
$3d^8 4s(a^4F)4d$	$e^5G$	6 5 4 3 2	56954.167 57829.405 58872.57 58629.55 59118.06	—875.238 —1043.16 243.02 —488.51	
$3d^8 4s(a^4F)4d$	$f^5F$	5 4 3 2 1	56973.707 57810.494 58588.168 58992.52 59226.03	—836.787 —777.674 —404.35 —233.51	
$3d^8 4s(a^4F)4d$	$i^3D$	3 2 1	57103.946		
$3d^8 4s(a^4F)6s$	$g^5F$	5 4 3 2 1	59862.69		
Ni II ( $a^2D_{3/2}$ )	<i>Limit</i>	-----	61579		
$3d^8 4s(a^2F)4d$	$j^3F$	4 3 2	61832.47		
$3d^8 4s(a^2F)4d$	$h^3G$	5 4 3	61843.28		
$3d^8 4s(a^2F)4d$	$f^3H$	6 5 4	61957.517		
$3d^8 4s(a^4F)5d$	$f^5H$	7 6 5 4 3	62782.614		
$3d^8 4s(a^4F)5d$	$f^5G$	6 5 4 3 2	62808.03		
$3d^8 4s(a^4F)5d$	$h^5F$	5 4 3 2 1	62815.34?		

## Ni I OBSERVED TERMS\*

Config.	Observed Terms		
$1s^2 2s^2 2p^6 3s^2 3p^6 +$			
$3d^8 4s^2$	$\left\{ \begin{array}{l} a^3P \\ a^1S \end{array} \right.$	$a^3F \quad a^1G$	
$3d^{10}$			
$3d^9(a^2D)nx$	$\left\{ \begin{array}{l} a, e, g^3D \\ a, e, g^1D \end{array} \right.$	$b^1D$	$ns (n \geq 4)$
$3d^8 4s(a^4F)nx$	$\left\{ \begin{array}{l} e, g^5F \\ f^3F \end{array} \right.$		$np (n \geq 4)$
$3d^8 4s(a^2F)nx$	$\left\{ \begin{array}{l} g^3F \\ f^1F \end{array} \right.$		$nd (n \geq 4)$
$3d^8 4s(b^2D)nx$			
$3d^8 4s(a^4P)nx$			
$3d^8 4s(a^2G)nx$			

\*For predicted terms in the spectra of the Ni I isoelectronic sequence, see Vol. II, Introduction.



## Ni II

(Co I sequence; 27 electrons)

 $Z=28$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^9 {}^2D_{3/2}$  $a {}^2D_{3/2}$  146408  $\text{cm}^{-1}$ 

I. P. 18.15 volts

The analysis is chiefly by Shenstone who has classified 242 lines in the interval from 1812 Å to 4362 Å, from measurements by Meggers between 3500 Å and 2150 Å, supplemented by his own observations in the short wave region. Further observations in the ultraviolet were needed to locate the ground term,  $a {}^2D$ . This term was found independently by both Lang and Menzies, who classified about 50 lines between 1252 Å and 1952 Å. The discovery of this term indicated that 8391  $\text{cm}^{-1}$  (Lang) or 8392.9 (Menzies) should be added to all of Shenstone's values. An improved value by Shenstone, 8394.1, has been adopted here.

Intersystem combinations connecting the doublet and quartet systems of terms, have been observed.

Shenstone has calculated the limit from the two levels  $a, e {}^4F_{4/2}$ , by assuming a Rydberg series. This is known to be too high. The correction derived from longer series in related spectra has been estimated by H. N. Russell as about  $-2792 \text{ cm}^{-1}$ . This adjustment has been made in the limit quoted here.

The listed  $g$ -values are from Lindsley; they are derived from measurements of Zeeman patterns of 128 lines observed at the Massachusetts Institute of Technology.

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## Ni II

## Ni II

Shenstone	Config.	Desig.	$J$	Level	Interval	Obs. $g$	Shenstone	Config.	Desig.	$J$	Level	Interval	Obs. $g$
	$3d^9$	$a {}^2D$	$2\frac{1}{2}$ $1\frac{1}{2}$	0. 0 1506. 9	—1506. 9		$a {}^4D'_{3/2}$ $a {}^4D'_{5/2}$ $a {}^4D'_{7/2}$ $a {}^4D'_{9/2}$	$3d^8({}^3F)4p$	$z {}^4D^\circ$	$3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	51558. 1 52738. 6 53635. 1 54176. 1	—1180. 5 —896. 5 —541. 0	1. 420 1. 356 1. 186 —0. 005
$a {}^4F'_5$ $a {}^4F'_4$ $a {}^4F'_3$ $a {}^4F'_2$	$3d^8({}^3F)4s$	$a {}^4F$	$4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$	8394. 1 9330. 5 10115. 9 10664. 2	—936. 4 —785. 4 —548. 3	1. 35 1. 24 1. 023 0. 397	$a {}^4G'_6$ $a {}^4G'_5$ $a {}^4G'_4$ $a {}^4G'_3$	$3d^8({}^3F)4p$	$z {}^4G^\circ$	$5\frac{1}{2}$ $4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$	53496. 8 53365. 2 54262. 7 55018. 8	131. 6 —897. 5 —756. 1	1. 305 1. 156 1. 02 0. 616
$a {}^2F'_4$ $a {}^2F'_3$	$3d^8({}^3F)4s$	$a {}^2F$	$3\frac{1}{2}$ $2\frac{1}{2}$	13550. 3 14995. 6	—1445. 3	1. 141 0. 866	$a {}^4F_5$ $a {}^4F_4$ $a {}^4F_3$ $a {}^4F_2$	$3d^8({}^3F)4p$	$z {}^4F^\circ$	$4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$	54557. 3 55417. 9 56075. 2 56424. 6	—860. 6 —657. 3 —349. 4	1. 26 1. 184 0. 985 0. 412
$a {}^2D_3$ $a {}^2D_2$	$3d^8({}^1D)4s$	$b {}^2D$	$2\frac{1}{2}$ $1\frac{1}{2}$	23108. 1 23796. 1	—688. 0	1. 428 1. 045	$a {}^2G'_5$ $a {}^2G'_4$	$3d^8({}^3F)4p$	$z {}^2G^\circ$	$4\frac{1}{2}$ $3\frac{1}{2}$	55300. 0 56371. 6	—1071. 6	1. 152 0. 940
$a {}^4P'_1$ $a {}^4P'_2$ $a {}^4P'_3$	$3d^8({}^3P)4s$	$a {}^4P$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$	24835. 9 24788. 1 25035. 8	—47. 8 247. 7	2. 667 1. 498 1. 368	$a {}^2F_4$ $a {}^2F_3$	$3d^8({}^3F)4p$	$z {}^2F^\circ$	$3\frac{1}{2}$ $2\frac{1}{2}$	57080. 3 58493. 0	—1412. 7	1. 154 0. 946
$a {}^2P'_2$ $a {}^2P'_1$	$3d^8({}^3P)4s$	$a {}^2P$	$1\frac{1}{2}$ $0\frac{1}{2}$	29070. 6 29593. 1	—522. 5	1. 322 0. 670	$a {}^2D'_3$ $a {}^2D'_2$	$3d^8({}^3F)4p$	$z {}^2D^\circ$	$2\frac{1}{2}$ $1\frac{1}{2}$	57419. 7 58705. 6	—1285. 9	1. 116 0. 795
$a {}^2G_5$ $a {}^2G_4$	$3d^8({}^1G)4s$	$a {}^2G$	$4\frac{1}{2}$ $3\frac{1}{2}$	32499. 4 32523. 4	—24. 0	1. 135 0. 895							



Ni II—Continued

Ni II—Continued

Shen-stone	Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>	Shen-stone	Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>
<i>b</i> <sup>4</sup> P <sub>3</sub> <i>b</i> <sup>4</sup> P <sub>2</sub> <i>b</i> <sup>4</sup> P <sub>1</sub>	3 <i>d</i> <sup>8</sup> ( <sup>3</sup> P)4 <i>p</i>	<i>z</i> <sup>4</sup> P°	2½ 1½ 0½	66570. 9 66579. 5 67030. 7	—8. 6 —451. 2	1. 48 1. 550 2. 331	<i>c</i> <sup>2</sup> S' <sub>1</sub> <i>b</i> <sup>4</sup> S' <sub>2</sub>	3 <i>d</i> <sup>8</sup> ( <sup>3</sup> P)4 <i>p</i> 3 <i>d</i> <sup>8</sup> ( <sup>3</sup> P)4 <i>p</i>	<i>z</i> <sup>2</sup> S° <i>z</i> <sup>4</sup> S°	0½ 1½	74283. 0 74300. 3		
<i>b</i> <sup>2</sup> F <sub>3</sub> <i>b</i> <sup>2</sup> F <sub>4</sub>	3 <i>d</i> <sup>8</sup> ( <sup>1</sup> D)4 <i>p</i>	<i>y</i> <sup>2</sup> F°	2½ 3½	67694. 2 68131. 0	436. 8	0. 960 1. 200	<i>b</i> <sup>2</sup> H <sub>5</sub> <i>b</i> <sup>2</sup> H <sub>6</sub>	3 <i>d</i> <sup>8</sup> ( <sup>1</sup> G)4 <i>p</i>	<i>z</i> <sup>2</sup> H°	4½ 5½	75149. 6 75721. 6	572. 0	0. 903 1. 119
<i>b</i> <sup>2</sup> D' <sub>2</sub> <i>b</i> <sup>2</sup> D <sub>3</sub>	3 <i>d</i> <sup>8</sup> ( <sup>1</sup> D)4 <i>p</i>	<i>y</i> <sup>2</sup> D°	1½ 2½	68154. 1 68735. 3	581. 2	1. 02 1. 26	<i>c</i> <sup>2</sup> F <sub>3</sub> <i>c</i> <sup>2</sup> F <sub>4</sub>	3 <i>d</i> <sup>8</sup> ( <sup>1</sup> G)4 <i>p</i>	<i>x</i> <sup>2</sup> F°	2½ 3½	75889. 5? 75917. 3?	27. 8	1. 16
<i>b</i> <sup>2</sup> P <sub>1</sub> <i>b</i> <sup>2</sup> P <sub>2</sub>	3 <i>d</i> <sup>8</sup> ( <sup>1</sup> D)4 <i>p</i>	<i>z</i> <sup>2</sup> P°	0½ 1½	68281. 4 68965. 5	684. 1	1. 008 1. 305	<i>b</i> <sup>2</sup> G' <sub>4</sub> <i>b</i> <sup>2</sup> G <sub>5</sub>	3 <i>d</i> <sup>8</sup> ( <sup>1</sup> G)4 <i>p</i>	<i>y</i> <sup>2</sup> G°	3½ 4½	79822. 7 79923. 8	101. 1	
<i>b</i> <sup>4</sup> D' <sub>1</sub> <i>b</i> <sup>4</sup> D' <sub>2</sub> <i>b</i> <sup>4</sup> D' <sub>3</sub> <i>b</i> <sup>4</sup> D' <sub>4</sub>	3 <i>d</i> <sup>8</sup> ( <sup>3</sup> P)4 <i>p</i>	<i>y</i> <sup>4</sup> D°	0½ 1½ 2½ 3½	70748. 5 70706. 6 70635. 2 70777. 4	—41. 9 —71. 4 142. 2	1. 190 1. 32 1. 38	<i>d</i> <sup>4</sup> F' <sub>5</sub> <i>d</i> <sup>4</sup> F' <sub>4</sub> <i>d</i> <sup>4</sup> F' <sub>3</sub> <i>d</i> <sup>4</sup> F' <sub>2</sub>	3 <i>d</i> <sup>8</sup> ( <sup>3</sup> F)5 <i>s</i>	<i>e</i> <sup>4</sup> F	4½ 3½ 2½ 1½	91798. 5 92323. 9 93388. 0 94065. 1	—525. 4 —1064. 1 —677. 1	1. 350 1. 188 1. 02 0. 39
<i>c</i> <sup>2</sup> D' <sub>3</sub> <i>c</i> <sup>2</sup> D <sub>2</sub>	3 <i>d</i> <sup>8</sup> ( <sup>3</sup> P)4 <i>p</i>	<i>x</i> <sup>2</sup> D°	2½ 1½	71770. 9 72375. 1	—604. 2	1. 240 0. 844	<i>d</i> <sup>2</sup> F' <sub>4</sub> <i>d</i> <sup>2</sup> F' <sub>3</sub>	3 <i>d</i> <sup>8</sup> ( <sup>3</sup> F)5 <i>s</i>	<i>e</i> <sup>2</sup> F	3½ 2½	93526. 3 94727. 1	—1200. 8	1. 166 0. 865
<i>c</i> <sup>2</sup> P <sub>2</sub> <i>c</i> <sup>2</sup> P <sub>1</sub>	3 <i>d</i> <sup>8</sup> ( <sup>3</sup> P)4 <i>p</i>	<i>y</i> <sup>2</sup> P°	1½ 0½	72985. 2 73902. 7	—917. 5	1. 326 1. 039		Ni III ( <sup>3</sup> F <sub>4</sub> )	<i>Limit</i>	----	146408		

October 1949.

Ni II OBSERVED TERMS\*

Config. 1 <i>s</i> <sup>2</sup> 2 <i>s</i> <sup>2</sup> 2 <i>p</i> <sup>6</sup> 3 <i>s</i> <sup>2</sup> 3 <i>p</i> <sup>6</sup> +	Observed Terms	
3 <i>d</i> <sup>9</sup>	<i>a</i> <sup>2</sup> D	
	<i>ns</i> ( <i>n</i> ≥ 4)	<i>np</i> ( <i>n</i> ≥ 4)
	$\left\{ \begin{array}{l} a, e \text{ } ^4\text{F} \\ a, e \text{ } ^2\text{F} \end{array} \right.$	$\begin{array}{lll} z \text{ } ^4\text{D}^\circ & z \text{ } ^4\text{F}^\circ & z \text{ } ^4\text{G}^\circ \\ z \text{ } ^2\text{D}^\circ & z \text{ } ^2\text{F}^\circ & z \text{ } ^2\text{G}^\circ \end{array}$
3 <i>d</i> <sup>8</sup> ( <sup>3</sup> F) <i>nx</i>		
3 <i>d</i> <sup>8</sup> ( <sup>3</sup> P) <i>nx</i>	$\left\{ \begin{array}{l} a \text{ } ^4\text{P} \\ a \text{ } ^2\text{P} \end{array} \right.$	$\begin{array}{lll} z \text{ } ^4\text{S}^\circ & z \text{ } ^4\text{P}^\circ & y \text{ } ^4\text{D}^\circ \\ z \text{ } ^2\text{S}^\circ & y \text{ } ^2\text{P}^\circ & x \text{ } ^2\text{D}^\circ \end{array}$
3 <i>d</i> <sup>8</sup> ( <sup>1</sup> G) <i>nx</i>	<i>a</i> <sup>2</sup> G	$\begin{array}{lll} & x \text{ } ^2\text{F}^\circ & y \text{ } ^2\text{G}^\circ & z \text{ } ^2\text{H}^\circ \end{array}$
3 <i>d</i> <sup>8</sup> ( <sup>1</sup> D) <i>nx</i>	<i>b</i> <sup>2</sup> D	$\begin{array}{lll} z \text{ } ^2\text{P}^\circ & y \text{ } ^2\text{D}^\circ & y \text{ } ^2\text{F}^\circ \end{array}$

\*For predicted terms in the spectra of the Co I isoelectronic sequence, see Vol. II, Introduction.

## Ni III

(Fe I sequence; 26 electrons) \*

 $Z=28$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^8 {}^3F_4$  $a {}^3F_4$  283700  $\text{cm}^{-1}$ 

I. P. 36.16 volts

This spectrum has been analyzed by Shenstone especially for inclusion here. His observations cover the range 700 Å to 3000 Å. There are 165 classified lines, and the triplet and quintet terms are connected by observed intersystem combinations.

Shenstone has determined the limit from the  $ns {}^5F$  series ( $n=4,5$ ) by using a Ritz formula and assuming  $\alpha=0.17 \times 10^{-6}$ , to be 284400  $\text{cm}^{-1}$ . From a study of isoelectronic data Catalán has derived an improved value, which is quoted here.

## REFERENCES

A. G. Shenstone, unpublished material (May 1950). (I P) (T) (C L)

M. A. Catalán, unpublished material (April 1952). (I P).

## Ni III

## Ni III

Config.	Desig.	<i>J</i>	Level	Interval	Config.	Desig.	<i>J</i>	Level	Interval
3 <i>d</i> <sup>8</sup>	<i>a</i> <sup>3</sup> F	4	0. 0		3 <i>d</i> <sup>7</sup> ( <sup>4</sup> F)4 <i>p</i>	<i>z</i> <sup>3</sup> D°	3	118745. 7	
		3	1360. 7	−1360. 7			2	119670. 0	−924. 3
		2	2269. 6	−908. 9			1	120272. 7	−602. 7
3 <i>d</i> <sup>8</sup>	<i>a</i> <sup>3</sup> P	2	16661. 6		3 <i>d</i> <sup>7</sup> ( <sup>4</sup> P)4 <i>p</i>	<i>z</i> <sup>5</sup> S°	2	122282. 3	
		1	16977. 8	−316. 2					
		0	17230. 7	−252. 9					
3 <i>d</i> <sup>7</sup> ( <sup>4</sup> F)4 <i>s</i>	<i>a</i> <sup>5</sup> F	5	53703. 7		3 <i>d</i> <sup>7</sup> ( <sup>4</sup> P)4 <i>p</i>	<i>y</i> <sup>5</sup> D°	0		
		4	54657. 9	−954. 2			1	129957. 6	−44. 8
		3	55406. 1	−748. 2			2	129912. 8	41. 1
		2	55952. 0	−545. 9			3	129953. 9	358. 4
		1	56308. 2	−356. 2			4	130312. 3	
3 <i>d</i> <sup>7</sup> ( <sup>4</sup> F)4 <i>s</i>	<i>b</i> <sup>3</sup> F	4	61339. 3		3 <i>d</i> <sup>7</sup> ( <sup>2</sup> G)4 <i>p</i>	1°	5, 4	131500. 3	
		3	62606. 3	−1267. 0			4	131792. 4	−1365. 9
		2	63472. 6	−866. 3			3	133153. 3	−1074. 4
3 <i>d</i> <sup>7</sup> ( <sup>4</sup> P)4 <i>s</i>	<i>a</i> <sup>5</sup> P	3	71067. 0		3 <i>d</i> <sup>7</sup> 4 <i>p</i>	2°	4	132156. 6	
		2	71383. 7	−316. 7					
		1	71841. 9	−458. 2			3°	3	133095. 7
3 <i>d</i> <sup>7</sup> ( <sup>2</sup> G)4 <i>s</i>	<i>a</i> <sup>3</sup> G	5	75123. 8		3 <i>d</i> <sup>7</sup> 4 <i>p</i>	4°	2, 1	133276. 8	
		4	75646. 9	−523. 1					
		3	76237. 8	−590. 9			5°	5, 4	133325. 1
3 <i>d</i> <sup>7</sup> ( <sup>4</sup> P)4 <i>s</i>	<i>b</i> <sup>3</sup> P	2	79143. 3		3 <i>d</i> <sup>7</sup> ( <sup>4</sup> P)4 <i>p</i>	<i>z</i> <sup>5</sup> P°	3	133390. 8	
		1					2	133500. 2	109. 4
		0					1		
3 <i>d</i> <sup>7</sup> ( <sup>4</sup> F)4 <i>p</i>	<i>z</i> <sup>5</sup> F°	5	110212. 4		3 <i>d</i> <sup>7</sup> ( <sup>2</sup> G)4 <i>p</i>	<i>y</i> <sup>3</sup> G°	5	133691. 8	
		4	110371. 1	−158. 7			4	134415. 4	−723. 6
		3	111220. 9	−849. 8			3		
		2	111914. 1	−693. 2					
		1	112401. 5	−487. 4					
3 <i>d</i> <sup>7</sup> ( <sup>4</sup> F)4 <i>p</i>	<i>z</i> <sup>5</sup> D°	4	111898. 5		3 <i>d</i> <sup>7</sup> 4 <i>p</i>	6°	5, 4	134217. 8	
		3	112935. 3	−1036. 8					
		2	113651. 0	−715. 7					
		1	114095. 4	−444. 4					
		0	114295. 2	−199. 8					
3 <i>d</i> <sup>7</sup> ( <sup>4</sup> F)4 <i>p</i>	<i>z</i> <sup>5</sup> G°	6	112787. 4		3 <i>d</i> <sup>7</sup> 4 <i>p</i>	7°	3, 2	134334. 9	
		5	113140. 8	−353. 4					
		4	113705. 0	−564. 2					
		3	114109. 9	−404. 9					
		2	114370. 8	−260. 9					
3 <i>d</i> <sup>7</sup> ( <sup>4</sup> F)4 <i>p</i>	<i>z</i> <sup>5</sup> G°	6	112787. 4		3 <i>d</i> <sup>7</sup> ( <sup>4</sup> F)5 <i>s</i>	<i>e</i> <sup>5</sup> F	5	181018. 7	
		5	113140. 8	−353. 4			4		
		4	113705. 0	−564. 2			3		
		3	114109. 9	−404. 9			2		
		2	114370. 8	−260. 9			1		
3 <i>d</i> <sup>7</sup> ( <sup>4</sup> F)4 <i>p</i>	<i>z</i> <sup>3</sup> G°	5	115272. 5		3 <i>d</i> <sup>7</sup> ( <sup>4</sup> F)5 <i>s</i>	<i>e</i> <sup>3</sup> F	4	183053. 1	
		4	116674. 5	−1402. 0			3		
		3	117543. 1	−868. 6			2		
3 <i>d</i> <sup>7</sup> ( <sup>4</sup> F)4 <i>p</i>	<i>z</i> <sup>3</sup> F°	4	116192. 1	−1058. 9	Ni IV( <sup>4</sup> F <sub>4/2</sub> )	<i>Limit</i>	-----	283700	-----
3	117251. 0	−864. 3							
2	118115. 3								

March 1951.

Ni III OBSERVED TERMS\*

Config. 1s <sup>2</sup> 2s <sup>2</sup> 2p <sup>6</sup> 3s <sup>2</sup> 3p <sup>6</sup> +	Observed Terms	
3d <sup>8</sup>	a <sup>3</sup> P    a <sup>3</sup> F	
	ns (n ≥ 4)	np (n ≥ 4)
	$\left\{ \begin{array}{l} a, e^5F \\ b, e^3F \end{array} \right.$	$\begin{array}{ccc} z^5D^\circ & z^5F^\circ & z^5G^\circ \\ z^3D^\circ & z^3F^\circ & z^3G^\circ \end{array}$
3d <sup>7</sup> ( <sup>4</sup> F)nx	$\left\{ \begin{array}{l} a^5P \\ b^3P \end{array} \right.$	$\begin{array}{ccc} z^5S^\circ & z^5P^\circ & y^5D^\circ \end{array}$
3d <sup>7</sup> ( <sup>4</sup> P)nx		
3d <sup>7</sup> ( <sup>2</sup> G)nx	a <sup>3</sup> G	$\begin{array}{cc} y^3F^\circ & y^3G^\circ \end{array}$

\*For predicted terms in the spectra of the Fe I isoelectronic sequence, see Vol. II, Introduction.

Ni V

(Cr I sequence; 24 electrons) Z=28

Ground state 1s<sup>2</sup> 2s<sup>2</sup> 2p<sup>6</sup> 3s<sup>2</sup> 3p<sup>6</sup> 3d<sup>6</sup> <sup>5</sup>D<sub>4</sub>

a <sup>5</sup>D<sub>4</sub>                      cm<sup>-1</sup> I. P.                  volts

From a study of isoelectronic sequence data, and especially by analogy with Fe III, Morell in 1928 classified 10 lines between 1123 Å and 1501 Å as combinations between 3d<sup>5</sup>(<sup>6</sup>S)4s<sup>7</sup>·<sup>5</sup>S and 3d<sup>5</sup>(<sup>6</sup>S)4p <sup>7</sup>·<sup>5</sup>P°. The present detailed analysis of Fe III indicates the urgent need of further investigation of the Ni V spectrum.

REFERENCE

L. Morell, Thesis (unpublished) Cornell University (1928). (T) (C L)  
January 1950.

Ni VI

(V I sequence; 23 electrons) Z=28

Ground state 1s<sup>2</sup> 2s<sup>2</sup> 2p<sup>6</sup> 3s<sup>2</sup> 3p<sup>6</sup> 3d<sup>5</sup> <sup>6</sup>S<sub>2½</sub>

a <sup>6</sup>S<sub>2½</sub>                      cm<sup>-1</sup> I. P.                  volts

This spectrum is very incompletely known. In 1931 Miss Gilroy published 6 terms, and 25 classified lines between 844 Å and 1191 Å. Later, Kruger and Gilroy classified three lines as transitions from the ground term to 3d<sup>4</sup> 4p <sup>6</sup>P° as follows:

Int.	I. A.	Wave No.	Desig.
400	260. 348	384101	3d <sup>5</sup> <sup>6</sup> S <sub>2½</sub> —4p <sup>6</sup> P <sub>3½</sub>
300	260. 591	383743	3d <sup>5</sup> <sup>6</sup> S <sub>2½</sub> —4p <sup>6</sup> P <sub>2½</sub>
250	260. 713	383564	3d <sup>5</sup> <sup>6</sup> S <sub>2½</sub> —4p <sup>6</sup> P <sub>1½</sub>

The later work indicates that the terms published in 1931 need revision.

REFERENCES

H. T. Gilroy, Phys. Rev. **38**, 2217 (1931). (T) (CL)  
P. G. Kruger and H. T. Gilroy, Phys. Rev. **48**, 720 (1935). (T) (C L)  
January 1950.



## Ni VII

(Ti I sequence; 22 electrons)

 $Z=28$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^4 {}^5D_0$  $a {}^5D_0$        $\text{cm}^{-1}$ 

I. P.      volts

The analysis is incomplete. Phillips and Kruger have classified 92 lines in the range between 205 Å and 229 Å. Intersystem combinations connecting the triplet and quintet systems of terms have been observed. No series have been found.

## REFERENCE

L. W. Phillips and P. G. Kruger, Phys. Rev. **54**, 839 (1938). (T) (C L)

## Ni VII

## Ni VII

Config.	Desig.	$J$	Level	Interval	Config.	Desig.	$J$	Level	Interval
$3d^4$	$a {}^5D$	0	0		$3d^3(a {}^4F)4p$	$z {}^5F^\circ$	1	469191	
		1	275	275			2	470075	884
		2	802	527			3	471115	1040
		3	1520	718			4	472074	959
		4	2379	859			5	472930	856
$3d^4$	$a {}^3P$	0	29334		$3d^3(a {}^4F)4p$	$z {}^3D^\circ$	1	470528	
		1	31100	1766			2	471258	730
		2	33706	2606			3	472514	1256
$3d^4$	$a {}^3H$	4	31052		$3d^3(a {}^4F)4p$	$z {}^3G^\circ$	3	475657	
		5	31668	616			4	476659	1002
		6	32267	599			5	477936	1277
$3d^4$	$a {}^3F$	2	33592		$3d^3(a {}^4F)4p$	$z {}^3F^\circ$	2	479348	
		3	33705	113			3	480494	1146
		4	33961	256			4	481639	1145
$3d^4$	$a {}^3G$	3	37551		$3d^3(a {}^4P)4p$	$z {}^3P^\circ$	1	486170	
		4	38141	590			2	487228	1058
		5	38638	497			3	488673	1445
$3d^4(a {}^4F)4p$	$z {}^5D^\circ$	0			$3d^3(a {}^2G)4p$	$y {}^3G^\circ$	3	493139	
		1	467048				4	494496	1357
		2	467730	682			5	495747	1251
		3	468717	987	$3d^3(a {}^2H)4p$	$x {}^3G^\circ$	5	510873	
		4	469870	1153			4	511101	-228
							3	511402	-301

January 1949.

## Ni VII OBSERVED TERMS\*

Config. $1s^2 2s^2 2p^6 3s^2 3p^6 +$	Observed Terms
$3d^4$	$\left\{ \begin{array}{ccccc} a^3P & a^5D & a^3F & a^3G & a^3H \end{array} \right.$
	$np \ (n \geq 4)$
$3d^3 (a^4F) \ nx$	$\left\{ \begin{array}{ccc} z^5D^\circ & z^5F^\circ & \\ z^3D^\circ & z^3F^\circ & z^3G^\circ \end{array} \right.$
$3d^3 (a^4P) \ nx$	$z^5P^\circ$
$3d^3 (a^2G) \ nx$	$y^3G^\circ$
$3d^3 (a^2H) \ nx$	$x^3G^\circ$

\*For predicted terms in the spectra of the Ti I isoelectronic sequence, see Vol. I, p. xxxvii.

## Ni VIII

(Sc I sequence; 21 electrons)

$Z=28$

Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^3 {}^4F_{1\frac{1}{2}}$

$a^4F_{1\frac{1}{2}}$        $\text{cm}^{-1}$

I. P.      volts

The analysis is by Anderson and Mack, who have classified 132 lines in the region between 530 Å and 611 Å. They have been unable to locate with certainty the  ${}^2P$  term having the configuration  $3d^3$ , but suggest tentatively for this term two possible pairs of levels whose reality is not yet established, as follows:

$J$	Level	
$1\frac{1}{2}$	31515?	32261?
$0\frac{1}{2}$	32089?	32939?

Intersystem combinations connecting the doublet and quartet systems of terms have been observed.

## REFERENCE

E. E. Anderson and J. E. Mack, Phys. Rev. **59**, 717 (1941). (T) (C L)

## Ni VIII

## Ni VIII

Config.	Desig.	<i>J</i>	Level	Interval	Config.	Desig.	<i>J</i>	Level	Interval
$3d^3$	$a^4F$	$1\frac{1}{2}$	0		$3d^2(a^3F)4p$	$z^2D^\circ$	$1\frac{1}{2}$	569667	
		$2\frac{1}{2}$	1012	1012			$2\frac{1}{2}$	571845	2178
		$3\frac{1}{2}$	2184	1172	$3d^2(a^3F)4p$	$z^4D^\circ$	$0\frac{1}{2}$	570353	-514
		$4\frac{1}{2}$	3721	1537			$1\frac{1}{2}$	569839	1678
$3d^3$	$a^4P$	$0\frac{1}{2}$	23261				$2\frac{1}{2}$	571517	1810
		$1\frac{1}{2}$	23710	449			$3\frac{1}{2}$	573327	
		$2\frac{1}{2}$	24669	959	$3d^2(a^3F)4p$	$z^2F^\circ$	$2\frac{1}{2}$	570546	
$3d^3$	$a^2G$	$3\frac{1}{2}$	26977				$3\frac{1}{2}$	571804	1258
		$4\frac{1}{2}$	28068	1091	$3d^2(a^3F)4p$	$z^2G^\circ$	$3\frac{1}{2}$	581337	
$3d^3$	$a^2D$	$2\frac{1}{2}$	34689				$4\frac{1}{2}$	583241	1904
		$1\frac{1}{2}$	35120	-431	$3d^2(a^3P)4p$	$z^4S^\circ$	$1\frac{1}{2}$	587305	
$3d^3$	$a^2H$	$4\frac{1}{2}$	36754		$3d^2(a^3P)4p$	$y^4D^\circ$	$0\frac{1}{2}$	590764	
		$5\frac{1}{2}$	37475	721			$1\frac{1}{2}$	592175	1411
$3d^2(a^3F)4p$	$z^4G^\circ$	$2\frac{1}{2}$	565124				$2\frac{1}{2}$	594068	1893
		$3\frac{1}{2}$	566964	1840			$3\frac{1}{2}$	596908	2840
		$4\frac{1}{2}$	569564	2600	$3d^2(a^3P)4p$	$z^4P^\circ$	$0\frac{1}{2}$	596770	
		$5\frac{1}{2}$	572969	3405			$1\frac{1}{2}$	596905?	135
$3d^2(a^3F)4p$	$z^4F^\circ$	$1\frac{1}{2}$	565388				$2\frac{1}{2}$	598570	1665
		$2\frac{1}{2}$	566831	1443	$3d^2(a^1G)4p$	$y^2G^\circ$	$3\frac{1}{2}$	598638	
		$3\frac{1}{2}$	568746	1915			$4\frac{1}{2}$	599079	441
		$4\frac{1}{2}$	570960	2214	$3d^2(a^1G)4p$	$z^2H^\circ$	$4\frac{1}{2}$	613417	
							$5\frac{1}{2}$	615725	2308

December 1948.

## Ni VIII OBSERVED TERMS\*

Config. $1s^2 2s^2 2p^6 3s^2 3p^6 +$	Observed Terms
$3d^3$	$a^4P$ $a^2D$ $a^4F$ $a^2G$ $a^2H$
	$np$ ( $n \geq 4$ )
	$z^4D^\circ$ $z^4F^\circ$ $z^4G^\circ$ $z^2D^\circ$ $z^2F^\circ$ $z^2G^\circ$
$3d^2(a^3F)nx$	
$3d^2(a^3P)nx$	$z^4S^\circ$ $z^4P^\circ$ $y^4D^\circ$
$3d^2(a^1G)nx$	$y^2G^\circ$ $z^2H^\circ$

\*For predicted terms in the spectra of the Sc I isoelectronic sequence, see Vol. I, p. xxxvi.



## Ni IX

(Ca I sequence; 20 electrons)

Z=28

Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^2 {}^3F_2$  $a {}^3F_2$  cm<sup>-1</sup>

I. P. volts

Although 20 lines between 146 Å and 154 Å were reported as classified in 1933, later study of the spectra of this sequence by Edlén indicates that the early interpretation is incorrect.

## REFERENCES

W. M. Cady, Phys. Rev. **43**, 325 (1933). (T) (C L)

B. Edlén, letter (Feb. 1949).

February 1949.

## Ni XII

(Cl I sequence; 17 electrons)

Z=28

Ground state  $1s^2 2s^2 2p^6 3s^2 3p^5 {}^2P_{1/2}$  $3p^5 {}^2P_{1/2}$  cm<sup>-1</sup>

I. P. 350 volts

This spectrum has not been analyzed. Edlén has tentatively attributed the faint coronal line at 4231.4 Å (wave number 23626 cm<sup>-1</sup>) to the transition  $3p^5 {}^2P_{1/2} - 3p^5 {}^2P_{3/2}$  of [Ni XII], since this interval for the ground term is confirmed by extrapolation along the isoelectronic sequence.

## REFERENCE

B. Edlén, Zeit. Astroph. **22**, 32 (1942). (I P) (T) (C L)

January 1948.

## Ni XIII

(Si I sequence; 16 electrons)

Z=28

Ground state  $1s^2 2s^2 2p^6 3s^2 3p^4 {}^3P_2$  $3p^4 {}^3P_2$  cm<sup>-1</sup>

I. P. volts

This spectrum has not been analyzed, but Edlén has calculated the relative positions of the five lowest levels, in his work on the identification of the coronal lines. He has tentatively attributed two coronal lines to [Ni XIII] as follows:

I. A.	Int.	Wave No.	Desig.
3642.9		27443	$3p^4 {}^3P_1 - 3p^4 {}^1D_2$
5116.03	4.3	19541.0	$3p^4 {}^3P_2 - 3p^4 {}^3P_1$

These lines have been used to calculate three levels listed in the table. The remaining two are Edlén's estimated values and are entered in brackets.

## REFERENCE

B. Edlén, Zeit. Astroph. **22**, 47 (1942). (T) (C L)

## Ni xiii

Config.	Desig.	$J$	Level	Interval
$3s^2 3p^4$	$3p^4 {}^4P$	2	0	-19541 [- 659]
		1	19541	
		0	[20200]	
$3s^2 3p^4$	$3p^4 {}^1D$	2	46984	
$3s^2 3p^4$	$3p^4 {}^1S$	0	[97000]	

January 1948.

## Ni xv

(Si i sequence; 14 electrons)

 $Z=28$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^2 {}^3P_0$  $3p^2 {}^3P_0$   $\text{cm}^{-1}$ 

I. P. 455 volts

This spectrum has not been analyzed. Edlén has, however, suggested that two coronal lines may tentatively be ascribed to the [Ni xv] transitions corresponding to the intervals of the ground term. The coronal data are as follows:

I. A.	Int.	Wave No.	Desig.
6701. 83	5. 4	14917. 2	$3p^2 {}^3P_0 - 3p^2 {}^1P_1$
8024. 21	0. 5	12458. 9	$3p^2 {}^3P_1 - 3p^2 {}^1P_2$

The listed term values have been calculated from the coronal wave numbers, except for the last two, which are Edlén's estimated values and are entered in brackets.

Edlén's unit,  $10^3 \text{ cm}^{-1}$ , has here been changed to  $\text{cm}^{-1}$ .

## REFERENCE

B. Edlén, Zeit. Astroph. **22**, 40 (1942). (I P) (T) (C L)

## Ni xv

Config.	Desig.	$J$	Level	Interval
$3s^2 3p^2$	$3p^2 {}^4P$	0	0. 0	14917. 2 12458. 9
		1	14917. 2	
		2	27376. 1	
$3s^2 3p^2$	$3p^2 {}^1D$	2	[62900]	
$3s^2 3p^2$	$3p^2 {}^1S$	0	[100000]	

October 1947.

## Ni xvi

(Al I sequence; 13 electrons)

 $Z=28$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^2 P_{0\frac{1}{2}}^\circ$  $3p^2 P_{0\frac{1}{2}}^\circ$  cm<sup>-1</sup>

I. P. volts

This spectrum has not been analyzed. Edlén has, however, suggested that the faint coronal line at 3601.0 Å, wave number 27762, may be classified as due to the forbidden transition that corresponds to the interval of the ground term of Ni xvi, i. e.,  $3p^2 P_{0\frac{1}{2}}^\circ - 3p^2 P_{1\frac{1}{2}}^\circ$ .

## REFERENCE

B. Edlén, *Zeit. Astroph.* **22**, 47 (1942). (T) (C L)

December 1947.

## Ni xviii

(Na I sequence; 11 electrons)

 $Z=28$ Ground state  $1s^2 2s^2 2p^6 3s^2 S_{\frac{1}{2}}$  $3s^2 S_{0\frac{1}{2}}$  4897400 cm<sup>-1</sup>

I. P. 607 volts

Edlén has classified four lines in the interval 43 Å to 52 Å, and extrapolated the absolute value of the ground term from isoelectronic sequence data.

One term,  $4d^2 D$ , has been calculated from the observed combination with  $3p^2 P^\circ$  listed by Edlén, and added to his published list.

The unit adopted by Edlén, 10<sup>3</sup> cm<sup>-1</sup>, has here been changed to cm<sup>-1</sup>.

## REFERENCE

B. Edlén, *Zeit. Phys.* **100**, 621 (1936). (I P) (T) (C L).

## Ni xviii

Config.	Desig.	$J$	Level	Interval
3s	3s $^2S$	0½	0	
3p	3p $^2P^\circ$	½ 1½	310600 341000	30400
3d	3d $^2D$	1½ 2½	766700 771300	4600
4d	4d $^2D$	1½ 2½	2593000 2595900	2900
4f	4f $^2F^\circ$	2½ 3½	2667400 2668200	800
-----	-----	---	-----	
Ni xix ( $^1S_0$ )	Limit	---	[4897400]	

June 1947.



## COPPER

## Cu I

29 electrons

Z=29

Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 S_{0\frac{1}{2}}$  $4s^2 S_{0\frac{1}{2}}$  62317.2  $\text{cm}^{-1}$ 

I. P. 7.724 volts

The analysis of the arc spectrum of copper affords one of the finest examples of a beautifully complete interpretation of a fairly complex spectrum. Shenstone has verified all of the earlier observations, extended them to include the ultraviolet region, and published a detailed analysis in his 1948 Monograph. This spectrum now furnishes accurate ultraviolet wave lengths for use as standards in investigating other spectra in this region. The number of classified lines totals 732, and the observations extend from 1504 Å to 18229 Å. Many intersystem combinations have been observed, connecting the terms of both multiplicities.

Shenstone remarks that all of the predictable types of electron structure have been identified. To quote, "The spectrum is unique in having many more identified levels above the point of easiest ionization, than below. There are a great many series converging to complex limits and showing various degrees of perturbation". The above limit is from both the  $^2S$  and  $^2D$  doublet series fitted to an extended Ritz formula, the differences in the calculated values being less than  $0.4 \text{ cm}^{-1}$ .

Shenstone (August 1948) calls attention to the important fact that "The  $3d^9 4s ns$  series is of special interest because it is the only known complex series in which individual series can be unambiguously assigned to the components of a limit of greater complexity than a doublet". Whenever he has designated the component of the  $^3D$  term which forms the limit of the separate components of Cu I terms, the  $J$ -value is entered in the configuration column of the table. (Lidén has recently reported a similar case in FI, Ark. Phys. (Stockholm) 1, No. 9, 229, 1949.)

In the term array the writer has tentatively assigned the limits  $^3D$  and  $^1D$  to the appropriate terms having the configuration  $3d^9 4s 4p$ , although Shenstone states that "it appears more reasonable to describe the electron coupling as  $3d^9 ^2D + 4s 4p ^3P, ^1P \dots$ ". He adds that "the arrangement of levels in the next series member,  $3d^9 4s 5p$ , should approach much more closely to a grouping which can be correlated to  $3d^9 4s ^3D, ^1D + p$ ". This is also discussed by Racah.

Shenstone has listed the levels in order of increasing numerical value. In order to conform to the general plan of the present volumes they are here grouped into terms on the basis of his assigned designations. Similarly, in column three under "Desig." the notation adopted for series spectra, and described in detail in Volume I, is entered, but Shenstone's notation is retained in column one.

Zeeman observations of Cu I are limited in both number and accuracy, except for the  $4p ^2P^\circ - 4d ^2D$  multiplet "which has been shown by Green to fit exceptionally well the formulae for the partial Paschen-Back effect developed by Darwin". The writer has derived the following tentative  $g$ -values from published and unpublished observations, using, for blended patterns, the formulae given by Russell, which are an extension of those by Shenstone and Blair. The  $g$ -values given by Sommer are included in the final means. A colon indicates that there is only one or a very weak mean determination of the  $g$ -value. Three place values are from measurements by Kiess who found selected Cu lines as impurities on plates of other spectra taken at Massachusetts Institute of Technology and at the National Bureau of Standards.

## Cu I—Continued

Desig.	<i>J</i>	Obs. <i>g</i>	Desig.	<i>J</i>	Obs. <i>g</i>	Desig.	<i>J</i>	Obs. <i>g</i>
4s <sup>2</sup> S	0½	2. 004	4p' <sup>2</sup> P°	0½ 1½	0. 48 1. 28	7p <sup>2</sup> P°	0½	0. 69:
4s² <sup>2</sup> D	2½ 1½	1. 22 0. 806	4p' <sup>2</sup> D°	1½ 2½	1. 00: 1. 20	5s' <sup>4</sup> D	3½ 0½	1. 42 0. 00
4p <sup>2</sup> P°	0½ 1½	0. 659 1. 338	5p <sup>2</sup> P°	1½	1. 35:	5s' <sup>2</sup> D	2½	1. 27:
4p' <sup>4</sup> P°	2½ 1½ 0½	1. 60 1. 75 2. 63	4d <sup>2</sup> D	1½ 2½	0. 82: 1. 19:	4d' <sup>4</sup> S	1½	1. 74:
4p' <sup>4</sup> F°	4½ 3½ 2½ 1½	1. 34 1. 25 1. 01 0. 43	6s <sup>2</sup> S	0½	1. 99	4d' <sup>2</sup> F	3½	1. 09
4p' <sup>4</sup> D°	3½ 2½ 1½ 0½	1. 45 1. 38 1. 18 0. 10	5d <sup>2</sup> D	1½ 2½	0. 77: 1. 22	4d' <sup>4</sup> G	5½ 4½ 2½	1. 27: 1. 18: 0. 53:
4p' <sup>2</sup> F°	2½ 3½	0. 92: 1. 21	4p'' <sup>2</sup> F°	3½ 2½	1. 14: 0. 84:	4d' <sup>4</sup> D	3½ 2½	1. 44 1. 36
			4p'' <sup>2</sup> P°	1½	1. 27:	4d' <sup>4</sup> F	4½ 3½ 2½	1. 29: 1. 19 1. 05
			4p'' <sup>2</sup> D°	2½	1. 17:	5d' <sup>4</sup> G	5½	1. 27:

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 A. G. Shenstone, Phys. Rev. **28**, 449 (1926). (T) (C L) (Z E)  
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 G. Racah, Phys. Rev. **62**, 525 (1942).  
 A. G. Shenstone, Phil. Trans. Roy. Soc. (London) [A] **241**, No. 832,297 (1948). (I P) (T) (C L) (Z E) (hfs)  
 C. C. Kiess, unpublished material (January 1950). (Z E)

## Cu I

## Cu I

Author	Config.	Desig.	<i>J</i>	Level	Interval	Author	Config.	Desig.	<i>J</i>	Level	Interval
4s <sup>2</sup> S <sub>½</sub>	3d <sup>10</sup> (1S) 4s	4s <sup>2</sup> S	0½	0. 000		z <sup>2</sup> D <sub>½</sub> <sub>½</sub>	3d <sup>9</sup> 4s(3D) 4p	4p' <sup>2</sup> D°	1½ 2½	46172. 842 46598. 34	425. 50
m <sup>2</sup> D <sub>½</sub> <sub>½</sub>	3d <sup>9</sup> 4s²	4s² <sup>2</sup> D	2½ 1½	11202. 565 13245. 423	—2042. 858	5p <sup>2</sup> P <sub>½</sub> <sub>½</sub>	3d <sup>10</sup> (1S) 5p	5p <sup>2</sup> P°	1½ 0½	49382. 95 49383. 26	—0. 31
m <sup>2</sup> D <sub>½</sub> <sub>½</sub>						5p <sup>2</sup> P <sub>½</sub> <sub>½</sub>					
4p <sup>2</sup> P <sub>½</sub> <sub>½</sub>	3d <sup>10</sup> (1S) 4p	4p <sup>2</sup> P°	0½ 1½	30535. 302 30783. 686	248. 384	4d <sup>2</sup> D <sub>½</sub> <sub>½</sub>	3d <sup>10</sup> (1S) 4d	4d <sup>2</sup> D	1½ 2½	49935. 200 49942. 057	6. 857
4p <sup>2</sup> P <sub>½</sub> <sub>½</sub>						4d <sup>2</sup> D <sub>½</sub> <sub>½</sub>					
z <sup>4</sup> F <sub>½</sub> <sub>½</sub>	3d <sup>9</sup> 4s(3D) 4p	4p' <sup>4</sup> P°	2½ 1½ 0½	39018. 652 40113. 99 40943. 73	—1095. 34 —829. 74	6s <sup>2</sup> S	3d <sup>10</sup> (1S) 6s	6s <sup>2</sup> S	0½	52848. 749	
z <sup>4</sup> F <sub>½</sub> <sub>½</sub>						6p <sup>2</sup> P <sub>½</sub> <sub>½</sub>	3d <sup>10</sup> (1S) 6p	6p <sup>2</sup> P°	1½ 0½	54784. 06 55027. 74	—243. 68
z <sup>4</sup> F <sub>½</sub> <sub>½</sub>	3d <sup>9</sup> 4s(3D) 4p	4p' <sup>4</sup> F°	4½ 3½ 2½ 1½	40909. 138 41153. 433 41562. 895 42302. 47	—244. 295 —409. 462 —739. 57	6p <sup>2</sup> P <sub>½</sub> <sub>½</sub>					
z <sup>4</sup> F <sub>½</sub> <sub>½</sub>						5d <sup>2</sup> D <sub>½</sub> <sub>½</sub>	3d <sup>10</sup> (1S) 5d	5d <sup>2</sup> D	1½ 2½	55387. 668 55391. 292	3. 624
z <sup>4</sup> F <sub>½</sub> <sub>½</sub>						5d <sup>2</sup> D <sub>½</sub> <sub>½</sub>					
5s <sup>2</sup> S <sub>½</sub>	3d <sup>10</sup> (1S) 5s	5s <sup>2</sup> S	0½	43137. 209		4f <sup>2</sup> F <sub>½</sub> <sub>½</sub>	3d <sup>10</sup> (1S) 4f	4f <sup>2</sup> F°	3½ 2½	55426. 3 55429. 8	—3. 5
z <sup>4</sup> D <sub>½</sub> <sub>½</sub>	3d <sup>9</sup> 4s(3D) 4p	4p' <sup>4</sup> D°	3½ 2½ 1½ 0½	43513. 95 44406. 268 44544. 153 44915. 61	—892. 32 —137. 885 —371. 46	4f <sup>2</sup> F <sub>½</sub> <sub>½</sub>					
z <sup>4</sup> D <sub>½</sub> <sub>½</sub>						y <sup>2</sup> F <sub>½</sub> <sub>½</sub>	3d <sup>9</sup> 4s(1D) 4p	4p'' <sup>2</sup> F°	3½ 2½	56029. 95 58119. 28	—2089. 33
z <sup>4</sup> D <sub>½</sub> <sub>½</sub>						y <sup>2</sup> F <sub>½</sub> <sub>½</sub>					
z <sup>2</sup> F <sub>½</sub> <sub>½</sub>	3d <sup>9</sup> 4s(3D) 4p	4p' <sup>2</sup> F°	2½ 3½	43726. 191 44963. 223	237. 032	y <sup>2</sup> P <sub>½</sub> <sub>½</sub>	3d <sup>9</sup> 4s(1D) 4p	4p'' <sup>2</sup> P°	1½ 0½	56343. 74 58364. 73	—2020. 99
z <sup>2</sup> F <sub>½</sub> <sub>½</sub>						y <sup>2</sup> P <sub>½</sub> <sub>½</sub>					
z <sup>2</sup> P <sub>½</sub> <sub>½</sub>	3d <sup>9</sup> 4s(3D) 4p	4p' <sup>2</sup> P°	0½ 1½	45821. 00 45879. 311	58. 31	y <sup>2</sup> D <sub>½</sub> <sub>½</sub>	3d <sup>9</sup> 4s(1D) 4p	4p'' <sup>2</sup> D°	2½ 1½	56651. 48 58690. 86	—2039. 38
z <sup>2</sup> P <sub>½</sub> <sub>½</sub>						y <sup>2</sup> D <sub>½</sub> <sub>½</sub>					



## Cu I—Continued

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Author	Config.	Desig.	<i>J</i>	Level	Interval	Author	Config.	Desig.	<i>J</i>	Level	Interval
7s $^2S_{1/2}$	$3d^{10} ({}^1S) 7s$	7s $^2S$	$0\frac{1}{2}$	56671. 387		<i>g</i> $^4S_{1/2}$	$3d^9 4s({}^3D_3) 4d$	$4d' {}^4S$	$1\frac{1}{2}$	70998. 12	
7p $^2P_{1/2}^o$	$3d^{10} ({}^1S) 7p$	7p $^2P^o$	$0\frac{1}{2}$	57419. 31	529. 40	<i>g</i> $^2D_{3/2}$	$3d^9 4s({}^3D_3) 4d$	$4d' {}^2D$	$2\frac{1}{2}$	71098. 17	—1006. 6
7p $^2P_{1/2}^o$			$1\frac{1}{2}$	57948. 71		<i>g</i> $^2D_{1/2}$	$3d^9 4s({}^3D_2) 4d$		$1\frac{1}{2}$	72104. 8	
6d $^2D_{1/2}$	$3d^{10} ({}^1S) 6d$	6d $^2D$	$1\frac{1}{2}$	57893. 05	2. 05	<i>g</i> $^2F_{3/2}$	$3d^9 4s({}^3D_3) 4d$	$4d' {}^2F$	$3\frac{1}{2}$	71127. 81	—1023. 37
6d $^2D_{3/2}$			$2\frac{1}{2}$	57895. 10		<i>g</i> $^2F_{5/2}$	$3d^9 4s({}^3D_2) 4d$		$2\frac{1}{2}$	72151. 18	
5f $^2F_{3/2}^o$	$3d^{10} ({}^1S) 5f$	5f $^2F^o$	$2\frac{1}{2}$	57905. 2	3. 5	<i>g</i> $^4G_{5/2}$	$3d^9 4s({}^3D_3) 4d$	$4d' {}^4G$	$5\frac{1}{2}$	71130. 69	—848. 01
5f $^2F_{3/2}^o$			$3\frac{1}{2}$	57908. 7		<i>g</i> $^4G_{4/2}$	$3d^9 4s({}^3D_2) 4d$		$4\frac{1}{2}$	71978. 70	—1124. 04
8s $^2S_{1/2}$	$3d^{10} ({}^1S) 8s$	8s $^2S$	$0\frac{1}{2}$	58568. 92		<i>g</i> $^4G_{3/2}$	$3d^9 4s({}^3D_1) 4d$		$3\frac{1}{2}$	73102. 74	—95. 97
						<i>g</i> $^4G_{2/2}$	"		$2\frac{1}{2}$	73198. 71	
7d $^2D_{1/2}$	$3d^{10} ({}^1S) 7d$	7d $^2D$	$1\frac{1}{2}$	59249. 46	1. 26	<i>g</i> $^4P_{3/2}$	$3d^9 4s({}^3D_3) 4d$	$4d' {}^4P$	$2\frac{1}{2}$	71178. 19	—749. 03
7d $^2D_{3/2}$			$2\frac{1}{2}$	59250. 72		<i>g</i> $^4P_{1/2}$	$3d^9 4s({}^3D_2) 4d$		$1\frac{1}{2}$	71927. 22	44. 26
						<i>g</i> $^4P_{1/2}$	"		$0\frac{1}{2}$	71882. 96	
8p $^2P_{1/2}^o$	$3d^{10} ({}^1S) 8p$	8p $^2P^o$	$1\frac{1}{2}$	59275. 33	—47. 84	<i>g</i> $^4D_{3/2}$	$3d^9 4s({}^3D_3) 4d$	$4d' {}^4D$	$3\frac{1}{2}$	71268. 21	—798. 76
8p $^2P_{1/2}^o$			$0\frac{1}{2}$	59323. 17		<i>g</i> $^4D_{2/2}$	$3d^9 4s({}^3D_2) 4d$		$2\frac{1}{2}$	72066. 97	—1037. 91
						<i>g</i> $^4D_{1/2}$	$3d^9 4s({}^3D_1) 4d$		$1\frac{1}{2}$	73104. 88	
9s $^2S_{1/2}$	$3d^{10} ({}^1S) 9s$	9s $^2S$	$0\frac{1}{2}$	59647. 88					$0\frac{1}{2}$		
8d $^2D_{1/2}$	$3d^{10} ({}^1S) 8d$	8d $^2D$	$1\frac{1}{2}$	60065. 51	0. 82	<i>g</i> $^4F_{4/2}$	$3d^9 4s({}^3D_3) 4d$	$4d' {}^4F$	$4\frac{1}{2}$	71290. 54	—802. 54
8d $^2D_{3/2}$			$2\frac{1}{2}$	60066. 33		<i>g</i> $^4F_{3/2}$	$3d^9 4s({}^3D_2) 4d$		$3\frac{1}{2}$	72093. 08	—1211. 59
9p $^2P_{1/2}^o$	$3d^{10} ({}^1S) 9p$	9p $^2P^o$	$1\frac{1}{2}$	60070. 6	—14. 6	<i>g</i> $^4F_{2/2}$	$3d^9 4s({}^3D_1) 4d$		$2\frac{1}{2}$	73304. 67	—11. 79
9p $^2P_{1/2}^o$			$0\frac{1}{2}$	60085. 2		<i>g</i> $^4F_{1/2}$	"		$1\frac{1}{2}$	73316. 46	
9d $^2D_{1/2}$	$3d^{10} ({}^1S) 9d$	9d $^2D$	$1\frac{1}{2}$	60594. 53	0. 52	<i>x</i> $^2D_{3/2}$	$3d^9 4s({}^3D) 5p$	$5p' {}^2D^o$	$2\frac{1}{2}$	71745. 5	—278. 7
9d $^2D_{3/2}$			$2\frac{1}{2}$	60595. 05		<i>x</i> $^2D_{1/2}$			$1\frac{1}{2}$	72024. 2?	
10p $^2P_{1/2}^o$	$3d^{10} ({}^1S) 10p$	10p $^2P^o$	$1\frac{1}{2}$	60595. 0	—6. 9	<i>x</i> $^2P_{1/2}$	$3d^9 4s({}^3D) 5p$	$5p' {}^2P^o$	$0\frac{1}{2}$		
10p $^2P_{1/2}^o$			$0\frac{1}{2}$	60601. 9					$1\frac{1}{2}$	71917 ?	
10d $^2D_{1/2}$	$3d^{10} ({}^1S) 10d$	10d $^2D$	$1\frac{1}{2}$	60956. 92	0. 43	<i>i</i> $^4D_{3/2}$	$3d^9 4s({}^3D_3) 6s$	$6s' {}^4D$	$3\frac{1}{2}$	73995. 15	—317. 76
10d $^2D_{3/2}$			$2\frac{1}{2}$	60957. 35		<i>i</i> $^4D_{2/2}$	"		$2\frac{1}{2}$	74312. 91	—730. 70
						<i>i</i> $^4D_{1/2}$	$3d^9 4s({}^3D_2) 6s$		$1\frac{1}{2}$	75043. 61	—1020. 76
11p $^2P^o$	$3d^{10} ({}^1S) 11p$	11p $^2P^o$	$\left\{ \begin{smallmatrix} 1\frac{1}{2} \\ 0\frac{1}{2} \end{smallmatrix} \right\}$	60958		<i>i</i> $^4D_{1/2}$	$3d^9 4s({}^3D_1) 6s$		$0\frac{1}{2}$	76064. 37	
	$3d^{10} ({}^1S) 11d$	11d $^2D$	$1\frac{1}{2}$	61215. 59		<i>w</i> $^2P_{1/2}^o$	$3d^9 4s({}^1D) 5p$	$5p'' {}^2P^o$	$1\frac{1}{2}$	74259. 5?	—831. 1
			$2\frac{1}{2}$			<i>w</i> $^2P_{1/2}^o$			$0\frac{1}{2}$	75090. 6?	
	Cu II ( ${}^1S_0$ )	Limit	----	62317. 2		<i>w</i> $^2F_{3/2}^o$	$3d^9 4s({}^1D) 5p$	$5p'' {}^2F^o$	$3\frac{1}{2}$	74341. 9	—581. 8
						<i>w</i> $^2F_{3/2}^o$			$2\frac{1}{2}$	74923. 7?	
<i>e</i> $^4D_{3/2}$	$3d^9 4s({}^3D_3) 5s$	$5s' {}^4D$	$3\frac{1}{2}$	62403. 320	—544. 97	<i>w</i> $^2D^o$	$3d^9 4s({}^1D) 5p$	$5p'' {}^2D^o$	$\left\{ \begin{smallmatrix} 2\frac{1}{2} \\ 1\frac{1}{2} \end{smallmatrix} \right\}$	74507. 6?	
<i>e</i> $^4D_{2/2}$	"		$2\frac{1}{2}$	62948. 29	—636. 28	<i>h</i> $^2P_{1/2}$	$3d^9 4s({}^1D) 4d$	$4d'' {}^2P$	$0\frac{1}{2}$	75109. 46	153. 99
<i>e</i> $^4D_{1/2}$	$3d^9 4s({}^3D_2) 5s$		$1\frac{1}{2}$	63584. 57	—887. 73	<i>h</i> $^2P_{1/2}$			$1\frac{1}{2}$	75263. 45	
<i>e</i> $^4D_{1/2}$	$3d^9 4s({}^3D_1) 5s$		$0\frac{1}{2}$	64472. 300		<i>i</i> $^2D_{3/2}$	$3d^9 4s({}^3D_2) 6s$	$6s' {}^2D$	$2\frac{1}{2}$	75170. 25	—1162. 0
						<i>i</i> $^2D_{1/2}$	$3d^9 4s({}^3D_1) 6s$		$1\frac{1}{2}$	76332. 3	
<i>e</i> $^2D_{3/2}$	$3d^9 4s({}^3D_2) 5s$	$5s' {}^2D$	$2\frac{1}{2}$	64657. 8	—602. 3	<i>h</i> $^2G_{3/2}$	$3d^9 4s({}^1D) 4d$	$4d'' {}^2G$	$3\frac{1}{2}$	75206. 4	139. 7
<i>e</i> $^2D_{1/2}$	$3d^9 4s({}^3D_1) 5s$		$1\frac{1}{2}$	65260. 1		<i>h</i> $^2G_{4/2}$			$4\frac{1}{2}$	75346. 1?	
<i>f</i> $^2D_{3/2}$	$3d^9 4s({}^1D) 5s$	$5s'' {}^2D$	$2\frac{1}{2}$	67142. 7	—829. 2	<i>h</i> $^2S_{1/2}$	$3d^9 4s({}^1D) 4d$	$4d'' {}^2S$	$0\frac{1}{2}$	75386. 7	
<i>f</i> $^2D_{1/2}$			$1\frac{1}{2}$	67971. 94		<i>h</i> $^2D_{1/2}$	$3d^9 4s({}^1D) 4d$	$4d'' {}^2D$	$1\frac{1}{2}$	75440. 1	6. 4
	$3d^9 4s({}^3D) 5p$	$5p' {}^4P^o$	$2\frac{1}{2}$			<i>h</i> $^2D_{3/2}$			$2\frac{1}{2}$	75446. 5	
<i>x</i> $^4P_{1/2}^o$			$1\frac{1}{2}$	70281 ?	—723	<i>h</i> $^2F_{2/2}$	$3d^9 4s({}^1D) 4d$	$4d'' {}^2F$	$2\frac{1}{2}$	75536. 2	36. 6
<i>x</i> $^4P_{1/2}^o$			$0\frac{1}{2}$	71004 ?		<i>h</i> $^2F_{3/2}$			$3\frac{1}{2}$	75572. 85	
	$3d^9 4s({}^3D) 5p$	$5p' {}^4F^o$	$4\frac{1}{2}$		—77. 6	<i>j</i> $^2G_{4/2}$	$3d^9 4s({}^3D_3) 5d$	$5d' {}^2G$	$4\frac{1}{2}$	76824. 3	—1074. 6
<i>x</i> $^4F_{3/2}$			$3\frac{1}{2}$	70336. 5 ?		<i>j</i> $^2G_{3/2}$	$3d^9 4s({}^3D_2) 5d$		$3\frac{1}{2}$	77898. 9	
<i>x</i> $^4F_{3/2}$			$2\frac{1}{2}$	70414. 1		<i>j</i> $^2P_{1/2}$	$3d^9 4s({}^3D_3) 5d$	$5d' {}^2P$	$1\frac{1}{2}$	76831. 31	
			$1\frac{1}{2}$						$0\frac{1}{2}$		
<i>x</i> $^4D_{3/2}$	$3d^9 4s({}^3D) 5p$	$5p' {}^4D^o$	$3\frac{1}{2}$	70441. 0 ?	—120. 2	<i>i</i> $^2D_{3/2}$	$3d^9 4s({}^3D_3) 5d$	$5d' {}^2D$	$2\frac{1}{2}$	76949. 2	—984. 1
<i>x</i> $^4D_{3/2}$			$2\frac{1}{2}$	70561. 2 ?	—468. 4	<i>j</i> $^2D_{1/2}$	$3d^9 4s({}^3D_2) 5d$		$1\frac{1}{2}$	77933. 3	
<i>x</i> $^4D_{1/2}$			$1\frac{1}{2}$	71029. 6							
			$0\frac{1}{2}$								
<i>g</i> $^2P_{1/2}$	$3d^9 4s({}^3D_3) 4d$	$4d' {}^2P$	$1\frac{1}{2}$	70853. 39	—1298. 10	$^4S_{1/2}$	$3d^9 4s({}^3D_3) 5d$	$5d' {}^4S$	$1\frac{1}{2}$	76959. 0	
<i>g</i> $^2P_{1/2}$	$3d^9 4s({}^3D_2) 4d$		$0\frac{1}{2}$	72151. 49?							
<i>g</i> $^2S_{1/2}$	$3d^9 4s({}^3D_3) 4d$	$4d' {}^2S$	$0\frac{1}{2}$	70853. 9 ?							
<i>g</i> $^2G_{4/2}$	$3d^9 4s({}^3D_3) 4d$	$4d' {}^2G$	$4\frac{1}{2}$	70859. 53	—1157. 23						
<i>g</i> $^2G_{3/2}$	$3d^9 4s({}^3D_2) 4d$		$3\frac{1}{2}$	72016. 76							
<i>x</i> $^2F_{3/2}$	$3d^9 4s({}^3D) 5p$	$5p' {}^2F^o$	$2\frac{1}{2}$	70959. 7 ?	654. 2	<i>j</i> $^2F_{3/2}$	$3d^9 4s({}^3D_3) 5d$	$5d' {}^2F$	$3\frac{1}{2}$	76960. 2	—999. 1
<i>x</i> $^2F_{3/2}$			$3\frac{1}{2}$	71613. 9 ?		<i>j</i> $^2F_{2/2}$	$3d^9 4s({}^3D_2) 5d$		$2\frac{1}{2}$	77959. 3	



### Cu I—Continued

Author	Config.	Desig.	$J$	Level	Interval
$j$ $^4\text{G}_{5\frac{1}{2}}$	$3d^9 4s(^3\text{D}_3)5d$	$5d' \ ^4\text{G}$	$5\frac{1}{2}$	77014. 1	—839. 9
$j$ $^4\text{G}_{4\frac{1}{2}}$	$3d^9 4s(^3\text{D}_2)5d$		$4\frac{1}{2}$	77854. 0	—1134. 3
$j$ $^4\text{G}_{3\frac{1}{2}}$	$3d^9 4s(^3\text{D}_1)5d$		$3\frac{1}{2}$	78988. 3	—65. 1
$j$ $^4\text{G}_{2\frac{1}{2}}$	$3d^9 4s(^1\text{D}_1)5d$		$2\frac{1}{2}$	79053. 4	
$j$ $^4\text{P}_{2\frac{1}{2}}$	$3d^9 4s(^3\text{D}_3)5d$	$5d' \ ^4\text{P}$	$2\frac{1}{2}$	77030. 59	—810. 3
$j$ $^4\text{P}_{1\frac{1}{2}}$	$3d^9 4s(^3\text{D}_2)5d$		$1\frac{1}{2}$	77840. 9	26. 4
$j$ $^4\text{P}_{\frac{1}{2}}$	$3d^9 4s(^1\text{D}_1)5d$		$0\frac{1}{2}$	77814. 5	
$j$ $^4\text{D}_{3\frac{1}{2}}$	$3d^9 4s(^3\text{D}_3)5d$	$5d' \ ^4\text{D}$	$3\frac{1}{2}$	77068. 2	—837. 3
$j$ $^4\text{D}_{2\frac{1}{2}}$	$3d^9 4s(^3\text{D}_2)5d$		$2\frac{1}{2}$	77905. 5	—1097. 6
$j$ $^4\text{D}_{1\frac{1}{2}}$	$3d^9 4s(^3\text{D}_1)5d$		$1\frac{1}{2}$	79003. 1	
			$0\frac{1}{2}$		
$j$ $^4\text{F}_{4\frac{1}{2}}$	$3d^9 4s(^3\text{D}_3)5d$	$5d' \ ^4\text{F}$	$4\frac{1}{2}$	77080. 5	—838. 9
$j$ $^4\text{F}_{3\frac{1}{2}}$	$3d^9 4s(^3\text{D}_2)5d$		$3\frac{1}{2}$	77919. 4	—1197. 1
$j$ $^4\text{F}_{2\frac{1}{2}}$	$3d^9 4s(^3\text{D}_1)5d$		$2\frac{1}{2}$	79116. 5	—2. 8
$j$ $^4\text{F}_{1\frac{1}{2}}$	$3d^9 4s(^1\text{D}_1)5d$		$1\frac{1}{2}$	79119. 3	
$k$ $^4\text{D}_{3\frac{1}{2}}$	$3d^9 4s(^3\text{D}_3)7s$	$7s' \ ^4\text{D}$	$3\frac{1}{2}$	78261. 2	—225. 3
$k$ $^4\text{D}_{2\frac{1}{2}}$	$3d^9 4s(^3\text{D}_2)7s$		$2\frac{1}{2}$	78486. 5	—771. 3
$k$ $^4\text{D}_{1\frac{1}{2}}$	$3d^9 4s(^3\text{D}_1)7s$		$1\frac{1}{2}$	79257. 8	—1072. 6
$k$ $^4\text{D}_{\frac{1}{2}}$	$3d^9 4s(^1\text{D}_1)7s$		$0\frac{1}{2}$	80330. 4	
$p$ $^2\text{D}_{2\frac{1}{2}}$	$3d^9 4s(^1\text{D})6s$	$6s'' \ ^2\text{D}$	$2\frac{1}{2}$	78349. 6	—228. 4
$p$ $^2\text{D}_{1\frac{1}{2}}$			$1\frac{1}{2}$	78578. 0	
$k$ $^2\text{D}_{2\frac{1}{2}}$	$3d^9 4s(^3\text{D}_2)7s$	$7s' \ ^2\text{D}$	$2\frac{1}{2}$	79268. 0	—1188. 4
$k$ $^2\text{D}_{1\frac{1}{2}}$	$3d^9 4s(^3\text{D}_1)7s$		$1\frac{1}{2}$	80456. 4?	
$l$ $^4\text{S}_{1\frac{1}{2}}$	$3d^9 4s(^3\text{D}_3)6d$	$6d' \ ^4\text{S}$	$1\frac{1}{2}$	79641. 4	
$l$ $^4\text{G}_{5\frac{1}{2}}$	$3d^9 4s(^3\text{D}_3)6d$	$6d' \ ^4\text{G}$	$5\frac{1}{2}$	79667. 9	—837. 6
$l$ $^4\text{G}_{4\frac{1}{2}}$	$3d^9 4s(^3\text{D}_2)6d$		$4\frac{1}{2}$	80505. 5	
			$3\frac{1}{2}$		
			$2\frac{1}{2}$		
$l$ $^4\text{P}_{2\frac{1}{2}}$	$3d^9 4s(^3\text{D}_3)6d$	$6d' \ ^4\text{P}$	$2\frac{1}{2}$	79675. 1	
			$1\frac{1}{2}$		
			$0\frac{1}{2}$		
$l$ $^4\text{D}_{3\frac{1}{2}}$	$3d^9 4s(^3\text{D}_3)6d$	$6d' \ ^4\text{D}$	$3\frac{1}{2}$	79694. 5	—847. 7
$l$ $^4\text{D}_{2\frac{1}{2}}$	$3d^9 4s(^3\text{D}_2)6d$		$2\frac{1}{2}$	80542. 2	
			$1\frac{1}{2}$		
			$0\frac{1}{2}$		
$l$ $^4\text{F}_{4\frac{1}{2}}$	$3d^9 4s(^3\text{D}_3)6d$	$6d' \ ^4\text{F}$	$4\frac{1}{2}$	79700. 5	—859. 5
$l$ $^4\text{F}_{3\frac{1}{2}}$	$3d^9 4s(^3\text{D}_2)6d$		$3\frac{1}{2}$	80560. 0	
			$2\frac{1}{2}$		
			$1\frac{1}{2}$		
$n$ $^4\text{D}_{3\frac{1}{2}}$	$3d^9 4s(^3\text{D}_3)8s$	$8s' \ ^4\text{D}$	$3\frac{1}{2}$	80318. 4	
			$2\frac{1}{2}$		
			$1\frac{1}{2}$		
			$0\frac{1}{2}$		
$l$ $^2\text{G}_{3\frac{1}{2}}$	$3d^9 4s(^3\text{D}_3)6d$	$6d' \ ^2\text{G}$	$4\frac{1}{2}$		
	$3d^9 4s(^3\text{D}_2)6d$		$3\frac{1}{2}$	80553. 8	
$l$ $^2\text{F}_{2\frac{1}{2}}$	$3d^9 4s(^3\text{D}_3)6d$	$6d' \ ^2\text{F}$	$3\frac{1}{2}$	80574	
	$3d^9 4s(^3\text{D}_2)6d$		$2\frac{1}{2}$		
$l$ $^2\text{D}_{1\frac{1}{2}}$	$3d^9 4s(^3\text{D}_3)6d$	$6d' \ ^2\text{D}$	$2\frac{1}{2}$	80586. 7?	
	$3d^9 4s(^3\text{D}_2)6d$		$1\frac{1}{2}$		
$o$ $^2\text{D}_{2\frac{1}{2}}$	$3d^9 4s(^1\text{D})5d$	$5d'' \ ^2\text{D}$	$2\frac{1}{2}$	81292. 5	—21. 2
$o$ $^2\text{D}_{1\frac{1}{2}}$			$1\frac{1}{2}$	81313. 7	
$o$ $^2\text{F}_{2\frac{1}{2}}$	$3d^9 4s(^1\text{D})5d$	$5d'' \ ^2\text{F}$	$2\frac{1}{2}$	81362. 7	13. 5
$o$ $^2\text{F}_{3\frac{1}{2}}$			$3\frac{1}{2}$	81376. 2	

December 1949.

## Cu I OBSERVED TERMS\*

Config. $1s^2 2s^2 2p^6 3s^2 3p^6 +$	Observed Terms			
$3d^9 4s^2$	$4s^2 2D$			
	$ns \ (n \geq 4)$	$np \ (n \geq 4)$	$nd \ (n \geq 4)$	$nf \ (n \geq 4)$
$3d^{10} (1S) nx$	$4-9s \ ^3S$	$4-11p \ ^2P^\circ$	$4-11d' \ ^2D$	$4, 5f \ ^3F^\circ$
$3d^9 4s(^3D) nx'$	$\left\{ \begin{array}{l} 5-8s' \ ^4D \\ 5-7s' \ ^2D \end{array} \right.$	$\begin{array}{l} 4, 5p' \ ^4P^\circ \ 4, 5p' \ ^4D^\circ \ 4, 5p' \ ^4F^\circ \\ 4, 5p' \ ^2P^\circ \ 4, 5p' \ ^2D^\circ \ 4, 5p' \ ^2F^\circ \end{array}$	$\begin{array}{l} 4-6d' \ ^4S \ 4-6d' \ ^4P \ 4-6d' \ ^4D \ 4-6d' \ ^4F \ 4-6d' \ ^4G \\ 4d' \ ^2S \ 4, 5d' \ ^2P \ 4-6d' \ ^2D \ 4-6d' \ ^2F \ 4-6d' \ ^2G \end{array}$	
$3d^9 4s(^1D) nx''$	$5-6s'' \ ^2D$	$4, 5p'' \ ^2P^\circ \ 4, 5p'' \ ^2D^\circ \ 4, 5p'' \ ^2F^\circ$	$4d'' \ ^2S \ 4d'' \ ^2P \ 4, 5d'' \ ^2D \ 4, 5d'' \ ^2F \ 4d'' \ ^2G$	

\*For predicted terms in the spectra of the Cu I isoelectronic sequence, see Vol. II, Introduction.

## Cu II

(Ni I sequence; 28 electrons)

 $Z=29$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} {}^1S_0$  $3d^{10} {}^1S_0$  163665.6  $\text{cm}^{-1}$ 

I. P. 20.29 volts

The unique honor of having produced a practically complete analysis of a complex spectrum is due Shenstone for his investigation of the Cu II spectrum. This spectrum has been photographed from 600 Å to 10000 Å. Of the 1350 lines observed only a few faint lines remain unclassified. He has extended the earlier work to include over 40 series of three or more levels; and identified  $d^9 f$  and  $d^9 g$  structures completely for the first time. He remarks that "the most striking feature is the number of levels which show the effects of mixed configurations." A theoretical discussion of the spin-orbit interaction of the almost closed shell as exhibited by the Cu II spectrum, is given by Shortley and Fried.

Shenstone has determined the limit from the  $3d^9 ns {}^3D {}^1D$  series ( $n=4$  to 8), using an extended Ritz formula described in detail in his Monograph (1936). The series are so long, and the separation of the components of the  ${}^2D$  limit term in Cu III is so large, that for this limit it can be determined without ambiguity which component is the limit of the separate components of the Cu II terms. The  $J$ -values indicating the components of this limit term are included with the configuration in column two of the table. When the  $J$ -value of the limit is the same for all components of the Cu II term, only one entry is given in this column, as for example, for the term  $4f {}^3P^o$  (135902  $\text{cm}^{-1}$ ). Shenstone remarks also that the intensities of the lines from the transition  $4f-5g$  "indicate very strongly that each empirical level is in reality double . . .". This is completely explained by  $jl$ -coupling.

In addition to the analysis, the accurate ultraviolet wavelengths of Cu II provide excellent standards for the measurement of other spectra in this region.

In Shenstone's Monograph the levels are given in numerical order "because to group them as terms in such a spectrum as this would be quite misleading". In the present table, as in Volume I, those levels which he gives as components of a term are grouped together. Shenstone's notation, which appears in column one, has, similarly, been altered in column three to conform to the notation adopted for other series spectra.

Racah has also emphasized the similarity of coupling between levels from the  $3d^9 nx$  configuration of Cu II and those of the inert gases from  $p^5 nx$ . He has furnished the writer with the following data indicating the  $jl$ -coupling notation for levels of Cu II.

## Cu II—Continued

Author	Config.	Desig.	<i>J</i>	Author	Config.	Desig.	<i>J</i>
<i>ns</i> $^3D_3$ $^3D_2$	$3d^9(^2D_{2\frac{1}{2}})ns$	<i>ns</i> $[2\frac{1}{2}]$	3 2	<i>nf</i> $^3P_1^\circ$ $^3P_0^\circ$	$3d^9(^2D_{2\frac{1}{2}})nf$	<i>nf</i> $[0\frac{1}{2}]^\circ$	1 0
<i>ns</i> $^3D_1$ $^1D_2$	$3d^9(^2D_{1\frac{1}{2}})ns$	<i>ns'</i> $[1\frac{1}{2}]$	1 2	<i>nf</i> $^3P_2^\circ$ $^1P_1$	"	<i>nf</i> $[1\frac{1}{2}]^\circ$	2 1
<i>np</i> $^3P_2^\circ$ $^3P_1$	$3d^9(^2D_{2\frac{1}{2}})np$	<i>np</i> $[1\frac{1}{2}]^\circ$	2 1	<i>nf</i> $^3H_6^\circ$ $^3H_5$	"	<i>nf</i> $[5\frac{1}{2}]^\circ$	6 5
<i>np</i> $^3F_3^\circ$ $^3F_4$	"	<i>np</i> $[3\frac{1}{2}]^\circ$	3 4	<i>nf</i> $^3D_3^\circ$ $^3D_2$	"	<i>nf</i> $[2\frac{1}{2}]^\circ$	3 2
<i>np</i> $^3D_3^\circ$ $^3D_2$	"	<i>np</i> $[2\frac{1}{2}]^\circ$	3 2	<i>nf</i> $^3F_3^\circ$ $^3F_4$	"	<i>nf</i> $[3\frac{1}{2}]^\circ$	3 4
<i>np</i> $^3P_0^\circ$ $^1P_1$	$3d^9(^2D_{1\frac{1}{2}})np$	<i>np'</i> $[0\frac{1}{2}]^\circ$	0 1	<i>nf</i> $^3G_5^\circ$ $^3G_4$	"	<i>nf</i> $[4\frac{1}{2}]^\circ$	5 4
<i>np</i> $^3F_3^\circ$ $^1F_3$	"	<i>np'</i> $[2\frac{1}{2}]^\circ$	2 3	<i>nf</i> $^1D_2^\circ$ $^3D_1$	$3d^9(^2D_{1\frac{1}{2}})nf$	<i>nf'</i> $[1\frac{1}{2}]^\circ$	2 1
<i>np</i> $^3D_3^\circ$ $^1D_2$	"	<i>np'</i> $[1\frac{1}{2}]^\circ$	1 2	<i>nf</i> $^1H_5^\circ$ $^3H_4$	"	<i>nf'</i> $[4\frac{1}{2}]^\circ$	5 4
<i>nd</i> $^3S_1$	$3d^9(^2D_{2\frac{1}{2}})nd$	<i>nd</i> $[0\frac{1}{2}]$	1	<i>nf</i> $^1F_3^\circ$ $^3F_2$	"	<i>nf'</i> $[2\frac{1}{2}]^\circ$	3 2
<i>nd</i> $^3G_5$ $^3G_4$	"	<i>nd</i> $[4\frac{1}{2}]$	5 4	<i>nf</i> $^1G_4^\circ$ $^3G_3$	"	<i>nf'</i> $[3\frac{1}{2}]^\circ$	4 3
<i>nd</i> $^3P_2$ $^3P_1$	"	<i>nd</i> $[1\frac{1}{2}]$	2 1	<i>ng</i> $^3D_{1,2}$	$3d^9(^2D_{2\frac{1}{2}})ng$	<i>ng</i> $[1\frac{1}{2}]$	1, 2
<i>nd</i> $^3D_3$ $^3D_2$	"	<i>nd</i> $[2\frac{1}{2}]$	3 2	<i>ng</i> $^3I_{6,7}$	"	<i>ng</i> $[6\frac{1}{2}]$	6, 7
<i>nd</i> $^3F_3$ $^3F_4$	"	<i>nd</i> $[3\frac{1}{2}]$	3 4	<i>ng</i> $^1D_2, ^3D_3$	"	<i>ng</i> $[2\frac{1}{2}]$	2, 3
<i>nd</i> $^3P_0$	"	<i>nd</i> $[0\frac{1}{2}]$	0	<i>ng</i> $^3F_{3,4}$	"	<i>ng</i> $[3\frac{1}{2}]$	3, 4
<i>nd</i> $^1P_1$	$3d^9(^2D_{1\frac{1}{2}})nd$	<i>nd'</i> $[0\frac{1}{2}]$	1	<i>ng</i> $^3H_{5,6}$	"	<i>ng</i> $[5\frac{1}{2}]$	5, 6
<i>nd</i> $^3G_3$ $^1G_4$	"	<i>nd'</i> $[3\frac{1}{2}]$	3 4	<i>ng</i> $^3G_{4,5}$	"	<i>ng</i> $[4\frac{1}{2}]$	4, 5
<i>nd</i> $^3D_1$ $^1D_2$	"	<i>nd'</i> $[1\frac{1}{2}]$	1 2	<i>ng</i> $^3F_2, ^1F_3$	$3d^9(^2D_{1\frac{1}{2}})ng$	<i>ng'</i> $[2\frac{1}{2}]$	2, 3
<i>nd</i> $^1F_3$ $^3F_2$	"	<i>nd'</i> $[2\frac{1}{2}]$	3 2	<i>ng</i> $^3I_5, ^1I_6$	"	<i>ng'</i> $[5\frac{1}{2}]$	5, 6
<i>nd</i> $^1S_0$	"	<i>nd'</i> $[0\frac{1}{2}]$	0	<i>ng</i> $^3G_3, ^1G_4$	"	<i>ng'</i> $[3\frac{1}{2}]$	3, 4
				<i>ng</i> $^3H_4, ^1H_5$	"	<i>ng'</i> $[4\frac{1}{2}]$	4, 5

Intersystem combinations have been observed.

The *g*-values given below have been determined by the writer from the observed Zeeman patterns published in Shenstone's 1927 paper. The formulae for blended patterns as given by Russell were used in making these calculations. These formulas are an extension of those by Shenstone and Blair.

Desig.	<i>J</i>	Obs. <i>g</i>	Desig.	<i>J</i>	Obs. <i>g</i>
$4s\ ^3D$	3	1.32	$4p\ ^3D^\circ$	2	1.08
	2	1.16		1	0.47
	1	0.48	$4p\ ^1D^\circ$	2	0.99
$4s\ ^1D$	2	1.00	$4p\ ^1P^\circ$	1	1.04
$4p\ ^3P^\circ$	2	1.49	$5s\ ^3D$	3	1.31
	1	1.49		2	1.14
$4p\ ^3F^\circ$	4	1.23		1	0.49:
	3	1.06	$5s\ ^1D$	2	1.04
	2	0.67			



## Cu II—Continued

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## Cu II

## Cu II

Author	Config.	Desig.	<i>J</i>	Level	Interval	Author	Config.	Desig.	<i>J</i>	Level	Interval
<i>a</i> $^1S_0$	$3d^{10}$	$3d^{10} \ ^1S$	0	0.00		$4d \ ^3S_1$	$3d^9(^2D_{3/2})4d$	$4d \ ^3S$	1	114511.44	
$4s \ ^3D_3$	$3d^9(^2D_{3/2})4s$	$4s \ ^3D$	3	21928.60	—918.43	$z \ ^3G_3$	$3d^8 \ 4s(^2F)4p$	$4p'' \ ^3G^\circ$	5	115546.3	186.5
$^3D_2$			2	22847.03	—1151.28	$^3G_4$			4	115359.8	—1783.2
$^3D_1$	$3d^9(^2D_{1/2})4s$		1	23998.31		$^3G_3$			3	118142.97	
$4s \ ^1D_2$	$3d^9(^2D_{1/2})4s$	$4s \ ^1D$	2	26264.52		$4d \ ^3G_5$	$3d^9(^2D_{3/2})4d$	$4d \ ^3G$	5	115569.20	—93.57
$4p \ ^3P_2$	$3d^9(^2D_{3/2})4p$	$4p \ ^3P^\circ$	2	66418.65	—1497.92	$^3G_4$	$3d^9(^2D_{1/2})4d$		4	115662.77	—2084.68
$^3P_1$			1	67916.57	—933.68	$^3G_3$			3	117747.45	
$^3P_0$	$3d^9(^2D_{1/2})4p$		0	68850.25		$4d \ ^3P_2$	$3d^9(^2D_{3/2})4d$	$4d \ ^3P$	2	115639.02	—26.38
$4p \ ^3F_4$	$3d^9(^2D_{3/2})4p$	$4p \ ^3F^\circ$	4	68730.82	283.07	$^3P_1$			1	115665.40	—911.41
$^3F_3$			3	68447.75	—1420.36	$^3P_0$			0	116576.81	
$^3F_2$	$3d^9(^2D_{1/2})4p$		2	69868.11		$4d \ ^3D_3$	$3d^9(^2D_{3/2})4d$	$4d \ ^3D$	3	116080.46	—307.54
$s^2 \ ^3F_4$	$3d^8 \ 4s^2$	$4s^2 \ ^3F$	4	69704.8	—1826.7	$^3D_2$	$3d^9(^2D_{1/2})4d$		2	116388.00	—1540.48
$^3F_3$			3	71531.5	—1192.5	$^3D_1$			1	117928.48	
$^3F_2$			2	72724.0		$4d \ ^3F_4$	$3d^9(^2D_{3/2})4d$	$4d \ ^3F$	4	116371.41	45.25
$4p \ ^3D_3$	$3d^9(^2D_{3/2})4p$	$4p \ ^3D^\circ$	3	70841.50	—652.42	$^3F_3$	$3d^9(^2D_{1/2})4d$		3	116326.16	—1205.99
$^3D_2$			2	71493.92	—1608.18	$^3F_2$			2	118532.15	
$^3D_1$	$3d^9(^2D_{1/2})4p$		1	73102.10		$z \ ^3D_3$	$3d^8 \ 4s(^2F)4p$	$4p'' \ ^3D^\circ$	3	116375.47	—754.89
$4p \ ^1F_3$	$3d^9(^2D_{1/2})4p$	$4p \ ^1F^\circ$	3	71920.13		$^3D_2$			2	117130.36	—940.98
$4p \ ^1D_2$	$3d^9(^2D_{1/2})4p$	$4p \ ^1D^\circ$	2	73353.43		$^3D_1$			1	118071.34	
$4p \ ^1P_1$	$3d^9(^2D_{1/2})4p$	$4p \ ^1P^\circ$	1	73595.86		$4d \ ^1P_1$	$3d^9(^2D_{1/2})4d$	$4d \ ^1P$	1	117231.69	
$s^2 \ ^1D_2$	$3d^8 \ 4s^2$	$4s^2 \ ^1D$	2	85388.77		$z \ ^3F_4$	$3d^8 \ 4s(^2F)4p$	$4p'' \ ^3F^\circ$	4	117666.6	1022.6
$s^2 \ ^3P_2$	$3d^8 \ 4s^2$	$4s^2 \ ^3P$	2	88362.03	—243.13	$^3F_3$			3	116643.96	—2395.72
$^3P_1$			1	88605.16	—320.93	$^3F_2$			2	119039.68	
$^3P_0$			0	88926.09		$4d \ ^1G_4$	$3d^9(^2D_{1/2})4d$	$4d \ ^1G$	4	117883.14	
$s^2 \ ^1G_4$	$3d^8 \ 4s^2$	$4s^2 \ ^1G$	4	95565.65		$4d \ ^1D_2$	$3d^9(^2D_{1/2})4d$	$4d \ ^1D$	2	118163.50	
$sp \ ^5D_4$	$3d^8 \ 4s(^4F)4p$	$4p' \ ^5D^\circ$	4	107942.1	—1333.8	$4d \ ^1F_3$	$3d^9(^2D_{1/2})4d$	$4d \ ^1F$	3	118484.00	
$^5D_3$			3	109275.9	—1087.5	$z \ ^1G_4$	$3d^8 \ 4s(^2F)4p$	$4p'' \ ^1G^\circ$	4	118991.5	
$^5D_2$			2	110363.4	—760.6	$5p \ ^3P_2$	$3d^9(^2D_{3/2})5p$	$5p \ ^3P^\circ$	2	120092.36	—827.32
$^5D_1$			1	111124.0?		$^3P_1$			1	120919.68	—1304.44
$^5D_0$			0			$^3P_0$	$3d^9(^2D_{1/2})5p$		0	122224.12	
$5s \ ^3D_3$	$3d^9(^2D_{3/2})5s$	$5s \ ^3D$	3	108014.86	—320.83	$5p \ ^3F_4$	$3d^9(^2D_{3/2})5p$	$5p \ ^3F^\circ$	4	120789.83	105.07
$^3D_2$			2	108335.69	—1748.93	$^3F_3$			3	120684.76	—2061.27
$^3D_1$	$3d^9(^2D_{1/2})5s$		1	110084.62		$^3F_2$	$3d^9(^2D_{1/2})5p$		2	122746.03	
$5s \ ^1D_2$	$3d^9(^2D_{1/2})5s$	$5s \ ^1D$	2	110366.25		$z \ ^1D_2$	$3d^8 \ 4s(^2F)4p$	$4p'' \ ^1D^\circ$	2	120876.13	
	$3d^8 \ 4s(^4F)4p$	$4p' \ ^5G^\circ$	6			$z \ ^1F_3$	$3d^8 \ 4s(^2F)4p$	$4p'' \ ^1F^\circ$	3	121079.12	
$sp \ ^5G_5$			5	110631.6	—587.2	$5p \ ^3D_3$	$3d^9(^2D_{3/2})5p$	$5p \ ^3D^\circ$	3	121524.88	—457.03
$^5G_4$			4	11218.8	—657.8	$^3D_2$			2	121981.91	—1323.05
$^5G_3$			3	11876.6	—547.9	$^3D_1$	$3d^9(^2D_{1/2})5p$		1	123304.96	
$^5G_2$			2	1424.5		$4d \ ^1S_0$	$3d^9(^2D_{1/2})4d$	$4d \ ^1S$	0	122416.1	
	$3d^8 \ 4s(^4F)4p$	$4p' \ ^5F^\circ$	4	113302.8	—697.2	$5p \ ^1P_1$	$3d^9(^2D_{1/2})5p$	$5p \ ^1P^\circ$	1	122867.92	
$sp \ ^5F_4$			3	114000.0	—482.5	$5p \ ^1F_3$	$3d^9(^2D_{1/2})5p$	$5p \ ^1F^\circ$	3	123016.93	
$^5F_3$			2	114482.5	—273.9						
$^5F_2$			1	114756.4							
$^5F_1$			0								

## Cu II—Continued

## Cu II—Continued

Author	Config.	Desig.	<i>J</i>	Level	Interval	Author	Config.	Desig.	<i>J</i>	Level	Interval
5p $^1D_2$	$3d^9(^2D_{1/2})5p$	5p $^1D^\circ$	2	123556.94		4f $^3F_4$	$3d^9(^2D_{3/2})4f$	4f $^3F^\circ$	4	136133.06	
<i>y</i> $^3D_3$	$3d^8 4s(^2D)4p$	4p $'''^3D^\circ$	3	125230.6	—17.2	$^3F_3$	$3d^9(^2D_{1/2})4f$		3	136035.64	97.42
$^3D_2$			2	125247.8	—320.9	$^3F_2$			2	138177.22	—2141.58
$^3D_1$			1	125568.7		4f $^3G_5$	$3d^9(^2D_{3/2})4f$	4f $^3G^\circ$	5	136160.93	—109.33
<i>y</i> $^1P_1$	$3d^8 4s(^2D)4p$	4p $'''^1P^\circ$	1	125399.8		$^3G_4$	$3d^9(^2D_{1/2})4f$		4	136270.26	—1991.57
<i>x</i> $^5S_2$	$3d^8 4s(^4P)4p$	4p $^{IV}^5S^\circ$	2	128365.7		$^3G_3$			3	138261.83	
<i>y</i> $^3F_5$	$3d^8 4s(^2D)4p$	4p $'''^3F^\circ$	2	128569.6	—10.7	5d $^3S_1$	$3d^9(^2D_{3/2})5d$	5d $^3S$	1	136336.88	
$^3F_3$			3	128553.9	219.2		$3d^8 4s(^2G)4p$	4p $^{VI}^3H^\circ$	6		
$^3F_1$			4	128778.1		<i>u</i> $^3H_4$			5	136694.1	
<i>x</i> $^5P_3$	$3d^8 4s(^4P)4p$	4p $^{IV}^5P^\circ$	3	129116.9	263.6	5d $^3G_5$	$3d^9(^2D_{3/2})5d$	5d $^3G$	5	136725.93	—39.45
$^5P_2$			2	128853.3	—906.3	$^3G_4$			4	136765.38	—2053.79
$^5P_1$			1	129759.6		$^3G_3$	$3d^9(^2D_{1/2})5d$		3	138819.17	
<i>y</i> $^3P_2$	$3d^8 4s(^2D)4p$	4p $'''^3P^\circ$	2	130386.4		5d $^3P_2$	$3d^9(^2D_{3/2})5d$	5d $^3P$	2	136754.11	—19.1
			1			$^3P_1$			1	136773.2	—841.1
			0			$^3P_0$			0	137614.3	
<i>y</i> $^1D_2$	$3d^8 4s(^2D)4p$	4p $'''^1D^\circ$	2	130632.4		5d $^3D_3$	$3d^9(^2D_{3/2})5d$	5d $^3D$	3	136919.35	—154.40
<i>x</i> $^5D_0$	$3d^8 4s(^4P)4p$	4p $^{IV}^5D^\circ$	0	131206.0	—261	$^3D_2$	$3d^9(^2D_{1/2})5d$		2	137073.75	—1824.68
$^5D_{2,1}$			1	130945		$^3D_1$			1	138898.43	
$^5D_3$			2	131312.7	368	5d $^3F_4$	$3d^9(^2D_{3/2})5d$	5d $^3F$	4	137044.45	—9.48
			3			$^3F_3$	$3d^9(^2D_{1/2})5d$		3	137034.97	—2107.1
			4			$^3F_2$			2	139142.1	
<i>y</i> $^1F_3$	$3d^8 4s(^2D)4p$	4p $'''^1F^\circ$	3	131044.1		<i>u</i> $^1H_3$	$3d^8 4s(^2G)4p$	4p $^{VI}^1H^\circ$	5	137082.5	
6s $^3D_3$	$3d^9(^2D_{3/2})6s$	6s $^3D$	3	133594.23	—133.84	<i>w</i> $^1P_1$	$3d^8 4s(^2P)4p$	4p $^V^1P^\circ$	1	137212.7	
$^3D_2$			2	133728.07	—1936.54	<i>u</i> $^3F_4$	$3d^8 4s(^2G)4p$	4p $^{VI}^3F^\circ$	4	137938.9	—463.3
$^3D_1$			1	135664.61		$^3F_3$			3	138402.2	—626.0
<i>w</i> $^3P_2$	$3d^8 4s(^2P)4p$	4p $^V^3P^\circ$	2	133826.2	—533.7	$^3F_2$			2	139028.2	
$^3P_1$			1	134359.9	—1124.4	4f $^1D_2$	$3d^9(^2D_{1/2})4f$	4f $^1D^\circ$	2	138003.20	
$^3P_0$			0	135484.3		4f $^1H_3$	$3d^9(^2D_{1/2})4f$	4f $^1H^\circ$	5	138064.32	
<i>w</i> $^3D_3$	$3d^8 4s(^2P)4p$	4p $^V^3D^\circ$	3	133984.6	—691.0	4f $^1F_3$	$3d^9(^2D_{1/2})4f$	4f $^1F^\circ$	3	138130.81	
$^3D_2$			2	134675.6	—460.0	4f $^1G_4$	$3d^9(^2D_{1/2})4f$	4f $^1G^\circ$	4	138220.07	
$^3D_1$			1	135135.6		5d $^1P_1$	$3d^9(^2D_{1/2})5d$	5d $^1P$	1	138593.10	
<i>v</i> $^3G_5$	$3d^8 4s(^4F)4p$	4p $^V^3G^\circ$	5	134110.6	—1724.3	5d $^1G_4$	$3d^9(^2D_{1/2})5d$	5d $^1G$	4	138883.0	
$^3G_4$			4	135834.9	—1242.7	5d $^1D_2$	$3d^9(^2D_{1/2})5d$	5d $^1D$	2	138981.3	
$^3G_3$			3	137077.6		5d $^1F_3$	$3d^9(^2D_{1/2})5d$	5d $^1F$	3	139119.5	
<i>v</i> $^3F_4$	$3d^8 4s(^4F)4p$	4p $^V^3F^\circ$	4	134743.0	—1699.0	6p $^3P_2$	$3d^9(^2D_{3/2})6p$	6p $^3P^\circ$	2	139217.3	—24.3
$^3F_3$			3	136442.05	—1207.1	$^3P_1$			1	139241.6	
$^3F_2$			2	137649.1		6p $^3F_4$	$3d^9(^2D_{3/2})6p$	6p $^3F^\circ$	4	139395.8	64.5
<i>v</i> $^3D_3$	$3d^8 4s(^4F)4p$	4p $^V^3D^\circ$	3	135733.6	—1065.7	$^3F_3$	$3d^9(^2D_{1/2})6p$		3	139331.3	—2402.6
$^3D_2$			2	136799.3		$^3F_2$			2	141733.9	
$^3D_1$			1	137913.8	—1114.5	6p $^3D_3$	$3d^9(^2D_{3/2})6p$	6p $^3D^\circ$	3	139741.1	30.9
6s $^1D_2$	$3d^9(^2D_{1/2})6s$	6s $^1D$	2	135760.27	—2139.52	$^3D_2$	$3d^9(^2D_{1/2})6p$		2	139710.2	—1534.4
4f $^3P_0$	$3d^9(^2D_{3/2})4f$	4f $^3P^\circ$	0	135902.43	—38.50	$^3D_1$			1	141244.6	
$^3P_1$			1	135863.93	47.06	1i	$3d^8 4s(^4P)4p$	4p $^{IV}^1P^\circ$	1	140481.7?	
$^3P_2$			2	135910.99		5d $^1S_0$	$3d^9(^2D_{1/2})5d$	5d $^1S$	0	140589.4	
4f $^3H_5$	$3d^9(^2D_{3/2})4f$	4f $^3H^\circ$	6	135931.27	—2.88	6p $^1P_1$	$3d^9(^2D_{1/2})6p$	6p $^1P^\circ$	1	140984.2	
$^3H_3$			5	135934.15		6p $^1F_3$	$3d^9(^2D_{1/2})6p$	6p $^1F^\circ$	3	141204.1	
$^3H_4$	$3d^9(^2D_{1/2})4f$		4	138073.67							
<i>w</i> $^1D_2$	$3d^8 4s(^2P)4p$	4p $^V^1D^\circ$	2	135952.55							
4f $^1P_1$	$3d^9(^2D_{3/2})4f$	4f $^1P^\circ$	1	135953.46							
4f $^3D_3$	$3d^9(^2D_{3/2})4f$	4f $^3D^\circ$	3	135990.15	—24.11						
$^3D_2$			2	136014.26	—2014.44						
$^3D_1$	$3d^9(^2D_{1/2})4f$		1	138023.70							



## Cu II—Continued

## Cu II—Continued

Author	Config.	Desig.	J	Level	Interval	Author	Config.	Desig.	J	Level	Interval
6p $^1D_2$	$3d^9(^2D_{1/2})6p$	6p $^1D^\circ$	2	141542.1		5f $^1H_3$	$3d^9(^2D_{1/2})5f$	5f $^1H^\circ$	5	148028.8	
3i	$3d^8 4s(^4P)4p$	4p <sup>IV</sup> $3^\circ$	1	144240.6		5f $^1F_3$	$3d^9(^2D_{1/2})5f$	5f $^1F^\circ$	3	148061.7	
7s $^3D_3$	$3d^9(^2D_{3/2})7s$	7s $^3D$	3	144814.93	—68.16	5f $^1G_4$	$3d^9(^2D_{1/2})5f$	5f $^1G^\circ$	4	148105.6	
$^3D_2$			2	144883.09	—2003.22	5g $^1F_3$	$3d^9(^2D_{1/2})5g$	5g $^1F$	3	148133.99	
$^3D_1$	$3d^9(^2D_{1/2})7s$		1	146886.31		5g $^1I_6$	$3d^9(^2D_{1/2})5g$	5g $^1I$	6	148145.77	
5f $^3P_0$	$3d^9(^2D_{3/2})5f$	5f $^3P^\circ$	0	145889.6	11.5	5g $^1G_4$	$3d^9(^2D_{1/2})5g$	5g $^1G$	4	148167.77	
$^3P_1$			1	145901.1	26.4	5g $^1H_5$	$3d^9(^2D_{1/2})5g$	5g $^1H$	5	148179.30	
$^3P_2$			2	145927.5		6d $^1P_1$	$3d^9(^2D_{1/2})6d$	6d $^1P$	1	148361.7	
5f $^3H_6$	$3d^9(^2D_{3/2})5f$	5f $^3H^\circ$	6	145951.7	5.9	6d $^1G_4$	$3d^9(^2D_{1/2})6d$	6d $^1G$	4	148515.6	
$^3H_5$			5	145945.8	—2037.9	6d $^1D_2$	$3d^9(^2D_{1/2})6d$	6d $^1D$	2	148559.3	
$^3H_4$	$3d^9(^2D_{1/2})5f$		4	148033.7		6d $^1F_3$	$3d^9(^2D_{1/2})6d$	6d $^1F$	3	148631.2	
5f $^1P_1$	$3d^9(^2D_{3/2})5f$	5f $^1P^\circ$	1	145955.7		6d $^1S_0$	$3d^9(^2D_{1/2})6d$	6d $^1S$	0	149203.1	
5f $^3D_3$	$3d^9(^2D_{3/2})5f$	5f $^3D^\circ$	3	145978.4	—7.0	<i>t</i> $^3P_2$	$3d^8 4s(^2S)4p$	4p <sup>VII</sup> $^3P^\circ$	2	150250	
$^3D_2$			2	145985.4	—2030.9				1		
$^3D_1$	$3d^9(^2D_{1/2})5f$		1	148016.3					0		
5f $^3F_4$	$3d^9(^2D_{3/2})5f$	5f $^3F^\circ$	4	146024.0	2.5						
$^3F_3$			3	146021.5	—2044.8						
$^3F_2$	$3d^9(^2D_{1/2})5f$		2	148066.3							
5f $^3G_5$	$3d^9(^2D_{3/2})5f$	5f $^3G^\circ$	5	146032.5	3.0						
$^3G_4$			4	146029.5	—2073.7						
$^3G_3$	$3d^9(^2D_{1/2})5f$		3	148103.2		8s $^3D_3$	$3d^9(^2D_{3/2})8s$	8s $^3D$	3	150742.9	—39.7
5g $^3D_1$	$3d^9(^2D_{3/2})5g$	5g $^3D$	1	146051.34	0.00	$^3D_2$			2	150782.6	
$^3D_2$			2	146051.34	21.61				1		
$^3D_3$			3	146072.95		6f $^3H_6$	$3d^9(^2D_{3/2})6f$	6f $^3H^\circ$	6	151377.8	5.5
5g $^3I_7$	$3d^9(^2D_{3/2})5g$	5g $^3I$	7	146069.01	0.00	$^3H_5$			5	151372.3	—2083.2
$^3I_6$			6	146069.01	—2076.76	$^3H_4$	$3d^9(^2D_{1/2})6f$		4	153455.5?	
$^3I_5$	$3d^9(^2D_{1/2})5g$		5	148145.77		6f $^3P_2$	$3d^9(^2D_{3/2})6f$	6f $^3P^\circ$	2	151375.3	
5g $^1D_2$	$3d^9(^2D_{3/2})5g$	5g $^1D$	2	146072.95					1		
5g $^3F_4$	$3d^9(^2D_{3/2})5g$	5g $^3F$	4	146094.11	0.00	6f $^3D_3$	$3d^9(^2D_{3/2})6f$	6f $^3D^\circ$	3	151402.4?	—1.4
$^3F_3$			3	146094.11	—2039.88	$^3D_2$			2	151403.8?	
$^3F_2$	$3d^9(^2D_{1/2})5g$		2	148133.99					1		
5g $^3H_6$	$3d^9(^2D_{3/2})5g$	5g $^3H$	6	146103.42	0.00	6f $^3F_3$	$3d^9(^2D_{3/2})6f$	6f $^3F^\circ$	4		
$^3H_5$			5	146103.42	—2075.88				3	151419.2?	
$^3H_4$	$3d^9(^2D_{1/2})5g$		4	148179.30					2		
5g $^3G_5$	$3d^9(^2D_{3/2})5g$	5g $^3G$	5	146107.33	0.00	7d $^3S_1$	$3d^9(^2D_{3/2})7d$	7d $^3S$	1	151550.0?	
$^3G_4$			4	146107.33	—2060.44	7d $^3G_5$	$3d^9(^2D_{3/2})7d$	7d $^3G$	5	151656.4	—12.0
$^3G_3$	$3d^9(^2D_{1/2})5g$		3	148167.77		$^3G_4$			4	151668.4	—2075.0
6d $^3S_1$	$3d^9(^2D_{3/2})6d$	6d $^3S$	1	146215.7		$^3G_3$	$3d^9(^2D_{1/2})7d$		3	153743.4?	
6d $^3G_5$	$3d^9(^2D_{3/2})6d$	6d $^3G$	5	146402.9	—20.5	7d $^3P_2$	$3d^9(^2D_{3/2})7d$	7d $^3P$	2	151663.4	—6.8
$^3G_4$			4	146423.4	—2058.6	$^3P_1$			1	151670.2	
$^3G_3$	$3d^9(^2D_{1/2})6d$		3	148482.0					0		
6d $^3P_2$	$3d^9(^2D_{3/2})6d$	6d $^3P$	2	146415.7	—11.9	7d $^3D_3$	$3d^9(^2D_{3/2})7d$	7d $^3D$	3	151708.3	
$^3P_1$			1	146427.6	—670.5				2		
$^3P_0$	$3d^9(^2D_{1/2})6d$		0	147098.1					1		
6d $^3D_3$	$3d^9(^2D_{3/2})6d$	6d $^3D$	3	146496.2	—79.1	7d $^3F_4$	$3d^9(^2D_{3/2})7d$	7d $^3F$	4	151745.1	1.5
$^3D_2$			2	146575.3	—1946.5	$^3F_3$			3	151743.6	
$^3D_1$	$3d^9(^2D_{1/2})6d$		1	148521.8					2		
6d $^3F_4$	$3d^9(^2D_{3/2})6d$	6d $^3F$	4	146559.8	3.2	6f $^1H_3$	$3d^9(^2D_{1/2})6f$	6f $^1H^\circ$	5	153450.1?	
$^3F_3$			3	146556.6	—2086.0						
$^3F_2$	$3d^9(^2D_{1/2})6d$		2	148642.6							
7s $^1D_2$	$3d^9(^2D_{1/2})7s$	7s $^1D$	2	146936.48			Cu III ( $^2D_{3/2}$ )	Limit	---	163665.6	
5f $^1D_2$	$3d^9(^2D_{1/2})5f$	5f $^1D^\circ$	2	147987.7							



Cu II OBSERVED TERMS\*

Config.		Observed Terms			
$1s^2 2s^2 2p^6 3s^2 3p^4 +$					
$3d^3 4s^2$	$\{$	$4s^2 3P$	$4s^2 3F$	$4s^2 1G$	
$3d^{10}$	$\{$	$3d^{10} 1S$			
		$ns \ (n \geq 4)$	$np \ (n \geq 4)$		
$3d^3 (2D) nx$	$\{$	$4-8s \ 3D$ $4-7s \ 1D$	$4-6p \ 3P^\circ$ $4-6p \ 1P^\circ$ $4p' \ 5D^\circ$ $4p' \ 3D^\circ$ $4p'' \ 3D^\circ$ $4p'' \ 1D^\circ$ $4p''' \ 3D^\circ$ $4p''' \ 1P^\circ$ $4p^{IV} \ 5S^\circ$ $4p^{IV} \ 5P^\circ$ $4p^V \ 3P^\circ$ $4p^V \ 1P^\circ$	$3D^\circ \ 4-6p \ 3F^\circ$ $1D^\circ \ 4-6p \ 1F^\circ$ $4p' \ 5G^\circ$ $4p' \ 3G^\circ$ $4p'' \ 3G^\circ$ $4p'' \ 1G^\circ$ $4p''' \ 3F^\circ$ $4p''' \ 1F^\circ$ $4p^{IV} \ 5D^\circ$ $4p^V \ 3D^\circ$ $4p^V \ 1D^\circ$	
$3d^3 4s(4F) nx'$	$\{$			$4p' \ 5G^\circ$ $4p' \ 3G^\circ$	
$3d^3 4s(2F) nx''$	$\{$			$4p'' \ 3G^\circ$ $4p'' \ 1G^\circ$	
$3d^3 4s(2D) nx'''$	$\{$			$4p''' \ 3F^\circ$ $4p''' \ 1F^\circ$	
$3d^3 4s(4P) nx^{IV}$	$\{$			$4p^{IV} \ 5D^\circ$	
$3d^3 4s(2P) nx^V$	$\{$			$4p^V \ 3D^\circ$ $4p^V \ 1D^\circ$	
$3d^3 4s(2G) nx^{VI}$	$\{$			$4p^{VI} \ 3F^\circ$ $4p^{VI} \ 3H^\circ$ $4p^{VI} \ 1H^\circ$	
$3d^3 4s(2S) nx^{VII}$	$\{$			$4p^{VII} 3P^\circ$	
		$nd \ (n \geq 4)$	$nf \ (n \geq 4)$		$ng \ (n \geq 5)$
$3d^3 (2D) nx$	$\{$	$4-7d \ 3S$ $4-6d \ 1S$ $4-7d \ 3P$ $4-6d \ 1P$ $4-7d \ 3D$ $4-6d \ 1D$ $4-7d \ 3F$ $4-6d \ 1F$ $4-7d \ 3G$ $4-6d \ 1G$	$4-6f \ 3P^\circ$ $4-6f \ 1P^\circ$ $4, 5f \ 4, 5f$ $3D^\circ \ 4-6f$ $1D^\circ \ 4, 5f$ $3F^\circ \ 4, 5f$ $1F^\circ \ 4, 5f$ $3G^\circ \ 4, 5f$ $1G^\circ \ 4, 5f$ $3H^\circ \ 4-6f$ $1H^\circ \ 4-6f$	$5g \ 3D$ $5g \ 1D$ $5g \ 3F$ $5g \ 1F$ $5g \ 3G$ $5g \ 1G$ $5g \ 3H$ $5g \ 1H$ $5g \ 3I$ $5g \ 1I$	

\*For predicted terms in the spectra of the Ni I isoelectronic sequence, see Vol. II, Introduction.

## Cu III

(Co I sequence; 27 electrons)

 $Z=29$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^9 {}^2D_{3/2}$  $a {}^2D_{3/2}$  297100  $\text{cm}^{-1}$ 

I. P. 36.83 volts

The analysis of the Cu III spectrum was begun by Gibbs and Vieweg, who reported in 1929 that they had some important multiplets. It has been seriously incomplete until recently, when Shenstone and Wilets undertook a detailed study of the spectrum, especially for inclusion here.

There are at present approximately 325 classified lines in the interval 672 Å to 2822 Å. According to Shenstone, not a single line of any considerable intensity remains unclassified.

He has determined the limit from the  ${}^4F$  series, by using a Ritz formula, with the assumption that  $\alpha=0.18 \times 10^{-6}$ , as 299145  $\text{cm}^{-1}$ . From a study of isoelectronic data Catalán has derived an improved value, which is quoted here.

The doublet and quartet systems of terms are connected by observed intersystem combinations.

## REFERENCES

- R. C. Gibbs and A. M. Vieweg, Phys. Rev. **33**, 1092 (A) (1929).  
 A. G. Shenstone and L. Wilets, Phys. Rev. **83**, 104 (1951). (I P) (T) (C L)  
 M. A. Catalán, unpublished material (April 1952). (I P)

## Cu III

## Cu III

Config.	Desig.	$J$	Level	Interval	Config.	Desig.	$J$	Level	Interval
$3d^9$	$a {}^2D$	$2\frac{1}{2}$ $1\frac{1}{2}$	0. 0 2071. 8	—2071. 8	$3d^8({}^3F)4p$	$z {}^4G^\circ$	$5\frac{1}{2}$ $4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$	121698. 5 121337. 2 122503. 6 123440. 2	361. 3 —1166. 4 —936. 6
$3d^8({}^3F)4s$	$a {}^4F$	$4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$	60804. 9* 62065. 0 63143. 6 63886. 3	—1260. 1 —1078. 6 —742. 7	$3d^8({}^3F)4p$	$z {}^4F^\circ$	$4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$	123549. 9 124557. 5 125381. 8 125744. 6	—1007. 6 —824. 3 —362. 8
$3d^8({}^3F)4s$	$a {}^2F$	$3\frac{1}{2}$ $2\frac{1}{2}$	67016. 6 68963. 6	—1947. 0	$3d^8({}^3F)4p$	$z {}^2G^\circ$	$4\frac{1}{2}$ $3\frac{1}{2}$	124442. 5 126093. 8	—1651. 3
$3d^8({}^1D)4s$	$b {}^2D$	$2\frac{1}{2}$ $1\frac{1}{2}$	77967. 6 78779. 4	—811. 8	$3d^8({}^3F)4p$	$z {}^2F^\circ$	$3\frac{1}{2}$ $2\frac{1}{2}$	126829. 4 128679. 4	—1850. 0
$3d^8({}^3P)4s$	$a {}^4P$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$	80422. 8 80305. 2 80551. 5	—117. 6 246. 3	$3d^8({}^3F)4p$	$z {}^2D^\circ$	$2\frac{1}{2}$ $1\frac{1}{2}$	126891. 9 128435. 3	—1543. 4
$3d^8({}^3P)4s$	$a {}^2P$	$1\frac{1}{2}$ $0\frac{1}{2}$	85446. 4 86133. 0	—686. 6	$3d^8({}^3P)4p$	$z {}^4P^\circ$	$2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	136607. 3 136482. 9 137041. 0	124. 4 —558. 1
$3d^8({}^1G)4s$	$a {}^2G$	$4\frac{1}{2}$ $3\frac{1}{2}$	89017. 7 89045. 9	—28. 2	$3d^8({}^1D)4p$	$y {}^2F^\circ$	$2\frac{1}{2}$ $3\frac{1}{2}$	138084. 0 138932. 0	898. 0
$3d^8({}^3F)4p$	$z {}^4D^\circ$	$3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	118864. 3 120577. 5 121863. 7 122637. 2	—1713. 2 —1286. 2 —773. 5	$3d^8({}^1D)4p$	$y {}^2D^\circ$	$1\frac{1}{2}$ $2\frac{1}{2}$	138938. 1 139756. 6	768. 5
					$3d^8({}^1D)4p$	$z {}^2P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	139260. 7 140200. 9	940. 2

## Cu III—Continued

## Cu III—Continued

Config.	Desig.	<i>J</i>	Level	Interval	Config.	Desig.	<i>J</i>	Level	Interval
$3d^8(^3P)4p$	$y^4D^\circ$	$0\frac{1}{2}$	142550. 1	— 37. 8 — 86. 0 393. 4	$3d^8(^3F)4d$	<b>3</b> $e^4G$	$3\frac{1}{2}, 4\frac{1}{2}$	194031. 6    194330. 8	— 1611. 3
		$1\frac{1}{2}$	142512. 3		$2\frac{1}{2}$				
		$2\frac{1}{2}$	142426. 3		$3\frac{1}{2}$				
		$3\frac{1}{2}$	142819. 7		$4\frac{1}{2}$				
$3d^8(^3P)4p$	$x^2D^\circ$	$2\frac{1}{2}$	144194. 2	— 681. 0			$5\frac{1}{2}$		
$1\frac{1}{2}$	144875. 2								
$3d^8(^3P)4p$	$y^2P^\circ$	$1\frac{1}{2}$	145353. 0	— 1322. 9	$3d^8(^3F)4d$	<b>4</b>	$3\frac{1}{2}, 4\frac{1}{2}$	195060. 4	
		$0\frac{1}{2}$	146675. 9		$3d^8(^3F)4d$		<b>5</b>	$3\frac{1}{2}$	
$3d^8(^1G)4p$	$z^2H^\circ$	$4\frac{1}{2}$	146533. 6	1113. 4	$3d^8(^3F)4d$	<b>6</b>	$3\frac{1}{2}, 4\frac{1}{2}$	195516. 9	
		$5\frac{1}{2}$	147647. 0		$3d^8(^3F)5s$		$e^2F$	$3\frac{1}{2}$	
$3d^8(^3P)4p$	$z^2S^\circ$	$0\frac{1}{2}$	147652. 5				$2\frac{1}{2}$	197398. 4	
$3d^8(^1G)4p$	$x^2F^\circ$	$3\frac{1}{2}$	147805. 9	— 857. 0	$3d^8(^3F)4d$	<b>7</b>	$2\frac{1}{2}$	196740. 2	
		$2\frac{1}{2}$	148662. 9		$3d^8(^3F)4d$		<b>8</b>	$2\frac{1}{2}, 3\frac{1}{2}$	
$3d^8(^3P)4p$	$z^4S^\circ$	$1\frac{1}{2}$	147816. 4		$3d^8(^3F)4d$	$f^2F$	$2\frac{1}{2}$	197373. 9	
$3d^8(^1G)4p$	$y^2G^\circ$	$3\frac{1}{2}$	153609. 2	199. 2			$3\frac{1}{2}$		
		$4\frac{1}{2}$	153808. 4			$3d^8(^3F)4d$	<b>9</b>	$1\frac{1}{2}, 2\frac{1}{2}$	
$3d^8(^3F)5s$	$e^4F$	$4\frac{1}{2}$	193369. 0	— 746. 6 — 1437. 6 — 891. 7	$3d^8(^3F)4d$	<b>10</b>	$3\frac{1}{2}$	198299. 4	
		$3\frac{1}{2}$	194115. 6						
		$2\frac{1}{2}$	195553. 2						
		$1\frac{1}{2}$	196444. 9						
$3d^8(^3F)4d$	<b>1</b>	$3\frac{1}{2}, 4\frac{1}{2}$	193519. 2		Cu iv ( $^3F_4$ )	<i>Limit</i>	-----	<b>297100</b>	

March 1951.

## Cu III OBSERVED TERMS\*

Config. $1s^2 2s^2 2p^6 3s^2 3p^6 +$	Observed Terms			
$3d^9$	$a^2D$			
	$ns (n \geq 4)$	$np (n \geq 4)$		$nd (n \geq 4)$
	$\left\{ \begin{array}{l} a, e^4F \\ a, e^2F \end{array} \right.$	$\left\{ \begin{array}{l} z^4D^\circ \\ z^2D^\circ \end{array} \right.$	$\left\{ \begin{array}{l} z^4F^\circ \\ z^2F^\circ \end{array} \right.$	$\left\{ \begin{array}{l} z^4G^\circ \\ z^2G^\circ \end{array} \right.$
$3d^8(^3F)nx$				$f^2F$ $e^4G$
$3d^8(^3P)nx$	$\left\{ \begin{array}{l} a^4P \\ a^2P \end{array} \right.$	$\left\{ \begin{array}{l} z^4S^\circ \\ z^2S^\circ \end{array} \right.$	$\left\{ \begin{array}{l} z^4P^\circ \\ y^2P^\circ \end{array} \right.$	$\left\{ \begin{array}{l} y^4D^\circ \\ x^2D^\circ \end{array} \right.$
$3d^8(^1G)nx$				
$3d^8(^1D)nx$	$b^2D$		$x^2F^\circ$ $y^2G^\circ$ $z^2H^\circ$	
		$z^2P^\circ$ $y^2D^\circ$ $y^2F^\circ$		

\*For predicted terms in the spectra of the Co I isoelectronic sequence, see Vol. II, Introduction.



## Cu VII

(V I sequence; 23 electrons)

 $Z=29$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 {}^6S_{5/2}$  $a {}^6S_{5/2}$  $\text{cm}^{-1}$ 

I. P.

volts

This spectrum is very incompletely known. Kruger and Gilroy have classified three lines as transitions from the ground term to  $3d^4 4p {}^6P^\circ$ , as follows:

Int.	I. A.	Wave No.	Desig.
200	200. 665	498343	$3d^5 {}^6S_{5/2} - 4p {}^6P_{3/2}^\circ$
150	200. 851	497881	$3d^5 {}^6S_{5/2} - 4p {}^6P_{1/2}^\circ$
100	200. 948	497640	$3d^5 {}^6S_{5/2} - 4p {}^6P_{1/2}^\circ$

## REFERENCE

P. G. Kruger and H. T. Gilroy, Phys. Rev. **48**, 720 (1935). (T) (C L)  
January 1950.

## Cu XIX

(Na I sequence; 11 electrons)

 $Z=29$ Ground state  $1s^2 2s^2 2p^6 3s {}^2S_{1/2}$  $3s {}^2S_{1/2}$  5410000  $\text{cm}^{-1}$ 

I. P. 671 volts

The terms are from Edlén, who lists one pair of classified lines at 47 Å. He has extrapolated the absolute value of the ground term from isoelectronic sequence data.

The unit adopted by Edlén,  $10^3 \text{ cm}^{-1}$ , has here been changed to  $\text{cm}^{-1}$ .

## REFERENCE

B. Edlén, Zeit. Phys. **100**, 621 (1936). (I P) (T) (C L)

## Cu XIX

Config.	Desig.	$J$	Level	Interval
$3s$	$3s {}^2S$	$0\frac{1}{2}$	0	
$3p$	$3p {}^2P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	327700 363800	36100
$3d$	$3d {}^2D$	$1\frac{1}{2}$ $2\frac{1}{2}$	812300 818100	5800
$4f$	$4f {}^2F^\circ$	$2\frac{1}{2}$ $3\frac{1}{2}$	2925200 2926200	1000
-----	-----	---	-----	
Cu xx ( ${}^1S_0$ )	Limit	---	[5410000]	

June 1947.

## ZINC

## Zn I

30 electrons

 $Z=30$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 {}^1S_0$  $4s^2 {}^1S_0$  75766.8  $\text{cm}^{-1}$ 

I. P. 9.391 volts

The well established series of Zn I are given by Paschen-Götze and by Fowler.

Hetzler, Boreman, and Burns observed the "*Spectrum of the Zinc Arc in Vacuum*" from 2138 Å to 7799 Å for the purpose of obtaining accurate wave lengths. From their prism, grating, and interferometric measurements they derived precise term values for the leading series terms. Their values are quoted in the table and are the only entries given to two or more decimal places. The limit, and remaining regular series terms are from Fowler. The term  $13d {}^3D$  has been calculated from its combination with  $4p {}^3P^{\circ}$ , since the absolute value given by Fowler does not fit the observed wave number. Brackets denote that the entry for  $5f {}^3F^{\circ}$  is calculated from the series formula. The  ${}^1D$  and  ${}^3P$  terms from the  $4p^2$  configuration are from Sawyer's paper. These and Fowler's values have been adjusted slightly by the writer, to fit the scale of Hetzler, Boreman, and Burns.

Beutler and Guggenheimer have observed in absorption 24 lines between 713Å and 1109 Å which they classify as transitions from the ground term to terms above the ionization limit having the configurations  $3d^9 4s^2({}^2D)np$  and  $3d^9 4s^2({}^2D)nf$ . The  $J$ -values of the limit term in Zn II, ( ${}^2D$ ), are quoted from their paper. Their values of  $8p'' {}^3P^{\circ}$  and  $9p'' {}^3P^{\circ}$ , counted from zero, have here been decreased by  $10 \text{ cm}^{-1}$  to fit the observed wave numbers on which these levels are based. For triplet terms only the component with  $J=1$  is indicated in the table, since only combinations with the ground term ( $J=0$ ) are relevant.

Intersystem combinations connecting the singlet and triplet systems of terms have been observed.

Long before the development of the quantum theory of the Zeeman effect, the lines of the Zn I triplet  $4p {}^3P^{\circ} - 5s {}^3S$ , 4680 Å, 4722 Å, and 4810 Å, were among those used to test Preston's postulate that corresponding series lines of different elements are separated in the same manner in a magnetic field of the same strength. Although observed  $g$ -values have apparently not been published for Zn I, these lines serve excellently for the calibration of the magnetic field strength in determining the observed Zeeman patterns of various spectra. The quoted values are from Kiess, who furnished them especially for inclusion here.

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 J. E. Mack, *Rev. Mod. Phys.* **22**, No. 1, 64 (1950). (Summary hfs)

## Zn I

## Zn I

Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>	Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>
$3d^{10} 4s^2$	$4s^2 \ ^1S$	0	0. 000			$3d^{10} 4s(2S)9p$	$9p \ ^1P^\circ$	1	73469. 7		
$3d^{10} 4s(2S)4p$	$4p \ ^3P^\circ$	0 1 2	32311. 308 32501. 390 32890. 317	190. 082 388. 927	1. 496 1. 505	$3d^{10} 4s(2S)8d$	$8d \ ^3D$	1, 2, 3	73471. 1		
$3d^{10} 4s(2S)4p$	$4p \ ^1P^\circ$	1	46745. 37			$3d^{10} 4s(2S)10s$	$10s \ ^3S$	1	73698. 6		
$3d^{10} 4s(2S)5s$	$5s \ ^3S$	1	53672. 241		2. 001	$3d^{10} 4s(2S)10p$	$10p \ ^1P^\circ$	1	74012. 4		
$3d^{10} 4s(2S)5s$	$5s \ ^1S$	0	55789. 220			$3d^{10} 4s(2S)9d$	$9d \ ^3D$	1, 2, 3	74016. 7		
$3d^{10} 4s(2S)5p$	$5p \ ^3P^\circ$	0 1 2	61247. 2 61273. 9 61330. 1	26. 7 56. 2		$3d^{10} 4s(2S)11s$	$11s \ ^3S$	1	74169. 0		
$3d^{10} 4s(2S)4d$	$4d \ ^1D$	2	62458. 51			$3d^{10} 4s(2S)10d$	$10d \ ^3D$	1, 2, 3	74387. 7		
$3d^{10} 4s(2S)4d$	$4d \ ^3D$	1 2 3	62768. 75 62772. 00 62776. 95	3. 25 4. 95		$3d^{10} 4s(2S)12s$	$12s \ ^3S$	1	74495. 8		
$3d^{10} 4s(2S)5p$	$5p \ ^1P^\circ$	1	62910. 0			$3d^{10} 4s(2S)11d$	$11d \ ^3D$	1, 2, 3	74651. 3		
$3d^{10} 4s(2S)6s$	$6s \ ^3S$	1	65432. 32			$3d^{10} 4s(2S)12d$	$12d \ ^3D$	1, 2, 3	74855. 1		
$3d^{10} 4s(2S)6s$	$6s \ ^1S$	0	66037. 60			$3d^{10} 4s(2S)13d$	$13d \ ^3D$	1, 2, 3	74994. 0		
$3d^{10} 4s(2S)6p$	$6p \ ^3P^\circ$	0 1 2	68070. 854 68080. 669 68101. 784	9. 815 21. 115		$3d^{10} 4s(2S)14d$	$14d \ ^3D$	1, 2, 3	75112. 2		
$3d^{10} 4s(2S)5d$	$5d \ ^1D$	2	68338. 48			Zn II ( $2S_{1/2}$ )	Limit	-----	75766. 8		
$3d^{10} 4s(2S)5d$	$5d \ ^3D$	1 2 3	68579. 13 68580. 60 68583. 03	1. 47 2. 43		$3d^{10} 4p^2$	$4p^2 \ ^3P$	0 1 2	80176 80395	219	
$3d^{10} 4s(2S)6p$	$6p \ ^1P^\circ$	1	68607. 26			$3d^{10} 4p^2$	$4p^2 \ ^1D$	2	80795		
$3d^{10} 4s(2S)4f$	$4f \ ^3F^\circ$	2, 3, 4	68834. 4			$3d^9 4s^2(2D_{3/2})4p$	$4p' \ ^1P^\circ$	1	90158		
$3d^{10} 4s(2S)7s$	$7s \ ^3S$	1	69745. 94			$3d^9 4s^2(2D_{1/2})4p$	$4p' \ ^3P^\circ$	1	94717		
$3d^{10} 4s(2S)7s$	$7s \ ^1S$	0	70003. 72			$3d^9 4s^2(2D_{1/2})4p$	$4p' \ ^3D^\circ$	1	95257		
$3d^{10} 4s(2S)7p$	$7p \ ^3P^\circ$	0 1 2	70977. 14 70981. 97 70992. 16	4. 83 10. 19		$3d^9 4s^2(2D_{3/2})5p$	$5p' \ ^1P^\circ$	1	123470		
$3d^{10} 4s(2S)6d$	$6d \ ^1D$	2	71050. 45			$3d^9 4s^2(2D_{1/2})5p$	$5p' \ ^3P^\circ$	1	125968		
$3d^{10} 4s(2S)6d$	$6d \ ^3D$	1 2 3	71212. 13 71212. 90 71214. 24	0. 77 1. 34		$3d^9 4s^2(2D_{1/2})5p$	$5p' \ ^3D^\circ$	1	126255		
$3d^{10} 4s(2S)7p$	$7p \ ^1P^\circ$	1	71219. 08			$3d^9 4s^2(2D_{3/2})6p$	$6p' \ ^1P^\circ$	1	130617		
$3d^{10} 4s(2S)5f$	$5f \ ^3F^\circ$	2, 3, 4	[71323. 4]			$3d^9 4s^2(2D_{3/2})4f$	$4f' \ ^3P^\circ?$	1	131671		
$3d^{10} 4s(2S)8s$	$8s \ ^3S$	1	71822. 5			$3d^9 4s^2(2D_{1/2})6p$	$6p' \ ^3P^\circ$	1	133214		
$3d^{10} 4s(2S)8s$	$8s \ ^1S$	0	71956. 20			$3d^9 4s^2(2D_{1/2})6p$	$6p' \ ^3D^\circ$	1	133349		
$3d^{10} 4s(2S)7d$	$7d \ ^1D$	2	72489. 13			$3d^9 4s^2(2D_{1/2})4f$	$4f' \ ^1P^\circ?$	1	133478		
$3d^{10} 4s(2S)8p$	$8p \ ^3P^\circ$	0 1 2	72495. 8 72498. 56 72504. 20	2. 8 5. 64		$3d^9 4s^2(2D_{3/2})7p$	$7p' \ ^1P^\circ$	1	133638		
$3d^{10} 4s(2S)8p$	$8p \ ^1P^\circ$	1	72626. 2			$3d^9 4s^2(2D_{3/2})5f$	$5f' \ ^3P^\circ?$	1	133989		
$3d^{10} 4s(2S)7d$	$7d \ ^3D$	1, 2, 3	72627. 9			$3d^9 4s^2(2D_{3/2})8p$	$8p' \ ^1P^\circ$	1	135185		
$3d^{10} 4s(2S)9s$	$9s \ ^3S$	1	72985. 4			$3d^9 4s^2(2D_{3/2})9p$	$9p' \ ^1P^\circ$	1	136066		
$3d^{10} 4s(2S)9s$	$9s \ ^1S$	0	73060. 63			$3d^9 4s^2(2D_{1/2})7p$	$7p' \ ^3P^\circ$	1	136292		
$3d^{10} 4s(2S)9p$	$9p \ ^3P^\circ$	0 1 2	73390. 7 73392. 27 73395. 86	1. 6 3. 59		$3d^9 4s^2(2D_{3/2})10p$	$10p' \ ^1P^\circ$	1	136656		
						$3d^9 4s^2(2D_{3/2})11p$	$11p' \ ^1P^\circ$	1	137060		
						$3d^9 4s^2(2D_{3/2})12p$	$12p' \ ^1P^\circ$	1	137344		
						$3d^9 4s^2(2D_{1/2})8p$	$8p' \ ^3P^\circ$	1	137883		
						$3d^9 4s^2(2D_{1/2})9p$	$9p' \ ^3P^\circ$	1	138813		
						$3d^9 4s^2(2D_{1/2})10p$	$10p' \ ^3P^\circ$	1	139377		
						$3d^9 4s^2(2D_{1/2})11p$	$11p' \ ^3P^\circ$	1	139762		
						$3d^9 4s^2(2D_{1/2})12p$	$12p' \ ^3P^\circ$	1	140059		



## Zn I OBSERVED TERMS\*

Config. $1s^2 2s^2 2p^6 3s^2 3p^6 +$	Observed Terms			
$3d^{10} 4s^2$	$4s^2 \ ^1S$			
$3d^{10} 4p^2$	{ $4p^2 \ ^3P$ $4p^2 \ ^1D$ }			
	$ns \ (n \geq 5)$	$np \ (n \geq 4)$	$nd \ (n \geq 4)$	$nf \ (n \geq 4)$
$3d^{10} 4s(2S)nx$	{ $5-12s \ ^3S$ $5-9s \ ^1S$ }	$4-9p \ ^3P^\circ$ $4-10p \ ^1P^\circ$	$4-14d \ ^3D$ $4-7d \ ^1D$	$4f \ ^3F^\circ$
$3d^9 4s^2(2D)nx'$		$4-12p' \ ^3P^\circ$ $4-6p' \ ^3D^\circ$ $4-12p' \ ^1P^\circ$		$4, 5f' \ ^3P^\circ$ $4f' \ ^1P^\circ$

\*For predicted terms in the spectra of the Zn I isoelectronic sequence, see Vol. II, Introduction.

## Zn II

(Cu I sequence; 29 electrons)

$Z=30$

Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s \ ^2S_{0,1/2}$

$4s \ ^2S_{0,1/2} \ 144890.6 \text{ cm}^{-1}$

I. P. 17.96 volts

In 1925 von Salis published an analysis giving well established doublet series in Zn II, from which most of the terms in the table are taken. He derived the limit from the  $^2D$ -series, by using a Ritz formula.

From infrared observations Paschen and Ritschl resolved the  $4f \ ^2F^\circ$  term and found the  $5g \ ^2G$ -term.

By analogy with Cu I, terms from  $3d^9 4s \ nx$  are to be expected. Takahashi, Kalia, and Mazumder have published, respectively, 21, 8, and 26 levels, and grouped some of them into terms from this configuration. The first and last of these three papers are, however, not independent. Mazumder utilizes 6 levels given by Takahashi in making up the 6 terms he suggests.

More recently Shenstone and Gibson have investigated this spectrum and furnished their results in advance of publication, for inclusion here. They ascribe 8 terms to  $3d^9 4s \ 4p$  and confirm 6 levels by Takahashi and 10 by Mazumder, of which 4 are common to both lists. Shenstone's interpretation of the terms from this configuration has been adopted here. He has also revised  $7p \ ^2P^\circ$ , added  $8p \ ^2P^\circ$ , and resolved  $8f \ ^2F^\circ$ . His revised term values have been used throughout, for the present compilation. The remaining published levels have been omitted, awaiting further confirmation.

There are approximately 120 classified lines in the interval between 984 Å and 9950 Å, including the infrared data, Lang's ultraviolet material, and the lists by von Salis and Shenstone. Observed intersystem combinations connect the doublet and quartet systems of terms.

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## Zn II

## Zn II

Config.	Desig.	<i>J</i>	Level	Interval	Config.	Desig.	<i>J</i>	Level	Interval
3d <sup>10</sup> (1S) 4s	4s <sup>2</sup> S	0½	0. 0		3d <sup>10</sup> (1S) 5g	5g <sup>2</sup> G	4½ 3½	127310. 1 127310. 2	-0. 1
3d <sup>10</sup> (1S) 4p	4p <sup>2</sup> P°	0½ 1½	48480. 6 49354. 4	873. 8	3d <sup>10</sup> (1S) 6d	6d <sup>2</sup> D	1½ 2½	127629. 9 127643. 1	13. 2
3d <sup>9</sup> 4s <sup>2</sup>	4s <sup>2</sup> <sup>2</sup> D	2½ 1½	62721. 9 65441. 1	-2719. 2	3d <sup>10</sup> (1S) 7p	7p <sup>2</sup> P°	1½ 0½	128343. 5 128517. 9	-174. 4
3d <sup>10</sup> (1S) 5s	5s <sup>2</sup> S	0½	88436. 8		3d <sup>9</sup> 4s (1D) 4p	4p'' <sup>2</sup> P°	1½ 0½	130371. 4	
3d <sup>10</sup> (1S) 4d	4d <sup>2</sup> D	1½ 2½	96909. 0 96959. 7	50. 7	3d <sup>9</sup> 4s (1D) 4p	4p'' <sup>2</sup> D°	2½ 1½	131651. 7	
3d <sup>10</sup> (1S) 5p	5p <sup>2</sup> P°	0½ 1½	101365. 3 101610. 8	245. 5	3d <sup>10</sup> (1S) 8s	8s <sup>2</sup> S	0½	131876. 0	
3d <sup>9</sup> 4s (3D) 4p	4p' <sup>4</sup> P°	2½ 1½ 0½	103690. 2 105322. 5 106527. 3	-1632. 3 -1204. 8	3d <sup>10</sup> (1S) 6f	6f <sup>2</sup> F°	2½ 3½	132603. 3 132638. 7	35. 4
3d <sup>9</sup> 4s (3D) 4p	4p' <sup>4</sup> F°	4½ 3½ 2½ 1½	106841. 9 107267. 6	-425. 7	3d <sup>10</sup> (1S) 6g	6g <sup>2</sup> G	{ 4½ 3½ }	132683. 4	
3d <sup>9</sup> 4s (3D) 4p	4p' <sup>4</sup> D°	3½ 2½ 1½ 0½	111743. 2 111993. 7 112534. 7	-250. 5 -541. 0	3d <sup>10</sup> (1S) 7d	7d <sup>2</sup> D	1½ 2½	132879. 8 132887. 7	7. 9
3d <sup>9</sup> 4s (3D) 4p	4p' <sup>2</sup> P°	0½ 1½	113492. 7 113499. 0	6. 3	3d <sup>10</sup> (1S) 8p	8p <sup>2</sup> P°	{ 1½ 0½ }	133805	
3d <sup>9</sup> 4s (3D) 4p	4p' <sup>2</sup> D°	1½ 2½	114044. 1 114834. 0	789. 9	3d <sup>10</sup> (1S) 9s	9s <sup>2</sup> S	0½	135423. 0	
3d <sup>9</sup> 4s (3D) 4p	4p' <sup>2</sup> F°	3½ 2½	114208. 3		3d <sup>10</sup> (1S) 7f	7f <sup>2</sup> F°	3½ 2½	135889. 3 135892. 2	-2. 9
3d <sup>10</sup> (1S) 6s	6s <sup>2</sup> S	0½	114498. 5		3d <sup>10</sup> (1S) 7g	7g <sup>2</sup> G	{ 4½ 3½ }	135923. 3	
3d <sup>10</sup> (1S) 4f	4f <sup>2</sup> F°	3½ 2½	117262. 7 117263. 3	-0. 6	3d <sup>10</sup> (1S) 8d	8d <sup>2</sup> D	1½ 2½	136051. 2 136056. 3	5. 1
3d <sup>10</sup> (1S) 5d	5d <sup>2</sup> D	1½ 2½	117968. 7 117992. 9	24. 2	3d <sup>10</sup> (1S) 8f	8f <sup>2</sup> F°	3½ 2½	138001. 3 138002. 6	-1. 3
3d <sup>10</sup> (1S) 6p	6p <sup>2</sup> P°	0½ 1½	119887. 9 119959. 0	71. 1	3d <sup>10</sup> (1S) 9d	9d <sup>2</sup> D	1½ 2½	138113. 7 138117. 3	3. 6
3d <sup>10</sup> (1S) 7s	7s <sup>2</sup> S	0½	125879. 5		Zn III (1S <sub>0</sub> )	Limit	-----	144890. 6	
3d <sup>10</sup> (1S) 5f	5f <sup>2</sup> F°	3½ 2½	127199. 0 127208. 6	-9. 6					

February 1950.

## Zn II OBSERVED TERMS\*

Config. 1s <sup>2</sup> 2s <sup>2</sup> 2p <sup>6</sup> 3s <sup>2</sup> 3p <sup>6</sup> +	Observed Terms				
3d <sup>9</sup> 4s <sup>2</sup>	4s <sup>2</sup> <sup>2</sup> D				
	ns (n ≥ 4)	np (n ≥ 4)		nd (n ≥ 4)	nf (n ≥ 4)    ng (n ≥ 5)
3d <sup>10</sup> (1S) nx	4-9s <sup>2</sup> S	4-8p <sup>2</sup> P°		4-9d <sup>2</sup> D	4-8f <sup>2</sup> F°    5-7g <sup>2</sup> G
3d <sup>9</sup> 4s (3D) nx'	{	4p' <sup>4</sup> P°	4p' <sup>4</sup> D°		
3d <sup>9</sup> 4s (1D) nx''		4p' <sup>2</sup> P°	4p' <sup>2</sup> D°		
		4p'' <sup>2</sup> P°	4p'' <sup>2</sup> D°		

\*For predicted terms of the Cu I isoelectronic sequence, see Vol. II, Introduction.

## Zn III

(Ni I sequence; 28 electrons)

 $Z=30$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 1S_0$  $3d^{10} 1S_0$  320300  $\text{cm}^{-1}$ 

I. P. 39.70 volts

The analysis is incomplete. In 1927 Laporte and Lang published 9 terms from the  $^2D$  limit in Zn IV, and classified 37 lines between 677 Å and 1839 Å. By extrapolation along the isoelectronic sequence they estimated the limit to be about 325000  $\text{cm}^{-1}$ .

From more extensive observations, Mazumder has classified 219 more lines and found 24 new terms in the range between 497 Å and 3133 Å. His value of the limit, based on the  $ns\ ^3D$  series ( $n=4,5$ ) and derived from a Rydberg formula, is 324405  $\text{cm}^{-1}$ . From a study of isoelectronic data Catalán has derived an improved value, which is quoted here.

The terms in the table are from these two papers. On the suggestion of Mack, Laporte, and Lang the two levels  $4p\ ^3D_1^\circ$  and  $4p\ ^1P_1^\circ$  have been interchanged, in order to agree better with the isoelectronic sequence data for Ga IV and Ge V.

The terms of all three multiplicities are connected by observed intersystem combinations.

## REFERENCES

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 K. C. Mazumder, Indian J. Physics **10**, 171 (1936). (I P) (T) (C L)  
 M. A. Catalán, unpublished material (April 1952). (I P)

## Zn III

## Zn III

Config.	Desig.	$J$	Level	Interval	Config.	Desig.	$J$	Level	Interval
$3d^{10}$	$3d^{10} 1S$	0	0		$3d^9(^2D)4d$	$4d\ ^3G$	5 4 3	216617 216473 217082	144 — 609
$3d^9(^2D)4s$	$4s\ ^3D$	3 2 1	78105 79283 80859	— 1178 — 1576	$3d^9(^2D)4d$	$4d\ ^1D$	2	216903	
$3d^9(^2D)4s$	$4s\ ^1D$	2	83509	—	$3d^9(^2D)4d$	$4d\ ^3P$	2 1 0	217664 218918 221363	— 1254 — 2445
$3d^9(^2D)4p$	$4p\ ^3P^\circ$	2 1 0	137876 140080 141401	— 2204 — 1321	$3d^9(^2D)4d$	$4d\ ^3D$	3 2 1	218048 218548 221350	— 500 — 2802
$3d^9(^2D)4p$	$4p\ ^3F^\circ$	4 3 2	141335 140664 142491	671 — 1827	$3d^9(^2D)4d$	$4d\ ^1F$	3	219352	
$3d^9(^2D)4p$	$4p\ ^3D^\circ$	3 2 1	144511 145252 147577	— 741 — 2325	$3d^9(^2D)4d$	$4d\ ^3F$	4 3 2	219368 219692 220674	— 324 — 982
$3d^9(^2D)4p$	$4p\ ^1F^\circ$	3	145974		$3d^9(^2D)4d$	$4d\ ^1P$	1	221332	
$3d^9(^2D)4p$	$4p\ ^1P^\circ$	1	147505		$3d^9(^2D)5s$	$5s\ ^1D$	2	227854	
$3d^9(^2D)4p$	$4p\ ^1D^\circ$	2	147928		$3d^9\ 4s(^4F)4p$	$4p'\ ^5G^\circ$	6 5 4 3 2		
$3d^9(^2D)4d$	$4d\ ^3S$	1	214362					252029 252580 256301	— 551 — 3721
$3d^9(^2D)5s$	$5s\ ^3D$	3 2 1	214885 215347 217669	— 462 — 2322	$3d^9\ 4s(^4F)4p$	$4p'\ ^5F^\circ$	5 4 3 2 1		
$3d^9(^2D)4d$	$4d\ ^1G$	4	215121					252287 252415 253703 255635	— 128 — 1288 — 1932
$3d^9(^2D)4d$	$4d\ ^1S$	0	215476						



## Zn III—Continued

## Zn III—Continued

Config.	Desig.	<i>J</i>	Level	Interval	Config.	Desig.	<i>J</i>	Level	Interval
$3d^8\ 4s(^4F)4p$	$4p'\ ^5D^\circ$	4	252311	—1821	$3d^8\ 4s(^2F)4p$	$4p''\ ^3G^\circ$	5	274154 275267	—1113
		3	254132				4		
		2	253739				3		
		1	255447				2		
		0	258072				1		
$3d^8\ 4s(^4F)4p$	$4p'\ ^3G^\circ$	5	263829 263523	306	$3d^8\ 4s(^2F)4p$	$4p''\ ^1D^\circ$	2	274339	—2111 —1977
		4					276128		
		3					278239 280216		
$3d^8\ 4s(^4F)4p$	$4p'\ ^3D^\circ$	3	265492	—4511 —2101	$3d^8\ 4s(^2F)4p$	$4p''\ ^1F^\circ$	3	276748	
		2	270003				4	277604	
		1	272104				2		
$3d^8\ 4s(^4F)4p$	$4p'\ ^3F^\circ$	4	265538	—423 —6175	$3d^8\ 4s(^2F)4p$	$4p''\ ^3F^\circ$	2	277968	—644 815
		3	265961				3	277324	
		2	272136				4	278139	
					Zn iv ( $^3D_{3/2}$ )	Limit	-----	320300	

March 1951.

## Zn III OBSERVED TERMS\*

Config. $1s^2 2s^2 2p^6 3s^2 3p^6 +$	Observed Terms				
$3d^{10}$	$3d^{10} ^1S$				
	<i>ns</i> ( $n \geq 4$ )	<i>np</i> ( $n \geq 4$ )			<i>nd</i> ( $n \geq 4$ )
	$\left\{ \begin{array}{l} 4, 5s ^3D \\ 4, 5s ^1D \end{array} \right.$	$4p ^3P^\circ$ $4p ^1P^\circ$	$4p ^3D^\circ$ $4p ^1D^\circ$	$4p ^3F^\circ$ $4p ^1F^\circ$	$4d ^3S$ $4d ^1S$ $4d ^3P^\circ$ $4d ^1P$ $4d ^3D$ $4d ^1D$ $4d ^3F$ $4d ^1F$ $4d ^3G$ $4d ^1G$
$3d^9(^2D)nx$	$\left\{ \right.$		$4p' ^3D^\circ$ $4p' ^1D^\circ$	$4p' ^3F^\circ$ $4p' ^1F^\circ$	$4p' ^3G^\circ$ $4p' ^1G^\circ$
$3d^8 4s(^4F)nx'$	$\left\{ \right.$				
$3d^8 4s(^2F)nx''$	$\left\{ \right.$		$4p'' ^3D^\circ$ $4p'' ^1D^\circ$	$4p'' ^3F^\circ$ $4p'' ^1F^\circ$	$4p'' ^3G^\circ$ $4p'' ^1G^\circ$

\*For predicted terms in the spectra of the Ni I isoelectronic sequence, see Vol. II, Introduction.

## Zn IV

(Co I sequence; 27 electrons)

 $Z=30$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^9 ^2D_{3/2}$  $3d^9 ^2D_{3/2}$     $\text{cm}^{-1}$ 

I. P.   volts

This spectrum has not been analyzed. Nine terms and 48 classified lines between 1029 Å and 1443 Å have been suggested by Subbaraya. Bloch and Bloch have also published 32 classified lines between 466 Å and 1449 Å but give no terms. A tolerance in the intervals of  $35 \text{ cm}^{-1}$  in the former paper and  $22 \text{ cm}^{-1}$  in the latter makes the analysis appear dubious in both cases, particularly since only one interval and possibly four lines are common to both papers.

## REFERENCES

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 L. Bloch et E. Bloch, Ann. de Phys. [11] **5**, 348 (1936). (C L)

March 1950.

## GALLIUM

## Ga I

31 electrons

 $Z=31$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^2 P_{0\frac{1}{2}}^\circ$  $4p^2 P_{0\frac{1}{2}}^\circ$  48380  $\text{cm}^{-1}$ 

I. P. 6.00 volts

Uhler and Tanch observed the spectrum from 2200 to 4172 Å, and extended two of the doublet series ( $^2S$  and  $^2D$ ) given by Fowler and by Paschen-Götze. Later Sawyer and Lang found the two terms  $4p^2\ ^2S$  and  $4p^2\ ^4P$  from their combination with  $4p^2\ P^\circ$ . Garton has since observed six intense absorption lines between 1500 and 1650 Å, which he classifies as combinations of the ground term with  $4p^2\ ^2S$  and  $4p^2\ ^2P$ . His absolute values for these two terms, calculated from the limit 48380, have been used for the present compilation. His work indicates a revision of Sawyer's value of  $4p^2\ ^2S$ , which, counted from zero, is 40265.

Meggers and Murphy have recently photographed the spectrum from 6396 to 12109 Å. They find the strong lines due to the transition  $5s\ ^2S-5p\ ^2P^\circ$  at 11949.24 and 12109.93 Å, thus confirming the early predictions which placed them near 12000 Å. They have also extended the two series  $5p\ ^2P^\circ-n s\ ^2S$ , and  $5p\ ^2P^\circ-n d\ ^2D$  to  $n=12$  and 11, respectively, and have observed the  $nf\ ^2F^\circ$  series ( $n=4-7$ ).

The writer has recalculated all of the term values with the aid of the new data. Fowler's limit, quoted above, is confirmed. The number of classified lines is now approximately 70.

## REFERENCES

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 F. Paschen und R. Götze, *Seriengesetze der Linienspektren*, p. 129 (Julius Springer, Berlin, 1922). (I P) (T) (C L)  
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 W. F. Meggers and R. J. Murphy, *J. Research Nat. Bur. Std.* **48**, 334 RP 2320 (1952).

## Ga I

## Ga I

Config.	Desig.	$J$	Level	Interval	Config.	Desig.	$J$	Level	Interval
$4s^2(^1S)4p$	$4p\ ^2P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	$0.00$ $826.24$	826.24	$4s^2(^1S)6p$	$6p\ ^2P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	$40376.46$ $40417.62$	41.16
$4s^2(^1S)5s$	$5s\ ^2S$	$0\frac{1}{2}$	24788.58		$4s^2(^1S)5d$	$5d\ ^2D$	$1\frac{1}{2}$ $2\frac{1}{2}$	40802.72 40811.20	8.48
$4s^2(^1S)5p$	$5p\ ^2P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	$33044.06$ $33155.03$	110.97	$4s^2(^1S)7s$	$7s\ ^2S$	$0\frac{1}{2}$	42158.44	
$4s^2(^1S)4d$	$4d\ ^2D$	$1\frac{1}{2}$ $2\frac{1}{2}$	34781.67 34787.92	6.25	$4s^2(^1S)7p$	$7p\ ^2P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	$43440.8$ $43461.7$	20.9
$4s^2(^1S)6s$	$6s\ ^2S$	$0\frac{1}{2}$	37584.62		$4s^2(^1S)6d$	$6d\ ^2D$	$1\frac{1}{2}$ $2\frac{1}{2}$	43575.38 43580.59	5.21
$4s\ 4p^2$	$4p^2\ ^4P$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$	37972 38338 38913	366 575	$4s^2(^1S)4f$	$4f\ ^2F^\circ$	$2\frac{1}{2}, 3\frac{1}{2}$	$43954.71$	
					$4s^2(^1S)8s$	$8s\ ^2S$	$0\frac{1}{2}$	44331.9	

## Ga I—Continued

## Ga I—Continued

Config.	Desig.	<i>J</i>	Level	Interval	Config.	Desig.	<i>J</i>	Level	Interval
$4s^2(^1S)7d$	$7d\ ^2D$	$1\frac{1}{2}, 2\frac{1}{2}$	45072. 0 45076. 11	4. 1	$4s^2(^1S)10d$	$10d\ ^2D$	$1\frac{1}{2}, 2\frac{1}{2}$	46941. 6	
$4s^2(^1S)9s$	$9s\ ^2S$	$0\frac{1}{2}$	45536. 66		$4s^2(^1S)7f$	$7f\ ^2F^\circ$	$2\frac{1}{2}, 3\frac{1}{2}$	47022. 0	
$4s^2(^1S)8d$	$8d\ ^2D$	$1\frac{1}{2}, 2\frac{1}{2}$	45969. 2 45972. 00	2. 8	$4s^2(^1S)12s$	$12s\ ^2S$	$0\frac{1}{2}$	47092. 52	
$4s^2(^1S)5f$	$5f\ ^2F^\circ$	$2\frac{1}{2}, 3\frac{1}{2}$	46130. 7		$4s^2(^1S)11d$	$11d\ ^2D$	$1\frac{1}{2}, 2\frac{1}{2}$	47222. 10	
$4s^2(^1S)10s$	$10s\ ^2S$	$0\frac{1}{2}$	46273. 9		Ga II( $^1S_0$ )				
$4s^2(^1S)9d$	$9d\ ^2D$	$1\frac{1}{2}, 2\frac{1}{2}$	46548. 3 46548. 9	0. 6		<b>Limit</b>		<b>48380</b>	
$4s^2(^1S)6f$	$6f\ ^2F^\circ$	$2\frac{1}{2}, 3\frac{1}{2}$	46660. 8		$4s\ 4p^2$	$4p^2\ ^2S$	$0\frac{1}{2}$	62100	
$4s^2(^1S)11s$	$11s\ ^2S$	$0\frac{1}{2}$	46758. 2		$4s\ 4p^2$	$4p^2\ ^2P$	$0\frac{1}{2}, 1\frac{1}{2}$	65796 66422	626

November 1951.

## Ga I OBSERVED TERMS\*

Config. $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} +$	Observed Terms			
$4s^2(^1S)4p$	$4p\ ^2P^\circ$			
$4s\ 4p^2$	{ $4p^2\ ^2S$ $4p^2\ ^4P$ $4p^2\ ^2P$			
	$ns\ (n \geq 5)$	$np\ (n \geq 5)$	$nd\ (n \geq 4)$	$nf\ (n \geq 4)$
$4s^2(^1S)nx$	5–12s $^2S$	5–7p $^2P^\circ$	4–11d $^2D$	4–7f $^2F^\circ$

\*For predicted terms in the spectra of the Ga I isoelectronic sequence, see Vol. II, Introduction.

## Ga II

(Zn I sequence; 30 electrons)

 $Z=31$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2\ ^1S_0$  $4s^2\ ^1S_0$  165458  $\text{cm}^{-1}$ 

I. P. 20.51 volts

The analysis has not been extended since 1929 when Sawyer and Lang classified about 90 lines in the region between 829 Å and 7793 Å. The terms are from their paper, predicted series members being entered in brackets. They have derived absolute values from the various series "in such a way as to make the deviations from true Rydberg type similar to those found in Al II." An evident misprint in their value of  $7p\ ^2P^\circ$  has here been corrected to fit the observed combinations.

The singlet and triplet terms are connected by observed intersystem combinations.

## REFERENCES

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Ga II

Ga II

Config.	Desig.	J	Level	Interval	Config.	Desig.	J	Level	Interval
4s <sup>3</sup>	4s <sup>3</sup> 1S	0	0		4s(2S)4f	4f 1F°	3	137343	
4s(2S)4p	4p 3P°	0 1 2	47370 47816 48750	446 934	4s(2S)6p	6p 3P°	0, 1, 2	[139260]	
4s(2S)4p	4p 1P°	1	70700		4s(2S)6p	6p 1P°	1	[139660]	
4s(2S)5s	5s 3S	1	102943		4s(2S)6d	6d 1D	2	139694	
4s(2S)5s	5s 1S	0	106656		4s(2S)7s	7s 3S	1	145493	
4s(2S)4d	4d 1D	2	107719		4s(2S)7s	7s 1S	0	146013	
4s(2S)4d	4d 3D	1 2 3	113816 113841 113875	25 34	4s(2S)5f	5f 3F°	2, 3, 4	147483	
4p <sup>3</sup>	4p <sup>2</sup> 3P	0 1 2	114701 115225 116137	524 912	4s(2S)5f	5f 1F°	3	147492	
4s(2S)5p	5p 3P°	0 1 2	118427 118516 118726	89 210	4s(2S)6d	6d 3D	1 2 3	147516 147524 147533	8 9
4s(2S)5p	5p 1P°	1	120540		4s(2S)7d	7d 1D	2	148437	
4s(2S)5d	5d 1D	2	[127190]		4s(2S)7p	7p 3P°	0, 1, 2	[148620]	
4s(2S)6s	6s 3S	1	133012		4s(2S)7p	7p 1P°	1	148707	
4s(2S)6s	6s 1S	0	[134310]		4s(2S)8s	8s 3S	1	151919	
4s(2S)5d	5d 3D	1 2 3	137154 137166 137183	12 17	4s(2S)8s	8s 1S	0	152193	
4s(2S)4f	4f 3F°	2, 3, 4	137333		4s(2S)6f	6f 3F°	2, 3, 4	153000	
					4s(2S)6f	6f 1F°	3	[153020]	
					4s(2S)7d	7d 3D	1, 2, 3	153061	
					Ga III (2S <sub>1/2</sub> )	Limit	-----	165458	

March 1950.

Ga II OBSERVED TERMS\*

Config. 1s <sup>2</sup> 2s <sup>2</sup> 2p <sup>6</sup> 3s <sup>2</sup> 3p <sup>6</sup> 3d <sup>10</sup> +	Observed Terms			
4s <sup>3</sup>	4s <sup>3</sup> 1S			
4p <sup>3</sup>	4p <sup>3</sup> 3P			
	ns (n ≥ 4)	np (n ≥ 4)	nd (n ≥ 4)	nf (n ≥ 4)
4s(2S)nx	{ 5 - 8s 3S 5, 7, 8s 1S	4, 5p 3P° 4, 5, 7p 1P°	4-7d 3D 4, 6, 7d 1D	4-6f 3F° 4, 5f 1F°

\*For predicted terms in the spectra of the Zn I isoelectronic sequence see Vol. II, Introduction.

## Ga III

(Cu I sequence; 29 electrons)

 $Z=31$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 S_{0\frac{1}{2}}$  $4s^2 S_{0\frac{1}{2}}$  247700  $\text{cm}^{-1}$ 

I. P. 30.70 volts

The early analysis was by Carroll, who reported six doublet series terms in 1925, and determined the limit as 247790 by assuming an absolute value of  $5g^2G$  consistent with extrapolated isoelectronic sequence data.

From improved measurements Lang revised Carroll's absolute term values slightly and added the second member of the principal series. His classification of two faint lines at 632.92 Å and 635.02 Å, respectively, as  $4s^2 S-5p^2 P^\circ$  was confirmed only by a rough extrapolation of the Rydberg formula. This places  $5p^2 P_{1\frac{1}{2}}^\circ$  at 157998 and  $5p^2 P_{0\frac{1}{2}}^\circ$  at 157475 (with  $4s^2 S=0$ ). The quoted value of the limit is an estimate by Catalán based on isoelectronic data.

Subsequently Rao extended the observations, added the terms  $6s^2 S$  and  $5d^2 D$ , and revised Lang's value of  $5p^2 P^\circ$  on the basis of combinations of this term with  $5s^2 S$  and  $4d^2 D$ . The revised value of  $5p^2 P^\circ$  has been adopted here. With this exception, Lang's values have been used in the present compilation, supplemented by the new terms from Rao. A correction of  $10 \text{ cm}^{-1}$  has here been added to the three terms from Rao's paper (from the ground state zero) to reduce them to Lang's scale. About 20 lines have been classified in the interval 1267 Å to 5992 Å.

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 M. A. Catalán, unpublished material (April 1952). (I P)

## Ga III

Config.	Desig.	$J$	Level	Interval
$4s$	$4s^2 S$	$0\frac{1}{2}$	0	
$4p$	$4p^2 P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	65167 66885	1718
$5s$	$5s^2 S$	$0\frac{1}{2}$	140744	
$4d$	$4d^2 D$	$1\frac{1}{2}$ $2\frac{1}{2}$	144078 144195	117
$5p$	$5p^2 P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	160761 161300	539
$4f$	$4f^2 F^\circ$	$2\frac{1}{2}$ $3\frac{1}{2}$	185431 185433	7
$6s$	$6s^2 S$	$0\frac{1}{2}$	187562	
$5d$	$5d^2 D$	$1\frac{1}{2}$ $2\frac{1}{2}$	189183 189246	63
$5g$	$5g^2 G$	$\left\{ \begin{array}{l} 3\frac{1}{2} \\ 4\frac{1}{2} \end{array} \right\}$	208252	
-----	-----	-----	-----	
Ga IV ( $^1S_0$ )	Limit	-----	247700	

March 1951.

Ga IV

(Ni I sequence; 28 electrons)

Z=31

Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} \ ^1S_0$

$3d^{10} \ ^1S_0$  517600  $\text{cm}^{-1}$

I. P. 64.2 volts

Mack, Laporte, and Lang have classified 39 lines in the interval 422 Å to 1465 Å, as combinations among 9 terms. They have determined the limit by linear extrapolation of the Moseley diagram "slightly modified by a consideration of the first order screening numbers." The value of the limit calculated from their quoted ionization potential is entered in brackets in the table.

Intersystem combinations connecting the singlet and triplet terms, have been observed.

REFERENCE

J. E. Mack, O. Laporte, and R. J. Lang, Phys. Rev. **31**, 748 (1928). (I P) (T) (C L)

Ga IV

Config.	Desig.	<i>J</i>	Level	Interval
$3d^{10}$	$3d^{10} \ ^1S$	0	0	
$3d^9 \ (^2D) 4s$	$4s \ ^3D$	3	149298	—1455 —2120
		2	150753	
		1	152873	
$3d^9(^2D)4s$	$4s \ ^1D$	2	155810	
$3d^9(^2D)4p$	$4p \ ^3P^o$	2	224028	—3081 —1820
		1	227109	
		0	228929	
$3d^9(^2D)4p$	$4p \ ^3F^o$	4	228742	1272 —2358
		3	227470	
		2	229828	
$3d^9(^2D)4p$	$4p \ ^3D^o$	3	232976	—636 —3080
		2	233612	
		1	236692	
$3d^9(^2D)4p$	$4p \ ^1F^o$	3	234724	
$3d^9(^2D)4p$	$4p \ ^1P^o$	1	236099	
$3d^9(^2D)4p$	$4p \ ^1D^o$	2	237243	
-----	-----	-----	-----	
Ga v ( $^2D_{3/2}$ )	Limit	-----	[517600]	

November 1949.

Ga IV OBSERVED TERMS\*

Config. $1s^2 2s^2 2p^6 3s^2 3p^6 +$	Observed Terms				
$3d^{10}$	$3d^{10} \ ^1S$				
	<i>ns</i> ( <i>n</i> ≥ 4)		<i>np</i> ( <i>n</i> ≥ 4)		
$3d^9(^2D)nx$	{	$4s \ ^3D$ $4s \ ^1D$	$4p \ ^3P^o$ $4p \ ^1P^o$	$4p \ ^3D^o$ $4p \ ^1D^o$	$4p \ ^3F^o$ $4p \ ^1F^o$

\*For predicted terms in the spectra of the Ni I isoelectronic sequence, see Vol. II, Introduction.



## GERMANIUM

## Ge I

32 electrons

 $Z=32$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^2 {}^3P_0$  $4p^2 {}^3P_0$  63600  $\text{cm}^{-1}$ 

I. P. 7.88 volts

K. R. Rao, in 1929, revised and extended the early work of Gartlein and others, and published a list of 139 classified lines between 1639 Å and 4685 Å. Kiess, in 1940, added 7 terms, from the  $5p$  and  $6p$  configurations, and 25 classified lines from his observations between 5265 Å and 11144 Å. The terms in the table are from these two sources, although it is difficult to choose between the arrangement suggested by Gartlein and that by Rao for the terms which they interpret differently.

Andrew and Meissner have contributed new terms from the  $np$  configuration ( $n=5$  to 7), and adjusted some other values. Their results are from unpublished material furnished especially for inclusion here.

The limit is from Gartlein, who derived it from the  $ns {}^1, {}^3P^\circ$  series ( $n=5$  to 7) and the  $nd {}^1P^\circ, {}^3D^\circ, {}^1F^\circ, {}^3P^\circ, {}^3D^\circ, {}^1F^\circ$  series ( $n=5, 6$ ) by the use of a Rydberg formula. Rao's value from the  $ns {}^1, {}^3P^\circ$  series ( $n=5$  to 7) is 63790  $\text{cm}^{-1}$ .

Two miscellaneous levels given by Rao have been omitted from the table. With the ground state equal to zero they are as follows:

Desig.	Level
${}^1X_1$	59522.5
${}^3X_2$	61250.9

The singlet and triplet systems of terms are connected by observed intersystem combinations.

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 K. L. Andrew and K. W. Meissner, unpublished material (October 1951). (T) (C L)

## Ge I

## Ge I

Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>	Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>
4s <sup>2</sup> 4p <sup>2</sup>	4p <sup>2</sup> <sup>3</sup> P	0	0. 00	557. 11		4s 4p <sup>3</sup>	4p <sup>3</sup> <sup>1</sup> P°	1	55473. 6		
		1	557. 10	852. 80	1. 476	4s <sup>2</sup> 4p(²P°)6p	6p <sup>3</sup> P	0	55503. 10	1183. 89	
		2	1409. 90		1. 514			1	56686. 99	260. 64	
4s <sup>2</sup> 4p <sup>2</sup>	4p <sup>2</sup> <sup>1</sup> D	2	7125. 26		0. 989			2	56947. 63		
4s <sup>2</sup> 4p <sup>2</sup>	4p <sup>2</sup> <sup>1</sup> S	0	16367. 14			4s <sup>2</sup> 4p(²P°)5d	5d <sup>1</sup> D°	2	55717. 6		
4s <sup>2</sup> 4p(²P°)5s	5s <sup>3</sup> P°	0	37451. 53	250. 62	1. 442	4s 4p <sup>3</sup>	4p <sup>3</sup> <sup>3</sup> P°	2	56654. 9	-742. 2	
		1	37702. 15	1415. 62	1. 499			1	57397. 1	-278. 0	
		2	39117. 77					0	57675. 1		
4s <sup>2</sup> 4p(²P°)5s	5s <sup>1</sup> P°	1	40020. 43		1. 058	4s <sup>2</sup> 4p(²P°)6p	6p <sup>1</sup> S	0	56772. 63		
4s <sup>2</sup> 4p(²P°)5p	5p <sup>1</sup> P	1	45985. 45			4s <sup>2</sup> 4p(²P°)5d	5d <sup>3</sup> F°	2			
4s <sup>2</sup> 4p(²P°)5p	5p <sup>3</sup> D	1	46765. 12	69. 11				3	56828. 3		
		2	46834. 23	1269. 74		4s <sup>2</sup> 4p(²P°)6p	6p <sup>3</sup> S	1	57083. 07		
		3	48103. 97			4s <sup>2</sup> 4p(²P°)7s	7s <sup>3</sup> P°	0	57166. 5	-245. 9	
4s <sup>2</sup> 4p(²P°)5p	5p <sup>3</sup> P	0	47502. 50	585. 70				1	56920. 6	2010. 8	
		1	48088. 20	637. 76				2	58931. 4		
		2	48725. 96			4s <sup>2</sup> 4p(²P°)5d	5d <sup>3</sup> P°	2	57178. 5	-252. 2	
4s <sup>2</sup> 4p(²P°)4d	4d <sup>1</sup> D°	2	48479. 7					1	57430. 7	-265. 4	
4s <sup>2</sup> 4p(²P°)4d	4d <sup>3</sup> D°	1	48962. 3	-80. 4				0	57696. 1		
		2	48881. 9	262. 2		4s <sup>2</sup> 4p(²P°)6p	6p <sup>1</sup> D	2	57250. 84		
		3	49144. 1			4s <sup>2</sup> 4p(²P°)5d	5d <sup>1</sup> P°	1	58056. 6		
4s <sup>2</sup> 4p(²P°)5p	5p <sup>3</sup> S	1	49075. 76			4s 4p <sup>3</sup>	4p <sup>3</sup> <sup>1</sup> D°	2	58091. 3		
4s <sup>2</sup> 4p(²P°)5p	5p <sup>1</sup> D	2	49649. 47			4s <sup>2</sup> 4p(²P°)7p	7p <sup>3</sup> D	1	58560. 69	26. 07	
4s <sup>2</sup> 4p(²P°)4d	4d <sup>3</sup> F°	2	50068. 7	254. 1				2	58586. 76		
		3	50322. 8					3			
		4				4s <sup>2</sup> 4p(²P°)5d	5d <sup>1</sup> F°	3	58941. 6		
4s <sup>2</sup> 4p(²P°)5p	5p <sup>1</sup> S	0	51011. 32			4s <sup>2</sup> 4p(²P°)7s	7s <sup>1</sup> P°	1	59113. 7		
4s <sup>2</sup> 4p(²P°)4d	4d <sup>3</sup> P°	2	51437. 4	-267. 2	1. 50	4s 4p <sup>3</sup>	4p <sup>3</sup> <sup>3</sup> D°	3	59655. 1	-33. 0	
		1	51704. 6	-275. 2				2	59688. 1	-36. 6	
		0	51979. 8					1	59724. 7		
4s <sup>2</sup> 4p(²P°)6s	6s <sup>3</sup> P°	0	52170. 3	-22. 1		4s <sup>2</sup> 4p(²P°)6d	6d <sup>1</sup> D°	2	60885. 2		
		1	52148. 2	1762. 3		4s <sup>2</sup> 4p(²P°)6d	6d <sup>1</sup> P°	1	61151. 9		
		2	53910. 5			4s <sup>2</sup> 4p(²P°)6d	6d <sup>1</sup> F°	3	61266. 8		
4s <sup>2</sup> 4p(²P°)4d	4d <sup>1</sup> F°	3	52592. 0			4s <sup>2</sup> 4p(²P°)8s	8s <sup>1</sup> P°	1	61342. 8		
4s <sup>2</sup> 4p(²P°)4d	4d <sup>1</sup> P°	1	52847. 0		1. 03						
4s <sup>2</sup> 4p(²P°)6s	6s <sup>1</sup> P°	1	54174. 6								
4s <sup>2</sup> 4p(²P°)6p	6p <sup>1</sup> P	1	54935. 74								
4s <sup>2</sup> 4p(²P°)6p	6p <sup>3</sup> D	1	55235. 68	30. 30							
		2	55265. 98	1501. 57							
		3	56767. 55?								
4s <sup>2</sup> 4p(²P°)5d	5d <sup>3</sup> D°	1	55469. 7	-97. 3							
		2	55372. 4	313. 2							
		3	55685. 6								
						Ge II (²P° <sub>3/2</sub> )	Limit	-----	63600		

October 1951.

## Ge I OBSERVED TERMS\*

Config. $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} +$	Observed Terms		
$4s^2 4p^2$	{ $4p^2 \ ^1S$ $4p^2 \ ^3P$ $4p^2 \ ^1D$ }		
$4s 4p^3$	{ $4p^3 \ ^3P^\circ$ $4p^3 \ ^3D^\circ$ $4p^3 \ ^1P^\circ$ $4p^3 \ ^1D^\circ$ }		
	$ns \ (n \geq 5)$	$np \ (n \geq 5)$	$nd \ (n \geq 4)$
$4s^2 4p(^2P^\circ)nx$	{ $5-7s \ ^3P^\circ$ $5-8s \ ^1P^\circ$ }	$5, 6p \ ^3S$ $5, 6p \ ^3P$ $5-7p \ ^3D$ $5, 6p \ ^1S$ $5, 6p \ ^1P$ $5, 6p \ ^1D$	$4, 5d \ ^3P^\circ$ $4, 5d \ ^3D^\circ$ $4, 5d \ ^3F^\circ$ $4-6d \ ^1P^\circ$ $4-6d \ ^1D^\circ$ $4-6d \ ^1F^\circ$

\*For predicted terms in the spectra of the Ge I isoelectronic sequence, see Vol. II, Introduction.

## Ge II

(Ga I sequence; 31 electrons)

$Z=32$

Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p \ ^2P_{0\frac{1}{2}}$

$4p \ ^2P_{0\frac{1}{2}} \ 128518 \text{ cm}^{-1}$

I. P. 15.93 volts

The analysis of this spectrum was begun by Lang, who classified 33 lines and found 10 terms. Rao and Narayan also reported 8 terms and an estimated value of the limit. It has been greatly extended by Gartlein, who has furnished his unpublished data especially for inclusion here. He has observed the spectrum from 813 Å to 6484 Å and now has 131 classified lines.

From three series,  $ns \ ^2S$  ( $n=5-9$ ),  $nd \ ^2D$  ( $n=4-10$ ), and  $nf \ ^2F^\circ$  ( $n=4-11$ ) he determines the limit quoted here. It is based on a Hicks formula and is derived by the method suggested by Shenstone. Meissner and Andrew have made further observations between 4741 and 7145 Å that have enabled the writer to derive improved term values for inclusion here. They have resolved the  $4-7f \ ^2F^\circ$  terms by combining their data with those of Gartlein. The three place entries in the table are from their interferometer observations.

The quartet terms are connected with the doublet terms by observed intersystem combinations.

The observed  $g$ -values have been determined by the writer from the Zeeman patterns published in the 1941 reference below.

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 K. W. Meissner and K. L. Andrew, unpublished material (November 1951). (T) (C L)



## Ge II

## Ge II

Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>	Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>
4s <sup>2</sup> ( <sup>1</sup> S)4 <i>p</i>	4 <i>p</i> <sup>2</sup> P°	0½ 1½	0. 0 1767. 1	1767. 1		4s <sup>2</sup> ( <sup>1</sup> S)6 <i>g</i>	6 <i>g</i> <sup>2</sup> G	{ 3½ 4½ }	116265. 94		
4s 4 <i>p</i> <sup>2</sup>	4 <i>p</i> <sup>2</sup> <sup>4</sup> P	0½ 1½ 2½	51575. 5 52290. 5 53366. 7	715. 0 1076. 2		4s <sup>2</sup> ( <sup>1</sup> S)9 <i>s</i>	9 <i>s</i> <sup>2</sup> S	0½	118522. 4		
4s <sup>2</sup> ( <sup>1</sup> S)5 <i>s</i>	5 <i>s</i> <sup>2</sup> S	0½	62402. 360		2. 00	4s <sup>2</sup> ( <sup>1</sup> S)8 <i>d</i>	8 <i>d</i> <sup>2</sup> D	1½ 2½	119337. 8 119345. 2	7. 4	
4s 4 <i>p</i> <sup>2</sup>	4 <i>p</i> <sup>2</sup> <sup>2</sup> D	1½ 2½	65015. 0 65184. 070	169. 1		4s <sup>2</sup> ( <sup>1</sup> S)7 <i>f</i>	7 <i>f</i> <sup>2</sup> F°	3½ 2½	119373. 27 119373. 72	—0. 45	
4s <sup>2</sup> ( <sup>1</sup> S)5 <i>p</i>	5 <i>p</i> <sup>2</sup> P°	0½ 1½	79006. 205 79365. 847	359. 642	0. 67 1. 33	4s <sup>2</sup> ( <sup>1</sup> S)7 <i>g</i>	7 <i>g</i> <sup>2</sup> G	{ 3½ 4½ }	119521. 03		
4s <sup>2</sup> ( <sup>1</sup> S)4 <i>d</i>	4 <i>d</i> <sup>2</sup> D	1½ 2½	80836. 05 81011. 80	175. 75		4s <sup>2</sup> ( <sup>1</sup> S)10 <i>s</i>	10 <i>s</i> <sup>2</sup> S	0½	120975. 9		
4s 4 <i>p</i> <sup>2</sup>	4 <i>p</i> <sup>2</sup> <sup>2</sup> S	0½	85889. 9			4s <sup>2</sup> ( <sup>1</sup> S)9 <i>d</i>	9 <i>d</i> <sup>2</sup> D	{ 1½ 2½ }	121512. 7		
4s 4 <i>p</i> <sup>2</sup>	4 <i>p</i> <sup>2</sup> <sup>2</sup> P	0½ 1½	91014. 8 92122. 1	1107. 3		4s <sup>2</sup> ( <sup>1</sup> S)8 <i>f</i>	8 <i>f</i> <sup>2</sup> F°	{ 2½ 3½ }	121531. 4		
4s <sup>2</sup> ( <sup>1</sup> S)6 <i>s</i>	6 <i>s</i> <sup>2</sup> S	0½	94783. 758			4s 4 <i>p</i> ( <sup>3</sup> P°)5 <i>s</i> :	5 <i>s</i> <sup>2</sup> P°	0½ 1½	121914. 1 123099. 8	1185. 7	
4s <sup>2</sup> ( <sup>1</sup> S)5 <i>d</i>	5 <i>d</i> <sup>2</sup> D	1½ 2½	100089. 32 100130. 18	40. 86	0. 77 1. 20	4s 4 <i>p</i> ( <sup>3</sup> P°)5 <i>s</i> :	5 <i>s</i> <sup>4</sup> P°	0½ 1½ 2½	122693. 7? 123401. 4 124730. 5	707. 7 329. 1	
4s <sup>2</sup> ( <sup>1</sup> S)4 <i>f</i>	4 <i>f</i> <sup>2</sup> F°	3½ 2½	100316. 50 100317. 14	—0. 64		4s <sup>2</sup> ( <sup>1</sup> S)10 <i>d</i>	10 <i>d</i> <sup>2</sup> D	{ 1½ 2½ }	122996. 0		
4s <sup>2</sup> ( <sup>1</sup> S)6 <i>p</i>	6 <i>p</i> <sup>2</sup> P°	{ 0½ 1½ }	101242. 8			4s <sup>2</sup> ( <sup>1</sup> S)9 <i>f</i>	9 <i>f</i> <sup>2</sup> F°	{ 2½ 3½ }	123007. 0		
4s <sup>2</sup> ( <sup>1</sup> S)7 <i>s</i>	7 <i>s</i> <sup>2</sup> S	0½	107935. 40			4s <sup>2</sup> ( <sup>1</sup> S)11 <i>d</i>	11 <i>d</i> <sup>2</sup> D	{ 1½ 2½ }	124053. 7		
4s <sup>2</sup> ( <sup>1</sup> S)6 <i>d</i>	6 <i>d</i> <sup>2</sup> D	1½ 2½	110377. 39 110396. 93	19. 54		4s <sup>2</sup> ( <sup>1</sup> S)10 <i>f</i>	10 <i>f</i> <sup>2</sup> F°	{ 2½ 3½ }	124061. 6		
4s <sup>2</sup> ( <sup>1</sup> S)5 <i>f</i>	5 <i>f</i> <sup>2</sup> F°	3½ 2½	110503. 69 110504. 43	—0. 74		4s <sup>2</sup> ( <sup>1</sup> S)11 <i>f</i>	11 <i>f</i> <sup>2</sup> F°	{ 2½ 3½ }	124840. 3		
4s <sup>2</sup> ( <sup>1</sup> S)7 <i>p</i>	7 <i>p</i> <sup>2</sup> P°	{ 0½ 1½ }	111016. 2			4s <sup>2</sup> ( <sup>1</sup> S)12 <i>f</i>	12 <i>f</i> <sup>2</sup> F°	{ 2½ 3½ }	125431. 5		
4s <sup>2</sup> ( <sup>1</sup> S)8 <i>s</i>	8 <i>s</i> <sup>2</sup> S	0½	114637. 84			-----	-----	-----	-----	-----	-----
4s <sup>2</sup> ( <sup>1</sup> S)7 <i>d</i>	7 <i>d</i> <sup>2</sup> D	1½ 2½	115977. 10 115987. 14	10. 04		Ge III( <sup>1</sup> S <sub>0</sub> )	<i>Limit</i>	-----	128518		
4s <sup>2</sup> ( <sup>1</sup> S)6 <i>f</i>	6 <i>f</i> <sup>2</sup> F°	3½ 2½	116040. 62 116041. 16	—0. 54		4 <i>p</i> <sup>3</sup>	4 <i>p</i> <sup>3</sup> <sup>4</sup> S°	1½	136237. 3		

November 1951.

## Ge II OBSERVED TERMS\*

Config. 1s <sup>2</sup> 2s <sup>2</sup> 2 <i>p</i> <sup>6</sup> 3s <sup>2</sup> 3 <i>p</i> <sup>2</sup> 3 <i>d</i> <sup>10</sup> +	Observed Terms				
4s <sup>2</sup> ( <sup>1</sup> S)4 <i>p</i>	4 <i>p</i> <sup>2</sup> P°				
4s 4 <i>p</i> <sup>2</sup>	{ 4 <i>p</i> <sup>2</sup> <sup>2</sup> S    4 <i>p</i> <sup>2</sup> <sup>4</sup> P    4 <i>p</i> <sup>2</sup> <sup>2</sup> P    4 <i>p</i> <sup>2</sup> <sup>2</sup> D				
4 <i>p</i> <sup>3</sup>	4 <i>p</i> <sup>3</sup> <sup>4</sup> S°:				
	<i>ns</i> ( <i>n</i> ≥ 5)	<i>np</i> ( <i>n</i> ≥ 5)	<i>nd</i> ( <i>n</i> ≥ 4)	<i>nf</i> ( <i>n</i> ≥ 4)	<i>ng</i> ( <i>n</i> ≥ 5)
4s <sup>2</sup> ( <sup>1</sup> S) <i>nx</i>	5–10 <i>s</i> <sup>2</sup> S	5–7 <i>p</i> <sup>2</sup> P°	4–11 <i>d</i> <sup>2</sup> D	4–12 <i>f</i> <sup>2</sup> F°	6, 7 <i>g</i> <sup>2</sup> G
4s 4 <i>p</i> ( <sup>3</sup> P°) <i>nx</i>	{ 5 <i>s</i> <sup>4</sup> P°: 5 <i>s</i> <sup>2</sup> P°:				

\*For predicted terms in the spectra of the Ga I isoelectronic sequence, see Vol. II, Introduction.

## Ge III

(Zn I sequence; 30 electrons)

 $Z=32$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 {}^1S_0$  $4s^2 {}^1S_0$  276036  $\text{cm}^{-1}$ 

I. P. 34.21 volts

The analysis is from Lang, who has revised and extended the earlier work on this spectrum, and published a list of 86 classified lines between 542 Å and 5256 Å. His term values "depend upon an arbitrary choice of 65500  $\text{cm}^{-1}$ " for the absolute value of  $4f {}^3F_4$ . This choice is based on isoelectronic sequence data and "has been made with reasonable accuracy."

Rao and Narayan list in addition 6 "even" miscellaneous levels that are not included here.

The writer has derived the tabulated  $g$ -values from the observed Zeeman patterns given in the 1941 reference below.

The singlet and triplet systems of terms are connected by observed intersystem combinations.

## REFERENCES

K. R. Rao and A. L. Narayan, Proc. Roy. Soc. London [A], **119**, 616 (1928). (I P) (T) (C L)

R. J. Lang, Phys. Rev. **34**, 696 (1929). (I P) (T) (C L)

J. C. van den Bosch and P. F. A. Klinkenberg, Proc. Ned. Akad. v. Wetensch. Amsterdam **44**, No. 5, 560 (1941). (Z E)

## Ge III

## Ge III

Config.	Desig.	$J$	Level	Interval	Obs. $g$	Config.	Desig.	$J$	Level	Interval	Obs. $g$
$4s^2$	$4s^2 {}^1S$	0	0			$4p({}^2P^\circ)4d$	$4d {}^1D^\circ$	2	197122		
$4s({}^2S)4p$	$4p {}^3P^\circ$	0 1 2	61733 62496 64138	763 1642		$4s({}^2S)4f$	$4f {}^3F^\circ$	2 3 4	210455.3 210472.7 210536	17.4 63	
$4s({}^2S)4p$	$4p {}^1P^\circ$	1	91873			$4s({}^2S)4f$	$4f {}^1F^\circ$	3	210531		
$4s({}^2S)4d$	$4d {}^1D$	2	144972			$4s({}^2S)6s$	$6s {}^3S$	1	211149		1.94
$4p^2$	$4p^2 {}^3P$	0 1 2	147691 148644 150373	953 1729		$4p({}^2P^\circ)4d$	$4d {}^1P^\circ$	1	212359		
$4p^2$	$4p^2 {}^1D$	2	148776			$4s({}^2S)5d$	$5d {}^3D$	1 2 3	213133.2 213163.8 213208.0	30.6 44.2	0.50 1.16 1.32
$4s({}^2S)5s$	$5s {}^3S$	1	158576.2		1.99	$4p({}^2P^\circ)4d$	$4d {}^1F^\circ$	3	213579		
$4s({}^2S)4d$	$4d {}^3D$	1 2 3	162851.0 162921.8 163028.3	70.8 106.5		$4s({}^2S)5g$	$5g {}^1G$	4	234910??		
$4s({}^2S)5s$	$5s {}^1S$	0	167450			$4s({}^2S)5g$	$5g {}^3G$	3, 4, 5	234928?		
$4s({}^2S)5p$	$5p {}^3P^\circ$	0 1 2	181871 182039 182498	168 459	1.48 1.49	$4d^2?$	$4d^2 {}^1D$	2	235908		
$4s({}^2S)5p$	$5p {}^1P^\circ$	1	184308.8			Ge IV ( ${}^2S_{1/2}$ )	Limit	-----	276036		

March 1950.

Ge III OBSERVED TERMS\*

Config. 1s <sup>2</sup> 2s <sup>2</sup> 2p <sup>6</sup> 3s <sup>2</sup> 3p <sup>6</sup> 3d <sup>10</sup> +	Observed Terms				
4s <sup>2</sup>	4s <sup>2</sup> <sup>1</sup> S				
4p <sup>2</sup>	{ 4p <sup>2</sup> <sup>3</sup> P      4p <sup>2</sup> <sup>1</sup> D				
4d <sup>2</sup>	4d <sup>2</sup> <sup>1</sup> D?				
	ns (n ≥ 5)	np (n ≥ 4)	nd (n ≥ 4)	nf (n ≥ 4)	ng (n ≥ 5)
4s( <sup>2</sup> S)nx	{ 5, 6s <sup>3</sup> S 5s <sup>1</sup> S	4, 5p <sup>3</sup> P° 4, 5p <sup>1</sup> P°	4, 5d <sup>3</sup> D 4d <sup>1</sup> D	4f <sup>3</sup> F° 4f <sup>1</sup> F°	5g <sup>3</sup> G? 5g <sup>1</sup> G?
4p( <sup>2</sup> P°)nx			4d <sup>1</sup> P°    4d <sup>1</sup> D°    4d <sup>1</sup> F°		

\*For predicted terms of the Zn I isoelectronic sequence, see Vol. II, Introduction.

Ge IV

(Cu I sequence; 29 electrons)

Z=32

Ground state 1s<sup>2</sup> 2s<sup>2</sup> 2p<sup>6</sup> 3s<sup>2</sup> 3p<sup>6</sup> 3d<sup>10</sup> 4s <sup>2</sup>S<sub>0½</sub>

4s <sup>2</sup>S<sub>0½</sub> **368701** cm<sup>-1</sup>

I. P. 45.7 volts

Carroll, in 1925, reported five doublet series terms, and determined the limit by assuming an absolute value of 4f <sup>2</sup>F° (111200 cm<sup>-1</sup>) consistent with extrapolated isoelectronic sequence data.

In 1929 Lang remeasured the spectrum, and revised and extended the earlier term values, retaining the same assumed absolute value of 4f <sup>2</sup>F°. He concludes from a study of the isoelectronic sequence that this value is as nearly accurate as can be hoped for at present. Lang's values have been used in the present compilation. Two probable misprints in his term list have been corrected, namely, the terms 4s<sup>2</sup> <sup>2</sup>D and 4f <sup>2</sup>F° are here entered as inverted.

The observed g-values have been derived by the writer from the observed Zeeman patterns given in the 1941 reference below.

There are 34 classified lines between 440 Å and 3676 Å.

REFERENCES

J. A. Carroll, Phil. Trans. Roy. Soc. (London) [A] **225**, 374 (1925). (I P) (T) (C L)  
R. J. Lang, Phys. Rev. **34**, 696 (1929). (I P) (T) (C L)  
J. C. van den Bosch and P. F. A. Klinkenberg, Proc. Ned. Akad. v. Wet. Amsterdam **44**, No. 5, 560 (1941). (Z E)

Ge IV

Ge IV

Config.	Desig.	J	Level	Interval	Obs. g	Config.	Desig.	J	Level	Interval	Obs. g
3d <sup>10</sup> ( <sup>1</sup> S)4s	4s <sup>2</sup> S	0½	0			3d <sup>10</sup> ( <sup>1</sup> S)5d	5d <sup>2</sup> D	1½ 2½	266637 266717	80	0. 80 1. 19
3d <sup>10</sup> ( <sup>1</sup> S)4p	4p <sup>2</sup> P°	0½ 1½	81315 84103	2788		3d <sup>10</sup> ( <sup>1</sup> S)6s	6s <sup>2</sup> S	0½	270058		
3d <sup>10</sup> ( <sup>1</sup> S)4d	4d <sup>2</sup> D	1½ 2½	190607 190861	254	0. 82 1. 26	3d <sup>10</sup> ( <sup>1</sup> S)6p	6p <sup>2</sup> P°	0½ 1½	283621 283763	142	
3d <sup>10</sup> ( <sup>1</sup> S)5s	5s <sup>2</sup> S	0½	199269		2. 04	3d <sup>10</sup> ( <sup>1</sup> S)5g	5g <sup>2</sup> G	{ 3½ 4½ }	298379		
3d <sup>10</sup> ( <sup>1</sup> S)5p	5p <sup>2</sup> P°	0½ 1½	226459 227397	938	0. 68 1. 34						
3d <sup>10</sup> ( <sup>1</sup> S)4f	4f <sup>2</sup> F°	3½ 2½	257496 257501	—5		Ge v ( <sup>1</sup> S <sub>0</sub> )	Limit	-----	368701		
3d <sup>9</sup> 4s <sup>2</sup>	4s <sup>2</sup> <sup>2</sup> D	2½ 1½	259942 264445	—4503							



## Ge v

(Ni I sequence; 28 electrons)

 $Z=32$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} {}^1S_0$  $3d^{10} {}^1S_0$  753800  $\text{cm}^{-1}$ 

I. P. 93.4 volts

Mack, Laporte, and Lang have found 8 terms and classified 33 lines between 942 Å and 1222 Å by using the observations by Carroll. From three lines at 294 Å, 295 Å, and 304 Å, the ground term was found by Kruger and Shoupp; who also determined the limit from an empirical formula based on extrapolation of isoelectronic sequence data. Their value of the limit, rounded off, is entered in brackets in the table. The observations in the far ultraviolet indicate a correction of  $+234231 \text{ cm}^{-1}$  to the terms by Mack, Laporte, and Lang, in order to reduce them to the ground term zero. This correction has been made in compiling the table below.

The singlet and triplet terms are connected by observed intersystem combinations.

## REFERENCES

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 J. E. Mack, O. Laporte, and R. J. Lang, Phys. Rev. **31**, 748 (1928). (T) (C L)  
 P. G. Kruger and W. E. Shoupp, Phys. Rev. **46**, 124 (1934). (I P) (T) (C L)

Ge v					Ge v				
Config.	Desig.	$J$	Level	Interval	Config.	Desig.	$J$	Level	Interval
$3d^{10}$	$3d^{10} {}^1S$	0	0		$3d^9(2D)4p$	$4p {}^3D^\circ$	3 2 1	335187 335549 339554	-362 -4005
$3d^9(2D)4s$	$4s {}^3D$	3 2 1	234231 235971 238767	-1740 -2796	$3d^9(2D)4p$	$4p {}^1F^\circ$	3	337192	
$3d^9(2D)4s$	$4s {}^1D$	2	241947		$3d^9(2D)4p$	$4p {}^1P^\circ$	1	338255	
$3d^9(2D)4p$	$4p {}^3P^\circ$	2 1 0	323772 327855 330342	-4083 -2487	$3d^9(2D)4p$	$4p {}^1D^\circ$	2	340311	
$3d^9(2D)4p$	$4p {}^3F^\circ$	4 3 2	329879 327766 330805	2113 -3039	Ge VI ( $2D_{3/2}$ )	Limit	-----	[753800]	

November 1949.

## Ge v OBSERVED TERMS\*

Config. $1s^2 2s^2 2p^6 3s^2 3p^6 +$	Observed Terms	
$3d^{10}$	$3d^{10} {}^1S$	
	$ns (n \geq 4)$	$np (n \geq 4)$
$3d^9(2D)nz$	{ $4s {}^3D$ $4s {}^1D$	$4p {}^3P^\circ$ $4p {}^3D^\circ$ $4p {}^3F^\circ$ $4p {}^1P^\circ$ $4p {}^1D^\circ$ $4p {}^1F^\circ$

\* For predicted terms in the spectra of the Ni I isoelectronic sequence, see Vol. II, Introduction.

## ARSENIC

## As I

33 electrons

 $Z=33$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^3 {}^4S_{1/2}$  $4p^3 {}^4S_{1/2}$  79165  $\text{cm}^{-1}$ 

I. P. 9.81 volts

Meggers has extended and revised the earlier work by himself and others. His observations extend from 1407 Å to 11679 Å, those of wavelength shorter than 2000 Å being from arc spectrograms made by Shenstone.

The present analysis has been submitted in manuscript especially for inclusion here. There are 246 classified lines, and the doublet and quartet terms are connected by observed intersystem combinations. More than 74 percent of the total number and 97 percent of the total intensity of observed lines have been explained as combinations of 30 odd energy levels arising from  $4s^2 4p^3$  and  $4s^2 4p^2 np$  electrons, and 58 even levels from  $4s 4p^4$ ,  $4s^2 4p^2 ns$ , and  $4s^2 4p^2 nd$ .

The limit is derived from the  $ns {}^4P$  series ( $n=5, 6$ ), and is based on a Ritz formula with the assumption that  $\alpha=2.5 \times 10^{-6}$ , as suggested by Shenstone.

## REFERENCES

- K. R. Rao, Proc. Roy. Soc. (London) [A] **125**, 238 (1929). (T) (C L)  
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 J. E. Mack, Rev. Mod. Phys. **22**, No. 1, 64 (1950). (Summary hfs)  
 W. F. Meggers, A. G. Shenstone, and C. E. Moore, Bur. Std. J. Research **45**, 346, RP2144 (1950). (I P) (T) (C L)

## As I

## As I

Config.	Desig.	$J$	Level	Interval	Obs. $g$	Config.	Desig.	$J$	Level	Interval	Obs. $g$
$4s^2 4p^3$	$4p^3 {}^4S^\circ$	$1\frac{1}{2}$	0. 0			$4s^2 4p^2({}^3P)5p$	$5p {}^4D^\circ$	$0\frac{1}{2}$	60791. 5		
$4s^2 4p^3$	$4p^3 {}^2D^\circ$	$1\frac{1}{2}$	10592. 5	322. 1	0. 813			$1\frac{1}{2}$	60860. 0	68. 5	
		$2\frac{1}{2}$	10914. 6		1. 208			$2\frac{1}{2}$	61685. 0	825. 0	
								$3\frac{1}{2}$	62871. 2	1186. 2	
$4s^2 4p^3$	$4p^3 {}^2P^\circ$	$0\frac{1}{2}$	18186. 1	461. 4	0. 687	$4s^2 4p^2({}^1D)5s$	$5s' {}^2D$	$2\frac{1}{2}$	60815. 0	—19. 8	0. 84
		$1\frac{1}{2}$	18647. 5		1. 313			$1\frac{1}{2}$	60834. 8		
$4s^2 4p^2({}^3P)5s$	$5s {}^4P$	$0\frac{1}{2}$	50693. 8	916. 4	2. 617	$4s^2 4p^2({}^3P)5p$	$5p {}^4P^\circ$	$0\frac{1}{2}$	62026. 3	371. 7	
		$1\frac{1}{2}$	51610. 2	1287. 7	1. 706			$1\frac{1}{2}$	62398. 0	884. 8	
		$2\frac{1}{2}$	52897. 9					$2\frac{1}{2}$	63282. 8		
$4s^2 4p^2({}^3P)5s$	$5s {}^2P$	$0\frac{1}{2}$	53135. 6	1469. 7	0. 736	$4s^2 4p^2({}^3P)5p$	$5p {}^2D^\circ$	$1\frac{1}{2}$	62554. 4	1614. 8	
		$1\frac{1}{2}$	54605. 3		1. 327			$2\frac{1}{2}$	64169. 2		
$4s 4p^4$	$4p^4 {}^4P$	$2\frac{1}{2}$	55366. 4	—1497. 2		$4s^2 4p^2({}^3P)4d$	$4d {}^4P$	$2\frac{1}{2}$	62751. 1	—752. 5	
		$1\frac{1}{2}$	56863. 6	—624. 5				$1\frac{1}{2}$	63503. 6	—478. 1	
		$0\frac{1}{2}$	57488. 1					$0\frac{1}{2}$	63981. 7		

As I—Continued

As I—Continued

Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>	Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>
4s <sup>2</sup> 4p <sup>2</sup> ( <sup>3</sup> P)5p	5p <sup>4</sup> S°	1½	63647. 0			4s <sup>2</sup> 4p <sup>2</sup> ( <sup>3</sup> P)6p	6p <sup>2</sup> S°	0½	71199. 1		
4s <sup>2</sup> 4p <sup>2</sup> ( <sup>3</sup> P)5p	5p <sup>2</sup> S°	0½	64059. 0			4s <sup>2</sup> 4p <sup>2</sup> ( <sup>3</sup> P)6p	6p <sup>2</sup> D°	1½ 2½	71621. 4 72944. 4	1323. 0	
4s <sup>2</sup> 4p <sup>2</sup> ( <sup>3</sup> P)4d	4d <sup>2</sup> P	0½ 1½	64122. 0 66485. 2	2363. 2		4s <sup>2</sup> 4p <sup>2</sup> ( <sup>1</sup> D)5p	5p' <sup>2</sup> P°	0½ 1½	71796. 2 71931. 7	135. 5	
4s <sup>2</sup> 4p <sup>2</sup> ( <sup>3</sup> P)5p	5p <sup>2</sup> P°	0½ 1½	64323. 8 64637. 6	363. 8		4s <sup>2</sup> 4p <sup>2</sup> ( <sup>1</sup> D)4d	4d' <sup>2</sup> P	0½ 1½	71924. 4 72125. 0	200. 6	
4s <sup>2</sup> 4p <sup>2</sup> ( <sup>3</sup> P)4d	4d <sup>2</sup> D	1½ 2½	64342. 4 66725. 4	2383. 0		4s <sup>2</sup> 4p <sup>2</sup> ( <sup>1</sup> S)5s	5s'' <sup>2</sup> S	0½	72399. 4		
4s <sup>2</sup> 4p <sup>2</sup> ( <sup>3</sup> P)4d	4d <sup>2</sup> F	2½ 3½	64639. 5 66785. 2	2145. 7			4	1½	72519. 4		
4s 4p <sup>4</sup>	4p <sup>4</sup> <sup>2</sup> P	1½ 0½	64811. 5 65497. 4	—685. 9		4s <sup>2</sup> 4p <sup>2</sup> ( <sup>3</sup> P)6p	6p <sup>4</sup> S°	1½	72620. 3		
4s 4p <sup>4</sup>	4p <sup>4</sup> <sup>2</sup> S	0½	66588. 3				5	1½	72779. 0		
4s <sup>2</sup> 4p <sup>2</sup> ( <sup>3</sup> P)6s	6s <sup>4</sup> P	0½ 1½ 2½	67008. 7 67920. 2 69314. 8	911. 5 1394. 6		4s <sup>2</sup> 4p <sup>2</sup> ( <sup>3</sup> P)6p	6p <sup>2</sup> P°	0½ 1½	72800. 6 73244. 8	444. 2	
4s 4p <sup>4</sup>	4p <sup>4</sup> <sup>2</sup> D	1½ 2½	68300. 6 68402. 7	102. 1			6	1½, 2½	73566. 0		
4s <sup>2</sup> 4p <sup>2</sup> ( <sup>3</sup> P)6s	6s <sup>2</sup> P	0½ 1½	68314. 5 69696. 2	1381. 7			7	1½	73635. 0		
	1	0½, 1½	69644. 8				8	1½, 2½	74049. 7		
	2	1½, 2½	69698. 3				9	0½, 1½	74143. 8		
4s <sup>2</sup> 4p <sup>2</sup> ( <sup>3</sup> P)6p	6p <sup>4</sup> P°	0½ 1½ 2½	69881. 5 70849. 7 72501. 9	968. 2 1652. 2		4s <sup>2</sup> 4p <sup>2</sup> ( <sup>1</sup> S)4d	4d'' <sup>2</sup> D	2½ 1½	74453. 1 74810. 5	—357. 4	
4s <sup>2</sup> 4p <sup>2</sup> ( <sup>1</sup> D)5p	5p' <sup>2</sup> D°	1½ 2½	70108. 4 70376. 6	268. 2			10	0½, 1½	75086. 0		
4s <sup>2</sup> 4p <sup>2</sup> ( <sup>3</sup> P)6p	6p <sup>4</sup> D°	0½ 1½ 2½ 3½	70274. 9 70516. 6 71131. 0 72341. 6	241. 7 614. 4 1210. 6			11	1½, 2½	75176. 4		
4s <sup>2</sup> 4p <sup>2</sup> ( <sup>1</sup> D)5p	5p' <sup>2</sup> F°	2½ 3½	70821. 4 70927. 5	106. 1			12	1½, 2½	75578. 7		
	3	1½	71055. 2				13	0½, 1½	75799. 4		
							14	1½	76076. 2		
							15	1½, 2½	76835. 6		
							16	1½, 2½	77121. 7		
							17	1½, 2½	77272. 5		
						As II ( <sup>3</sup> P <sub>0</sub> )	Limit	-----	79165		

May 1950.

As I OBSERVED TERMS\*

1s <sup>2</sup> 2s <sup>2</sup> 2p <sup>6</sup> 3s <sup>2</sup> 3p <sup>6</sup> 3d <sup>10</sup> +	Observed Terms		
4s <sup>2</sup> 4p <sup>3</sup>	{ 4p <sup>3</sup> <sup>4</sup> S°      4p <sup>3</sup> <sup>2</sup> P°      4p <sup>3</sup> <sup>2</sup> D°		
4s 4p <sup>4</sup>	{ 4p <sup>4</sup> <sup>2</sup> S      4p <sup>4</sup> <sup>4</sup> P      4p <sup>4</sup> <sup>2</sup> P      4p <sup>4</sup> <sup>2</sup> D		
	ns (n ≥ 5)	np (n ≥ 5)	nd (n ≥ 4)
4s <sup>2</sup> 4p <sup>2</sup> ( <sup>3</sup> P)nx	{ 5, 6s <sup>4</sup> P 5, 6s <sup>2</sup> P	5, 6p <sup>4</sup> S°   5, 6p <sup>4</sup> P°   5, 6p <sup>4</sup> D° 5, 6p <sup>2</sup> S°   5, 6p <sup>2</sup> P°   5, 6p <sup>2</sup> D°	4d <sup>4</sup> P 4d <sup>2</sup> P   4d <sup>2</sup> D   4d <sup>2</sup> F
4s <sup>2</sup> 4p <sup>2</sup> ( <sup>1</sup> D)nx'	5s' <sup>2</sup> D	5p' <sup>2</sup> P°      5p' <sup>2</sup> D°      5p' <sup>2</sup> F°	4d' <sup>2</sup> P
4s <sup>2</sup> 4p <sup>2</sup> ( <sup>1</sup> S)nx''	5s'' <sup>2</sup> S		4d'' <sup>2</sup> D

\*For predicted terms in the spectra of the As I isoelectronic sequence, see Introduction.



(Ge I sequence; 32 electrons)

 $Z=33$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^2 {}^3P_0$  $4p^2 {}^3P_0$  163000  $\text{cm}^{-1}$ 

I. P. 20.2 volts

A. S. Rao has published 187 classified lines in the interval 802 Å to 6528 Å, 22 terms, and 14 miscellaneous levels. C. W. Gartlein has also studied this spectrum and confirmed 15 of these terms and four of the miscellaneous levels, with the conclusion that the spectrum needs careful observation over the entire range for three reasons: existing wavelengths need to be improved in precision, the lines due only to As II need to be carefully selected, and the series should be extended.

The writer has adopted Gartlein's term values when available, supplemented by those of Rao, adding  $5d {}^3F_2^\circ$  and  $5d {}^3D_2^\circ$  from the paper by Green and Barrows on Zeeman Effect. Decimals are omitted throughout, since the discordances between the two term lists exceed  $1 \text{ cm}^{-1}$  in many cases. All  $g$ -values are from the 1935 paper, that for  $4i$  having been derived by the writer. All others are either the  $g$ -values adopted by these authors, or means taken by the writer from the individual  $g$ -values they derive.

Miscellaneous levels have here been assigned numbers as follows: those labeled by Rao "a to g" are here called  $1^\circ$  to  $7^\circ$  respectively; and, similarly those called "A to G" are here designated 1 to 7, respectively. The combinations do not indicate which of the two  $J$ -values entered in the table is correct for the levels 1, 2, 3, 5, and 6.

Rao has determined the limit  $162788 \text{ cm}^{-1}$  by applying a Rydberg formula to the lines designated as  $5s {}^1P_1^\circ - 4p^2 {}^1D_2$  and  $5s {}^1P_1^\circ - 5p {}^1D_2$ . Similarly, the writer obtains the value  $163040 \text{ cm}^{-1}$  from the  $ns {}^3P_2^\circ$  series ( $n=5,6$ ). The round figure 163000 is adopted in the table pending further observations.

Observed intersystem combinations connect the singlet and triplet systems of terms.

## REFERENCES

- A. S. Rao, Ind. J. Phys. **7**, 561 (1932). (I P) (T) (C L)  
 J. B. Green and W. M. Barrows, Jr., Phys. Rev. **47**, 133 (1935). (C L) (Z E)  
 J. E. Mack, Rev. Mod. Phys. **22**, No. 1, 64 (1950). (Summary hfs)  
 C. W. Gartlein, unpublished material, December 1950. (T)

## As II

## As II

Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>	Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>
4s <sup>2</sup> 4p <sup>2</sup>	4p <sup>2</sup> <sup>3</sup> P	0	0	1061 1479		4s <sup>2</sup> 4p( <sup>2</sup> P°) 5s	5s <sup>1</sup> P°	1	82818		1. 075
		1	1061								
		2	2540			4s 4p <sup>3</sup>	4p <sup>3</sup> <sup>1</sup> P°	1	83099		
4s <sup>2</sup> 4p <sup>2</sup>	4p <sup>2</sup> <sup>1</sup> D	2	10093			4s 4p <sup>3</sup>	4p <sup>3</sup> <sup>3</sup> P°	0	84449	189 467	
4s <sup>2</sup> 4p <sup>2</sup>	4p <sup>2</sup> <sup>1</sup> S	0	22593					1	84638		
4s 4p <sup>3</sup>		4p <sup>3</sup> <sup>3</sup> D°	1			73748	2	85105			
		2	73860	112 382	0. 508 1. 176 1. 335	4s <sup>2</sup> 4p( <sup>3</sup> P°) 4d	4d <sup>3</sup> F°	2	88827	718	0. 58 1. 07
		3	74242					3	89545		
		4s <sup>2</sup> 4p( <sup>2</sup> P°) 5s	5s <sup>3</sup> P°			0	78729	0/0			
		1	79128	399	1. 424						
		2	81506	2378	1. 492	4s <sup>2</sup> 4p( <sup>3</sup> P°) 5p	5p <sup>1</sup> P	1	95327		0. 812

## As II—Continued

## As II—Continued

Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>	Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>
$4s^2 4p(^2P^\circ)5p$	$5p\ ^3D$	1	96912		0. 895		$4^\circ$	1	120769		1. 60
		2	97114	202	1. 174		$5^\circ$	1	121355		0. 726
		3	99195	2081	1. 325						
$4s^2 4p(^2P^\circ)5p$	$5p\ ^3P$	0	98235		0/0		1	2, 3	121519		
		1	99179	944	1. 389	$4s^2 4p(^2P^\circ)4f$	$4f\ ^3F$	2	121623		0. 88
		2	100260	1081	1. 433			3	121568	-55 1064	1. 06
$4s^2 4p(^2P^\circ)4d$	$4d\ ^3D^\circ$	1	99063		0. 895			4	122632		
		2	99545	482	1. 27						
		3	100390	845			2	2, 3	121625		
$4s^2 4p(^2P^\circ)5p$	$5p\ ^3S$	1	101088		1. 896	$4s^2 4p(^2P^\circ)5d$	$5d\ ^3D^\circ$	1			
$4s^2 4p(^2P^\circ)4d$	$4d\ ^1P^\circ$	1	101486					2	123190		1. 110
		3						3			
$4s^2 4p(^2P^\circ)5p$	$5p\ ^1D$	2	102388		1. 046	$4s^2 4p(^2P^\circ)6s$	$6s\ ^3P^\circ$	0			
$4s^2 4p(^2P^\circ)4d$	$4d\ ^1D^\circ$	2	102486		0. 94			1			
	$1^\circ$	1	102602					2	123223		1. 14
$4s^2 4p(^2P^\circ)5p$	$5p\ ^1S$	0	105786		0/0		$6^\circ$	1	123784		1. 135
$4s^2 4p(^2P^\circ)4d$	$4d\ ^1F^\circ$	3	109872				3	1, 2	124065		
$4s^2 4p(^2P^\circ)4d$	$4d\ ^3P^\circ$	2	111846				4	3	124137		0. 93
		1	112321	-475 80			5	2, 3	124206		
		0	112241				$7^\circ$	1	124547		
	$2^\circ$	1	117741		1. 11		6	2, 3	124867		
	$3^\circ$	1	118847				7	2	125243		
$4s^2 4p(^2P^\circ)5d$	$5d\ ^3F^\circ$	2	118887		0. 698						
		3									
		4									
						As III ( $^2P_{3/2}^\circ$ )	Limit	-----	163000		

January 1951.

## As II OBSERVED TERMS\*

Config. $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} +$	Observed Terms			
$4s^2 4p^2$	{ $4p^2\ ^1S$ $4p^2\ ^3P$ $4p^2\ ^1D$			
$4s 4p^3$	{ $4p^3\ ^3P^\circ$ $4p^3\ ^1D^\circ$ $4p^3\ ^1P^\circ$			
	$ns\ (n \geq 5)$	$np\ (n \geq 5)$	$nd\ (n \geq 4)$	$nf\ (n \geq 4)$
$4s^2 4p(^2P^\circ)5s$	{ $5, 6s\ ^3P^\circ$ $5s\ ^1P^\circ$	$5p\ ^3S$ $5p\ ^3P$ $5p\ ^3D$ $5p\ ^1S$ $5p\ ^1P$ $5p\ ^1D$	$4d\ ^3P^\circ$ $4, 5d\ ^3D^\circ$ $4, 5d\ ^3F^\circ$ $4d\ ^1P^\circ$ $4d\ ^1D^\circ$ $4d\ ^1F^\circ$	$4f\ ^3F$

\*For predicted terms in the spectra of the Ge I isoelectronic sequence, see Vol. II, Introduction.

## As III

(Ga I sequence; 31 electrons)

 $Z=33$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^2 P_{0\frac{1}{2}}^\circ$  $4p^2 P_{0\frac{1}{2}}^\circ$  228400  $\text{cm}^{-1}$ 

I. P. 28.3 volts

This spectrum needs further study. In 1928 Lang published 10 terms, and 35 classified lines in the interval between 603 Å and 4226 Å. He estimated the limit from isoelectronic sequence data to be  $226500 \pm 1500 \text{ cm}^{-1}$ .

K. R. Rao, in 1931, extended and revised Lang's analysis slightly, and from an assumed absolute value of  $5g^2 G = 39500 \text{ cm}^{-1}$  derived the limit  $228406 \text{ cm}^{-1}$ . The latter value in round numbers is entered in brackets in the table. The terms in the table are also from this paper.

Six additional series members and five multiplets involving suggested quartet combinations are given in the 1929 reference below. They are omitted here awaiting confirmation.

## REFERENCES

P. Pattabhiramiah and A. S. Rao, Indian J. Phys. **3**, 437 (1928). (I P) (T) (C L)

R. J. Lang, Phys. Rev. **32**, 737 (1928). (I P) (T) (C L)

A. S. Rao and A. L. Narayan, Zeit. Phys. **57**, 865 (1929). (C L)

K. R. Rao, Proc. Phys. Soc. London **43**, 68 (1931). (I P) (T) (C L)

J. B. Green and W. M. Barrows, Jr., Phys. Rev. **47**, 135 (1935). (Z E)

## As III

## As III

Config.	Desig.	$J$	Level	Interval	Obs. $g$	Config.	Desig.	$J$	Level	Interval	Obs. $g$
$4s^2(1S)4p$	$4p^2 P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	$0$ $2940$	2940		$4s^2(1S)5p$	$5p^2 P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	$131458$ $132181$	723	1. 333 0. 658
$4s 4p^2$	$4p^2^2 D$	$1\frac{1}{2}$ $2\frac{1}{2}$	85309 85630	321		$4s^2(1S)6s$	$6s^2 S$	$0\frac{1}{2}$	162889		
$4s^2(1S)5s$	$5s^2 S$	$0\frac{1}{2}$	106694		1. 996	$4s^2(1S)4f$	$4f^2 F^\circ$	$3\frac{1}{2}$ $2\frac{1}{2}$	$164105$ $164114$	—9	
$4s 4p^2$	$4p^2^2 S$	$0\frac{1}{2}$	107806			$4s^2(1S)5d$	$5d^2 D$	$1\frac{1}{2}$ $2\frac{1}{2}$	165623 165708	85	
$4s 4p^2$	$4p^2^2 P$	$0\frac{1}{2}$ $1\frac{1}{2}$	113938 115425	1487		$4s^2(1S)5g$	$5g^2 G$	$3\frac{1}{2}, 4\frac{1}{2}$	188906		
$4s^2(1S)4d$	$4d^2 D$	$1\frac{1}{2}$ $2\frac{1}{2}$	117651 117742	91		As IV ( $1S_0$ )		Limit	[228400]		

April 1950.



## As IV

(Zn I sequence; 30 electrons)

Z=33

Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 {}^1S_0$  $4s^2 {}^1S_0$  404369  $\text{cm}^{-1}$ 

I. P. 50.1 volts

Three triplet terms  $4p {}^3P^\circ$ ,  $4d {}^3D$ , and  $5s {}^3S$ , and also the combinations  $4p {}^3P^\circ - 4p {}^3P$  and  $4s^2 {}^1S_0 - 4p {}^1P_1^\circ$ , were found by Sawyer and Humphreys, who classified 16 lines between 692 Å and 980 Å. Later Rao extended the analysis from observations in the interval 530 Å to 4533 Å, and added about 70 newly classified lines including intersystem combinations connecting the singlet and triplet systems of terms. He determined the limit from the two series  $5p {}^3P^\circ - nd {}^3D$  ( $n=4, 5$ ) and  $5p {}^3P^\circ - ns {}^3S$  ( $n=5, 6$ ) by using a Rydberg formula.

Three miscellaneous levels called, respectively,  $\alpha$ ,  $\beta$ ,  $\gamma$  by Rao have been omitted here.

## REFERENCES

- R. A. Sawyer and C. J. Humphreys, Phys. Rev. **32**, 583 (1928). (T) (C L)  
 K. R. Rao, Proc. Roy. Soc. (London) [A] **134**, 604 (1931). (I P) (T) (C L)  
 J. E. Mack, Rev. Mod. Phys. **22**, No. 1, 64 (1950). (Summary hfs)

## As IV

## As IV

Config.	Desig.	<i>J</i>	Level	Interval	Config.	Desig.	<i>J</i>	Level	Interval
$4s^3$	$4s^2 {}^1S$	0	0		$4s(2S)5p$	$5p {}^3P^\circ$	0	251212. 0	
$4s(2S)4p$	$4p {}^3P^\circ$	0	75812	1150			1	251466. 9	254. 9
		1	76962	2530			2	252285. 0	818. 1
		2	79492		$4s(2S)5p$	$5p {}^1P^\circ$	1	254039. 9	
$4s(2S)4p$	$4p {}^1P^\circ$	1	112022		$4s(2S)4f$	$4f {}^3F^\circ$	2	284456	
$4s(2S)4d$	$4d {}^1D$	2	179563				3	284730	274
							4	285143	413
$4p^2$	$4p^2 {}^3P$	0	179934	1534	$4s(2S)4f$	$4f {}^1F^\circ$	3	285730	
		1	181468	2926	$4s(2S)5d$	$5d {}^1D$	2	293834. 4	
		2	184394		$4s(2S)5d$	$5d {}^3D$	1	295580. 8	
$4p^2$	$4p^2 {}^1D$	2	204658				2	295639. 0	58. 2
$4s(2S)4d$	$4d {}^3D$	1	210597. 0	132. 8			3	295730. 2	91. 2
		2	210729. 8	202. 8	$4s(2S)6s$	$6s {}^3S$	1	298875. 1	
		3	210932. 6		$4s(2S)6s$	$6s {}^1S$	0	300698. 9	
$4p^2$	$4p^2 {}^1S$	0	211683						
$4s(2S)5s$	$5s {}^3S$	1	220127. 6						
$4s(2S)5s$	$5s {}^1S$	0	229420. 5		As v ( $2S_{0\frac{1}{2}}$ )	Limit		404369	

March 1950.

As IV OBSERVED TERMS\*

Config. 1s <sup>2</sup> 2s <sup>2</sup> 2p <sup>6</sup> 3s <sup>2</sup> 3p <sup>6</sup> 3d <sup>10</sup> +	Observed Terms			
4s <sup>2</sup>	4s <sup>2</sup> <sup>1</sup> S			
	{ 4p <sup>2</sup> <sup>1</sup> S      4p <sup>2</sup> <sup>3</sup> P      4p <sup>2</sup> <sup>1</sup> D			
	ns (n ≥ 5)	np (n ≥ 4)	nd (n ≥ 4)	nf (n ≥ 4)
4s(2S)nx	{ 5,6s <sup>3</sup> S 5,6s <sup>1</sup> S	4,5p <sup>3</sup> P° 4,5p <sup>1</sup> P°	4,5d <sup>3</sup> D 4,5d <sup>1</sup> D	4f <sup>3</sup> F° 4f <sup>1</sup> F°

\*For predicted terms in the spectra of the Zn I isoelectronic sequence, see Vol. II, Introduction.

As V

(Cu I sequence; 29 electrons)

Z=33

Ground state 1s<sup>2</sup> 2s<sup>2</sup> 2p<sup>6</sup> 3s<sup>2</sup> 3p<sup>6</sup> 3d<sup>10</sup> 4s <sup>2</sup>S<sub>0½</sub>

4s <sup>2</sup>S<sub>0½</sub> 505136 cm<sup>-1</sup>

I. P. 62.6 volts

This spectrum is incompletely analyzed. By extrapolation along the isoelectronic sequence Sawyer and Humphreys have classified 9 lines between 600 Å and 1056 Å and determined the limit quoted here.

REFERENCE

R. A. Sawyer and C. J. Humphreys, Phys. Rev. **32**, 583 (1928). (I P) (T) (C L).

As V

Config.	Desig.	J	Level	Interval
4s	4s <sup>2</sup> S	0½	0	4110
4p	4p <sup>2</sup> P°	0½ 1½	97135 101245	
4d	4d <sup>2</sup> D	1½ 2½	236897 237342	445
5s	5s <sup>2</sup> S	0½	263596	
4f	4f <sup>2</sup> F°	{ 3½ 2½ }	331987	
-----	-----	-----	-----	
As VI ( <sup>1</sup> S <sub>0</sub> )	Limit	-----	505136	

February 1950.

## As VI

(Ni I sequence; 28 electrons)

 $Z=33$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} {}^1S_0$  $3d^{10} {}^1S_0$  1028800  $\text{cm}^{-1}$ 

I. P. 127.5 volts

Mack and Borg have found 8 terms and classified about 30 lines between 803 Å and 1050 Å. Kruger and Shoupp subsequently observed 4 lines in the interval 219 Å to 232 Å, and classified 3 as combinations from the ground term. These later observations indicate a correction of  $+331180 \text{ cm}^{-1}$  to Mack's values, to reduce them to the ground term zero. In compiling the terms in the table this correction has been made, and the last figure has been rounded off throughout.

Kruger and Shoupp have determined the limit from an empirical formula based on extrapolation of isoelectronic sequence data. Their limit is entered in brackets in the table.

The singlet and triplet terms are connected by observed intersystem combinations.

## REFERENCES

- J. E. Mack and D. Borg, Phys. Rev. **37**, 470 (A) (1931) and unpublished material (see 1934 ref. below). (T)  
 P. G. Kruger and W. E. Shoupp, Phys. Rev. **46**, 124 (1934). (I P) (T) (C L)  
 J. E. Mack, letter (Dec. 1949).

## As VI

## As VI

Config.	Desig.	$J$	Level	Interval	Config.	Desig.	$J$	Level	Interval
$3d^{10}$	$3d^{10} {}^1S$	0	0		$3d^9(2D)4p$	$4p {}^3D^\circ$	3 2 1	449470 449460 454570	10 -5110
$3d^9(2D)4s$	$4s {}^3D$	3 2 1	331180 333230 336870	-2050 -3640	$3d^9(2D)4p$	$4p {}^1F^\circ$	3	451800	
$3d^9(2D)4s$	$4s {}^1D$	2	340230		$3d^9(2D)4p$	$4p {}^1P^\circ$	1	452400	
$3d^9(2D)4p$	$4p {}^3P^\circ$	2 1 0	435430 440890 444060	-5460 -3170	$3d^9(2D)4p$	$4p {}^1D^\circ$	2	455560	
$3d^9(2D)4p$	$4p {}^3F^\circ$	4 3 2	443070 439910 443800	3160 -3890	As VII ( $2D_{3/2}$ )	Limit		[1028800]	

December 1949.

## As VI OBSERVED TERMS\*

Config. $1s^2 2s^2 2p^6 3s^2 3p^6 +$	Observed Terms			
$3d^{10}$	$3d^{10} {}^1S$			
	$ns (n \geq 4)$		$np (n \geq 4)$	
$3d^9(2D)nx$	{	$4s {}^3D$	$4p {}^3P^\circ$	$4p {}^3D^\circ$
		$4s {}^1D$	$4p {}^1P^\circ$	$4p {}^1D^\circ$
			$4p {}^3F^\circ$	$4p {}^1F^\circ$

\*For predicted terms in the spectra of the Ni I isoelectronic sequence, see Vol. II, Introduction.



## SELENIUM

## Se I

34 electrons

 $Z=34$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^4 {}^3P_2$  $4p^4 {}^3P_2$  78658.22  $\text{cm}^{-1}$ 

I. P. 9.75 volts

The analysis is by Ruedy and Gibbs. They photographed the spectrum, as excited by means of a positive column discharge in helium, from 300 Å to 11000 Å. Out of a total of 510 observed lines they have classified 391. Their limit is well determined from two long series:  $5p {}^5P - ns {}^5S^\circ$  ( $n=5$  to 11), and  $5p {}^5P_3 - nd {}^5D_4^\circ$  ( $n=4$  to 11). Observed intersystem combinations connect the terms of all three multiplicities.

An analysis of the Se I spectrum has also been published independently by Meissner, Bartelt, and Eckstein, who observed it from 3588 Å to 9665 Å, using a condensed discharge through selenium vapor as the source.

The two published line lists are surprisingly discordant with regard to the wavelengths of a number of lines common to both, and also with regard to the number of lines recorded independently from the two sets of observations, i. e., not common to both lists. This raises two questions: (1) the proper source of excitation to be used in observing the spectrum, and (2) the accuracy of the measured wavelengths. Further observations are needed to clarify this puzzling situation.

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## Se I

## Se I

Config.	Desig.	<i>J</i>	Level	Interval	Config.	Desig.	<i>J</i>	Level	Interval	
4 <i>p</i> <sup>4</sup>	4 <i>p</i> <sup>4</sup> <sup>3</sup> P	2	0. 00	—1989. 49 —544. 86	4 <i>p</i> <sup>3</sup> ( <sup>4</sup> S°)4 <i>d</i>	4 <i>d</i> <sup>5</sup> D°	4	63370. 07	—17. 39 14. 27 —9. 55 1. 90	
		1	1989. 49				3	63387. 46		
		0	2534. 35				2	63373. 19		
4 <i>p</i> <sup>4</sup>	4 <i>p</i> <sup>4</sup> <sup>1</sup> D	2	9576. 08					1		63382. 74
								0		63380. 84
4 <i>p</i> <sup>4</sup>	4 <i>p</i> <sup>4</sup> <sup>1</sup> S	0	22446. 03		4 <i>p</i> <sup>3</sup> ( <sup>2</sup> D°)5 <i>s</i>	5 <i>s</i> ' <sup>1</sup> D°	2	63479. 31		
4 <i>p</i> <sup>3</sup> ( <sup>4</sup> S°)5 <i>s</i>	5 <i>s</i> <sup>5</sup> S°	2	48182. 19		4 <i>p</i> <sup>3</sup> ( <sup>4</sup> S°)4 <i>d</i>	4 <i>d</i> <sup>3</sup> D°	1	65299. 44	—21. 48 61. 76	
4 <i>p</i> <sup>3</sup> ( <sup>4</sup> S°)5 <i>s</i>	5 <i>s</i> <sup>3</sup> S°	1	50996. 93				2	65277. 96		
							3	65339. 72		
4 <i>p</i> <sup>3</sup> ( <sup>4</sup> S°)5 <i>p</i>	5 <i>p</i> <sup>5</sup> P	1	59242. 88	45. 03 103. 47	4 <i>p</i> <sup>3</sup> ( <sup>4</sup> S°)6 <i>s</i>	6 <i>s</i> <sup>5</sup> S°	2	65989. 12		
		2	59287. 91				6 <i>s</i> <sup>3</sup> S°	1	66623. 12	
		3	59391. 38							
4 <i>p</i> <sup>3</sup> ( <sup>4</sup> S°)5 <i>p</i>	5 <i>p</i> <sup>3</sup> P	2	60677. 46	55. 09 —73. 70	4 <i>p</i> <sup>3</sup> ( <sup>4</sup> S°)6 <i>p</i>	6 <i>p</i> <sup>5</sup> P				1
		1	60622. 37				2	69277. 78		
		0	60696. 07				3	69314. 58		
4 <i>p</i> <sup>3</sup> ( <sup>2</sup> D°)5 <i>s</i>	5 <i>s</i> ' <sup>3</sup> D°	1	61681. 31	147. 21 419. 10	4 <i>p</i> <sup>3</sup> ( <sup>4</sup> S°)6 <i>p</i>	6 <i>p</i> <sup>3</sup> P	2	69614. 07	14. 58 —29. 98	
		2	61828. 52				1	69599. 49		
		3	62247. 62				0	69629. 47		

## Se I—Continued

## Se I—Continued

Config.	Desig.	<i>J</i>	Level	Interval	Config.	Desig.	<i>J</i>	Level	Interval
$4p^3(^4S^{\circ})5d$	$5d\ ^5D^{\circ}$	0 1 2 3 4	 70388.56 70389.06 70391.72 70391.04	 0.50 2.66 -0.68	$4p^3(^2D^{\circ})4d$	$4d'\ ^2^{\circ}$	1	75258.47	
$4p^3(^2P^{\circ})5s$	$5s''\ ^3P^{\circ}$	0 1 2	 70995.0 71199.6 71659.02	 204.6 459.4	$4p^3(^2D^{\circ})5p$	$5p'\ ^1D$	2	75309.88	
$4p^3(^4S^{\circ})5d$	$5d\ ^3D^{\circ}$	1 2 3	 71106.25 71096.24 71154.96	 -10.01 58.72	$4p^3(^4S^{\circ})7d$	$7d\ ^3D^{\circ}$	3 2 1	 75312.00 75312.84 75364.92	-0.84 -52.08
$4p^3(^4S^{\circ})7s$	$7s\ ^5S^{\circ}$	2	71638.28		$4p^3(^4S^{\circ})9s$	$9s\ ^5S^{\circ}$	2	75574.14	
$4p^3(^2D^{\circ})5p$	$5p'\ ^3D$	1 2 3	 71856.09 72427.31 73030.93	 571.22 603.62	$4p^3(^4S^{\circ})7f$	$7f\ ^5F$	1 to 5	75587.25	
$4p^3(^4S^{\circ})7s$	$7s\ ^3S^{\circ}$	2	71638.28		$4p^3(^4S^{\circ})7f$	$7f\ ^3F$	2 to 4	75588.92	
$4p^3(^2D^{\circ})5p$	$5p'\ ^3D$	1 2 3	 71856.09 72427.31 73030.93	 571.22 603.62	$4p^3(^4S^{\circ})9s$	$9s\ ^3S^{\circ}$	1	75638.12	
$4p^3(^4S^{\circ})7s$	$7s\ ^3S^{\circ}$	1	71890.33		$4p^3(^2D^{\circ})4d$	$4d'\ ^3^{\circ}$	2	75973.6	
$4p^3(^2P^{\circ})5s$	$5s''\ ^1P^{\circ}$	1	72568.56		$4p^3(^4S^{\circ})9p$	$9p\ ^5P$	1 2 3	 76013.93 76016.64 76021.52	2.71 4.88
$4p^3(^2D^{\circ})5p$	$5p'\ ^3F$	2 3 4	 72618.29 72716.62 73254.10	 -1.67 537.48	$4p^3(^4S^{\circ})9p$	$9p\ ^3P$	0 1 2	 76104.53 76113.36	8.83
$4p^3(^2D^{\circ})5p$	$5p'\ ^1P$	1	72866.21		$4p^3(^4S^{\circ})8d$	$8d\ ^3D^{\circ}$	3 2 1	 76128.78 76248.69 76216.28	-19.91 32.41
$4p^3(^4S^{\circ})7p$	$7p\ ^3P$	0 1 2	 73042.05 73043.04 73052.55	 0.99 9.51	$4p^3(^4S^{\circ})8d$	$8d\ ^5D^{\circ}$	4 3 2 1 0	 76159.61 76161.59 76160.45 76160.95	-1.98 1.14 -0.50
$4p^3(^4S^{\circ})7p$	$7p\ ^5P$	1 2 3	 73083.23 73094.42 73101.20	 11.19 6.78	$4p^3(^4S^{\circ})10s$	$10s\ ^5S^{\circ}$	2	76397.26	
$4p^3(^2D^{\circ})5p$	$5p'\ ^1F$	3	73264.03		$4p^3(^2D^{\circ})4d$	$4d'\ ^4^{\circ}$	3	76400.41	
$4p^3(^4S^{\circ})6d$	$6d\ ^5D^{\circ}$	0 1 2 3 4	 73543.68 73541.42 73547.56 73547.7	 -2.26 6.14 0.1	$4p^3(^4S^{\circ})8f$	$8f\ ^5F$	1 to 5	76403.68	
$4p^3(^4S^{\circ})6d$	$6d\ ^3D^{\circ}$	1 2 3	 73863.88 73819.99 73860.68	 -43.89 40.69	$4p^3(^4S^{\circ})8f$	$8f\ ^3F$	2 to 4	76404.89	
$4p^3(^2D^{\circ})5p$	$5p'\ ^3P$	0 1 2	 74034.06 74083.57 74092.10	 49.51 8.53	$4p^3(^4S^{\circ})10s$	$10s\ ^3S^{\circ}$	1	76435.27	
$4p^3(^2D^{\circ})4d$	$4d'\ ^1^{\circ}$	2	74161.70		$4p^3(^4S^{\circ})9d$	$9d\ ^5D^{\circ}$	0 1 2 3 4	 76766.58 76770.41 76771.74 76767.39	3.83 1.33 -4.35
$4p^3(^4S^{\circ})8s$	$8s\ ^5S^{\circ}$	2	74210.06		$4p^3(^4S^{\circ})9d$	$9d\ ^3D^{\circ}$	1 2 3	 76777.65 76781.85 76783.34	4.20 1.49
$4p^3(^4S^{\circ})6f$	$6f\ ^5F$	1 to 5	74232.47		$4p^3(^4S^{\circ})11s$	$11s\ ^5S^{\circ}$	2	76929.68	
$4p^3(^4S^{\circ})6f$	$6f\ ^3F$	2 to 4	74234.58		$4p^3(^4S^{\circ})9f$	$9f\ ^5F$	1 to 5	76933.25	
$4p^3(^4S^{\circ})8s$	$8s\ ^3S^{\circ}$	1	74318.20		$4p^3(^4S^{\circ})10d$	$10d\ ^5D^{\circ}$	0 1 2 3 4	 77184.09 77183.79 77183.48 77186.79	-0.30 -0.31 3.31
$4p^3(^4S^{\circ})8p$	$8p\ ^5P$	1 2 3	 74948.23 74951.92 74960.30	 3.69 8.38	$4p^3(^4S^{\circ})10f$	$10f\ ^5F$	1 to 5	77295.98	
$4p^3(^4S^{\circ})8p$	$8p\ ^3P$	0 1 2	 75137.89 75142.32 75146.71	 4.43 4.39	$4p^3(^4S^{\circ})11d$	$11d\ ^5D^{\circ}$	0 1 2 3 4	 77471.5 77473.70 77474.18	2.2 0.48
$4p^3(^4S^{\circ})7d$	$7d\ ^5D^{\circ}$	0 1 2 3 4	 75154.12 75197.03 75195.77 75195.7	 42.91 -1.26 -0.1	$4p^3(^4S^{\circ})11f$	$11f\ ^5F$	1 to 5	77555.41	
					Se II ( $^4S_{1/2}$ )	Limit		78658.22	



## Se I OBSERVED TERMS\*

Config. $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 +$	Observed Terms			
$4p^4$	{ $4p^4 \ ^1S$ $4p^4 \ ^3P$ $4p^4 \ ^1D$			
	$ns \ (n \geq 5)$	$np \ (n \geq 5)$	$nd \ (n \geq 4)$	$nf \ (n \geq 4)$
$4p^3(^4S^\circ)nx$	{ $5-11s \ ^4S^\circ$ $5-10s \ ^3S^\circ$	$5-9p \ ^5P$ $5-9p \ ^3P$	$4-11d \ ^4D^\circ$ $4-9d \ ^3D^\circ$	$6-11f \ ^6F$ $6-8f \ ^4F$
$4p^3(^2D^\circ)nx'$	{ $5s' \ ^3D^\circ$ $5s' \ ^1D^\circ$	$5p' \ ^3P$ $5p' \ ^3D$ $5p' \ ^3F$ $5p' \ ^1P$ $5p' \ ^1D$ $5p' \ ^1F$		
$4p^3(^2P^\circ)nx''$	{ $5s'' \ ^3P^\circ$ $5s'' \ ^1P^\circ$			

\*For predicted terms in the spectra of the Se I isoelectronic sequence, see Vol. II, Introduction.

## Se II

(As I sequence; 33 electrons)

$Z=34$

Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^3 \ ^4S_{1/2}$

$4p^3 \ ^4S_{1/2} \ 173557 \text{ cm}^{-1}$

I. P. 21.5 volts

Three different term lists having a number of levels in common, have been published for Se II. Martin gives 192 classified lines in the range between 694 Å and 9816 Å, and discusses the other investigations in detail, noting which levels were found by Krishnamurty and Rao. His analysis is quoted in the table. The observed  $g$ -values are from van den Bosch, who suggests the following additions and corrections:

Level	Martin	K and R*	v d B*	Obs. $g$
98182.1		$4d \ ^4F_{4/2}$	$4d \ ^4F_{4/2}$	1.27
127984.3	$21\frac{3}{2}$		$5p' \ ^2F_{3/2}$	1.24
131165.4	$23\frac{3}{2}(5p' \ ^2F_{3/2})$	$d$	$5p' \ ^2P_{1/2}$	1.26
132189.6	$5p' \ ^2P_{1/2}$		$5p'' \ ^2P_{1/2}$	1.16
138365.7	$5d \ ^4F_{1/2}?$	$5d \ ^4D_{1/2}$	$5d \ ^4D_{1/2}?$	1.44
140946.0	$31\frac{3}{2}$	$5d \ ^4D_{3/2}$	$5d \ ^4D_{3/2}$	1.25
142128.7		$5d \ ^4D_{3/2}$	$5d \ ^4D_{3/2}$	1.33
142302.2	$33\frac{1}{2}$		$33\frac{3}{2}$	0.87

\*Letters refer to authors listed under references.

The corrected  $J$ -value of the level 131165 has been adopted. The other changes are noted separately because some lines acquire two designations if any two sets of terms are combined. Further study will doubtless clarify some of the present differences in this respect. An evident misprint in level "27" has also been corrected.

The limit is also from Martin. He has determined it from the  $5,6s \ ^4P$  and  $5,6s \ ^2P$  series, by using a Rydberg formula.

The doublet and quartet systems of terms are connected by observed intersystem combinations.



## Se II—Continued

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## Se II

## Se II

Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>	Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>
$4s^2 4p^3$	$4p^3 {}^4S^\circ$	$1\frac{1}{2}$	0. 0			$4s^2 4p^2({}^3P)5p$	$5p {}^2P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	$121273.2$ $121381.9$	108. 7	0. 64 1. 27
$4s^2 4p^3$	$4p^3 {}^2D^\circ$	$1\frac{1}{2}$ $2\frac{1}{2}$	$13168.2$ $13784.4$	616. 2			15	$2\frac{1}{2}$	121730		
$4s^2 4p^3$	$4p^3 {}^1P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	$23038.3$ $23894.8$	856. 5			16	$2\frac{1}{2}$	122720		
$4s 4p^4$	$4p^4 {}^1P$	$2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	83876. 7 85579. 5 86437. 7	-1702. 8 -858. 2	1. 57 1. 67 2. 60		17	$1\frac{1}{2}$	123323		
$4s^2 4p^2({}^3P)5s$	$5s {}^4P$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$	95270. 0 96753. 3 98674. 4	1483. 3 1921. 1	2. 51 1. 68 1. 56	$4s^2 4p^2({}^1D)5p$	$5p {}^2D^\circ$	$2\frac{1}{2}$ $1\frac{1}{2}$	$127415.7$ $127921.4$	-505. 7	0. 97 0. 8
	1	$0\frac{1}{2}$	96517. 4				19	$1\frac{1}{2}$	126464. 7		
	2	$2\frac{1}{2}$	96655. 3		1. 30		20	$0\frac{1}{2}$	127867. 5		
	3	$0\frac{1}{2}$	98118. 2				21°	$2\frac{1}{2}$	127984. 3		1. 24
$4s^2 4p^2({}^3P)5s$	$5s {}^3P$	$0\frac{1}{2}$ $1\frac{1}{2}$	98896. 1 101356. 0	2459. 9	0. 77 1. 37		22	$1\frac{1}{2}$	129010. 4		
	4	$1\frac{1}{2}$	99368. 5		0. 82	$4s^2 4p^2({}^1D)5p$	$5p {}^1P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	$132189.6$		1. 16
$4s 4p^4$	$4p^4 {}^3P$	$1\frac{1}{2}$ $0\frac{1}{2}$	100295. 1		1. 14		24	$2\frac{1}{2}$	133867. 1		
	5	$2\frac{1}{2}$	101631. 5		1. 12	$4s^2 4p^2({}^3P)6s$	$6s {}^4P$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$	134042. 9 135635. 6 137669. 1	1592. 7 2033. 5	2. 35 1. 67 1. 60
	6	$1\frac{1}{2}$	104694. 4				25	$1\frac{1}{2}$	136188. 2		1. 29
	7	$1\frac{1}{2}$	104873. 7			$4s^2 4p^2({}^3P)5d$	$5d {}^4F$	$1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$ $4\frac{1}{2}$	138365. 7? 138923. 1 140011. 8 141710. 1	557. 4 1088. 7 1698. 3	1. 44 1. 14 1. 27 1. 27
	8	$0\frac{1}{2}$	105258. 0			$4s^2 4p^2({}^3P)6s$	$6s {}^3P$	$0\frac{1}{2}$ $1\frac{1}{2}$	138525. 7 140939. 9	2414. 2	0. 90
	9	$0\frac{1}{2}$	105973. 8				26	$2\frac{1}{2}$	138535. 9		
$4s^2 4p^2({}^1D)5s$	$5s {}^2D$	$2\frac{1}{2}$ $1\frac{1}{2}$	108355. 7 108449. 8	-94. 1	1. 15 0. 81		27	$1\frac{1}{2}$	138701. 0		
	10	$2\frac{1}{2}$	108833. 9				28	$1\frac{1}{2}$	140131. 3		1. 85
	11	$2\frac{1}{2}$	110297. 4				29	$1\frac{1}{2}$	140745. 8		
	12	$1\frac{1}{2}$	112403. 4				30	$2\frac{1}{2}$	140930. 1		
$4s^2 4p^2({}^3P)5p$	$5p {}^4P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$	113048. 7 116776. 6 118398. 0	3727. 9 1621. 4	1. 64 1. 45 1. 40		31	$2\frac{1}{2}$	140946. 0		1. 25
$4s^2 4p^2({}^3P)5p$	$5p {}^4D^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$	114299. 0 114711. 7 116068. 1 117798. 7	412. 7 1356. 4 1730. 6	0. 62 1. 28 1. 39 1. 38		32	$2\frac{1}{2}$	142171. 0		
$4s^2 4p^2({}^3P)5p$	$5p {}^2S^\circ$	$0\frac{1}{2}$	117406. 0		2. 49		33	$1\frac{1}{2}$	142302. 2		
$4s^2 4p^2({}^3P)5p$	$5p {}^2D^\circ$	$1\frac{1}{2}$ $2\frac{1}{2}$	117739. 6 120387. 1	2647. 5	1. 10 1. 31		34	$1\frac{1}{2}$	142374. 1		
$4s^2 4p^2({}^3P)5p$	$5p {}^4S^\circ$	$1\frac{1}{2}$	119308. 5		1. 78		35	$2\frac{1}{2}$	143341. 7		1. 24
	13	$0\frac{1}{2}$	119343				36	$2\frac{1}{2}$	143919. 5		
	14°	$1\frac{1}{2}$	121051. 5			Se III ( ${}^3P_0$ )	Limit	-----	173557		

## Se II OBSERVED TERMS\*

Config. $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} +$	Observed Terms		
$4s^2 4p^3$	{ $4p^3 {}^4S^\circ$ $4p^3 {}^2P^\circ$ $4p^3 {}^2D^\circ$		
$4s 4p^4$	{ $4p^4 {}^4P$ $4p^4 {}^2P$		
	$ns (n \geq 5)$	$np (n \geq 5)$	$nd (n \geq 4)$
$4s^2 4p^2 ({}^3P) nx$	{ $5,6s {}^4P$ $5,6s {}^2P$ $5s' {}^2D$	$5p {}^4S^\circ$ $5p {}^4P^\circ$ $5p {}^4D^\circ$	$5d {}^4F$
$4s^2 4p^2 ({}^1D) nx'$		$5p {}^2S^\circ$ $5p {}^2P^\circ$ $5p {}^2D^\circ$	

\*For predicted terms in the spectra of the As I isoelectronic sequence, see Vol. II, Introduction.

## Se III

(Ge I sequence; 32 electrons)

$Z=34$

Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^2 {}^3P_0$

$4p^2 {}^3P_0$  258000  $\text{cm}^{-1}$

I. P. 32.0 volts

The analysis is incomplete. The authors have observed the spectrum from 517 Å to 6613 Å and classified 218 lines. They give the limit  $274924 \text{ cm}^{-1}$ , derived from the combinations  $4p^2 {}^3P - 5s {}^3P^\circ$ ;  $5s {}^3P^\circ - 5p {}^3P$ ; and  $4p^2 {}^1D - 5s {}^1P^\circ$ ;  $5s {}^1P^\circ - 5p {}^1D$ . The writer has recalculated the limit from the series  $5,6s {}^1, {}^3P^\circ$ ;  $4,5d {}^1, {}^3F^\circ$ ;  $4,5d {}^1D_2^\circ$ ;  $4,5d {}^3D_3^\circ$ ;  $4,5d {}^3P_{2,1}^\circ$  by using a Rydberg formula and assuming that  $5,6s {}^3P_2$ ;  $5,6s {}^1P_1^\circ$ ;  $4,5d {}^3F_{4,3,2}^\circ$  have as a limit the component  $4p {}^2P_{1\frac{1}{2}}^\circ$  in Se IV. This component is  $4376 \text{ cm}^{-1}$  above the ground state of the ion,  $4p {}^2P_{0\frac{1}{2}}^\circ = 0$ . Consequently, this correction has been taken into account in determining the final value of the limit quoted in the table.

Observed intersystem combinations connect the singlet and triplet systems of terms.

## REFERENCES

- J. S. Badami and K. R. Rao, Proc. Roy. Soc. London [A] **140**, 387 (1933). (I P) (T) (C L)  
 K. R. Rao and S. G. K. Murti, Proc. Roy. Soc. London [A] **145**, 681 (1934). (T) (C L)

## Se III

## Se III

Config.	Desig.	<i>J</i>	Level	Interval	Config.	Desig.	<i>J</i>	Level	Interval
$4s^2 4p^2$	$4p^2 \ ^3P$	0	0		$4s^2 4p(^2P^\circ)5p$	$5p \ ^1P$	1	150761. 1	
		1	1741	1741	$4s^2 4p(^2P^\circ)5p$	$5p \ ^3D$	1	153211. 4	309. 5 3172. 0
		2	3937	2196			2	153520. 9	
$4s^2 4p^2$	$4p^2 \ ^1D$	2	13032				3	156692. 9	
$4s \ 4p^3$	$4p^3 \ ^3D^\circ$	1	91091	1632 3825	$4s^2 4p(^2P^\circ)5p$	$5p \ ^3P$	0	154783. 0	1577. 4 1513. 8
		2	92723				1	156360. 4	
		3	96548				2	157874. 2	
$4s \ 4p^3$	$4p^3 \ ^3P^\circ$	0	106482	109 -76	$4s^2 4p(^2P^\circ)5p$	$5p \ ^3S$	1	159302. 9	
		1	106591		$4s^2 4p(^2P^\circ)5p$	$5p \ ^1D$	2	161170. 2	
		2	106515						
$4s \ 4p^3$	$4p^3 \ ^1D^\circ$	2	112565		$4s^2 4p(^2P^\circ)6s$	$6s \ ^3P^\circ$	0	187168. 7	257. 8 4096. 5
					$4s^2 4p(^2P^\circ)6s$	$6s \ ^3P^\circ$	1	187426. 5	
							2	191523. 0	
$4s^2 4p(^2P^\circ)4d$	$4d \ ^3F^\circ$	2	124051. 9	1257. 9 2099. 7	$4s^2 4p(^2P^\circ)5d$	$5d \ ^3F^\circ$	2	188429. 2	1218. 7 1945. 7
		3	125309. 8				3	189647. 9	
		4	127409. 5				4	191593. 6	
$4s^2 4p(^2P^\circ)5s$	$5s \ ^3P^\circ$	0	126276. 9	504. 5 3609. 6	$4s^2 4p(^2P^\circ)5d$	$5d \ ^3D^\circ$	1	190841. 2	-821. 0 3894. 8
		1	126781. 4				2	190020. 2	
		2	130391. 0				3	193915. 0	
$4s^2 4p(^2P^\circ)5s$	$5s \ ^1P^\circ$	1	131655. 9		$4s^2 4p(^2P^\circ)6s$	$6s \ ^1P^\circ$	1	192161. 8	
$4s^2 4p(^2P^\circ)4d$	$4d \ ^1P^\circ$	1	136946. 5		$4s^2 4p(^2P^\circ)5d$	$5d \ ^1D^\circ$	2	193304. 4	
$4s^2 4p(^2P^\circ)4d$	$4d \ ^1D^\circ$	2	139203. 7		$4s^2 4p(^2P^\circ)5d$	$5d \ ^3P^\circ$	0		-223. 5
$4s^2 4p(^2P^\circ)4d$	$4d \ ^3D^\circ$	1	140639. 7	-1230. 0 2604. 9	$4s^2 4p(^2P^\circ)5d$	$5d \ ^3P^\circ$	1	194950. 5	
		2	139409. 7				2	194727. 0	
		3	142014. 6						
$4s^2 4p(^2P^\circ)4d$	$4d \ ^3P^\circ$	0	142315. 8	442. 4 -52. 1	$4s^2 4p(^2P^\circ)5d$	$5d \ ^1F^\circ$	3	196845. 4	
		1	142758. 2						
		2	142706. 1						
$4s^2 4p(^2P^\circ)4d$	$4d \ ^1F^\circ$	3	148675		Se IV ( $2P_{3/2}$ )	Limit	-----	258000	

August 1950.

## Se III OBSERVED TERMS\*

Config. $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} +$	Observed Terms			
$4s^2 4p^2$	{ $4p^2 \ ^3P$ $4p^2 \ ^1D$ }			
$4s \ 4p^3$	{ $4p^3 \ ^3P^\circ$ $4p^3 \ ^3D^\circ$ $4p^3 \ ^1D^\circ$ }			
	$ns \ (n \geq 5)$	$np \ (n \geq 5)$	$nd \ (n \geq 4)$	
$4s^2 4p(^2P^\circ)nx$	{ $5,6s \ ^3P^\circ$ $5,6s \ ^1P^\circ$ }	$5p \ ^3S$ $5p \ ^3P$ $5p \ ^3D$ $5p \ ^1P$ $5p \ ^1D$	$4,5d \ ^3P^\circ$ $4,5d \ ^3D^\circ$ $4,4d \ ^3F^\circ$ $4d \ ^1P^\circ$ $4,5d \ ^1D^\circ$ $4,5d \ ^1F^\circ$	

\*For predicted terms in the spectra of the Ge I isoelectronic sequence, see Vol. II, Introduction.



## Se IV

(Ga I sequence; 31 electrons)

 $Z=34$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^2 P^{\circ}_{0/4}$  $4p^2 P^{\circ}_{0/4}$  346094  $\text{cm}^{-1}$ 

I. P. 42.9 volts

The analysis is by Rao and Badami who have published 35 classified lines between 635 Å and 3059 Å. Their limit "depends upon a choice of  $70240 \text{ cm}^{-1}$  for the term  $5g^2 G$ , which is assumed to be very nearly hydrogenic." It is entered in brackets in the table.

## REFERENCE

K. R. Rao and J. S. Badami, Proc. Roy. Soc. London [A] **131**, 159 (1931). (I P) (T) (C L)

Se IV					Se IV				
Config.	Desig.	$J$	Level	Interval	Config.	Desig.	$J$	Level	Interval
$4s^2(1S)4p$	$4p^2 P^{\circ}$	$0\frac{1}{2}$ $1\frac{1}{2}$	$0$ 4376	4376	$4s^2(1S)4f$	$4f^2 F^{\circ}$	$3\frac{1}{2}$ $2\frac{1}{2}$	229684 229714	-30
$4s 4p^2$	$4p^2^2 D$	$1\frac{1}{2}$ $2\frac{1}{2}$	104211 104706	495	$4s^2(1S)5d$	$5d^2 D$	$1\frac{1}{2}$ $2\frac{1}{2}$	237747 237899	152
$4s 4p^2$	$4p^2^2 S$	$0\frac{1}{2}$	128787		$4s^2(1S)6s$	$6s^2 S$	$0\frac{1}{2}$	240745	
$4s 4p^2$	$4p^2^2 P$	$0\frac{1}{2}$ $1\frac{1}{2}$	136134 138354	2220	$4s^2(1S)5g$	$5g^2 G$	$3\frac{1}{2}, 4\frac{1}{2}$	275854	
$4s^2(1S)4d$	$4d^2 D$	$1\frac{1}{2}$ $2\frac{1}{2}$	153217 153606	389	$4s^2(1S)7s$	$7s^2 S$	$0\frac{1}{2}$	288146?	
$4s^2(1S)5s$	$5s^2 S$	$0\frac{1}{2}$	157241		Se v ( $1S_0$ )	Limit	-----	[346094]	
$4s^2(1S)5p$	$5p^2 P^{\circ}$	$0\frac{1}{2}$ $1\frac{1}{2}$	189913 191111	1198					

May 1950.

## Se v

(Zn I sequence; 30 electrons)

 $Z=34$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 1S_0$  $4s^2 1S_0$  589781  $\text{cm}^{-1}$ 

I. P. 73.1 volts

This spectrum is incompletely analyzed. Sawyer and Humphreys found the three triplet terms  $4p^3 P^{\circ}$ ,  $4d^3 D$ , and  $5s^3 S$ , and also the combinations  $4s^2 1S-4p^1 P^{\circ}$  and  $4p^3 P^{\circ}-4p^2^3 P$ , from 16 lines between 505 Å and 839 Å. They estimated the absolute term values by an extrapolation of the Moseley diagram.

Subsequently Rao and Badami classified 6 more lines from observations extending to 1227 Å. They added the singlet term  $4d^1 D$  together with 5 intersystem combinations connecting the singlet and triplet systems of terms. Their limit is based on these observations and the absolute values of Sawyer and Humphreys.

## REFERENCES

R. A. Sawyer and C. J. Humphreys, Phys. Rev. **32**, 583 (1928). (T) (C L)K. R. Rao and J. S. Badami, Proc. Roy. Soc. London [A] **131**, 166 (1931). (I P) (T) (C L)

Se v

Config.	Desig.	<i>J</i>	Level	Interval
4s <sup>2</sup>	4s <sup>2</sup> <sup>1</sup> S	0	0	
4s(2S)4p	• 4p <sup>2</sup> P <sup>o</sup>	0	89756	1595
		1	91351	3610
		2	94961	
4s(2S)4p	4p <sup>1</sup> P <sup>o</sup>	1	131733	
4p <sup>2</sup>	4p <sup>2</sup> <sup>3</sup> P	0	211789	2298
		1	214087	2528
		2	218615	
4s(2S)4d	4d <sup>1</sup> D	2	213194	
4s(2S)4d	4d <sup>3</sup> D	1	257534	214
		2	257748	335
		3	258083	
4s(2S)5s	5s <sup>3</sup> S	1	287426	
-----	-----	-----	-----	
Se vi (2S <sub>1/2</sub> )	<i>Limit</i>	-----	589781	

March 1950.

Se vi

(Cu i sequence; 29 electrons)

*Z*=34

Ground state 1s<sup>2</sup> 2s<sup>2</sup> 2p<sup>6</sup> 3s<sup>2</sup> 3p<sup>6</sup> 3d<sup>10</sup> 4s 2S<sub>0½</sub>

4s 2S<sub>0½</sub> 658994 cm<sup>-1</sup>

I. P. 81.7 volts

By extrapolation along the isoelectronic sequence Sawyer and Humphreys have classified seven lines between 452 Å and 886 Å, and determined the limit quoted here.

REFERENCE

R. A. Sawyer and C. J. Humphreys, Phys. Rev. **32**, 583 (1928). (I P). (T) (C L)

Se vi

Config.	Desig.	<i>J</i>	Level	Interval
4s	4s <sup>2</sup> S	0½	0	
4p	4p <sup>2</sup> P <sup>o</sup>	0½	112762	5700
		1½	118462	
4d	4d <sup>2</sup> D	1½	282830	679
		2½	283509	
5s	5s <sup>2</sup> S	0½	333594	
-----	-----	-----	-----	
Se vii (1S <sub>0</sub> )	<i>Limit</i>	-----	[658994]	

February 1950.

## Se VII

(Ni I sequence; 28 electrons)

 $Z=34$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} {}^1S_0$  $3d^{10} {}^1S_0$  1253300  $\text{cm}^{-1}$ 

I. P. 155 volts

Kruger and Shoupp have observed four lines between 171 Å and 180 Å and classified three of them as combinations of the ground term with terms from  $3d^9 4p$ .

From preliminary measurements, Edlén has confirmed these results, extended the analysis, and derived provisional absolute term values from the Rydberg  $nf$ -series. All the values in the table except those from  $3d^9 4p$  are from his unpublished manuscript. His unit,  $10^3 \text{ cm}^{-1}$  has here been changed to  $\text{cm}^{-1}$ .

Rao and Murti attribute some 40 lines in the interval 560 Å to 860 Å to Se VII and suggest tentative classifications of five of them. Further study of these assignments is needed.

## REFERENCES

- P. G. Kruger and W. E. Shoupp, Phys. Rev. **46**, 124 (1934). (I P) (T) (C L)  
 K. R. Rao and S. G. K. Murti, Proc. Roy. Soc. London [A] **145**, 696 (1934).  
 B. Edlén, letter (July 1950). (I P) (T)

## Se VII

## Se VII

Config.	Desig.	$J$	Level	Config.	Desig.	$J$	Level
$3d^{10}$	$3d^{10} {}^1S$	0	0	$3d^9({}^2D)5f$	$5f {}^1P^\circ$	1	1033500
$3d^9({}^2D)4p$	$4p {}^3P^\circ$	2		$3d^9({}^2D)5f$	$5f {}^3D^\circ$	3	
		1	565700			2	
		0				1	1040900
$3d^9({}^2D)4p$	$4p {}^1P^\circ$	1	578300	$3d^9({}^2D)6f$	$6f {}^1P^\circ$	1	1101000
$3d^9({}^2D)4p$	$4p {}^3D^\circ$	3		$3d^9({}^2D)6f$	$6f {}^3D^\circ$	3	
		2				2	
		1	581500			1	1108000
$3d^9({}^2D)5p$	$5p {}^1P^\circ$	1	889200	$3d^9({}^2D)7f$	$7f {}^1P^\circ$	1	1141700
$3d^9({}^2D)5p$	$5p {}^3D^\circ$	3		$3d^9({}^2D)7f$	$7f {}^3D^\circ$	3	
		2				2	
		1	894100			1	1148400
$3d^9({}^2D)4f$	$4f {}^3P^\circ$	2		$3d^9({}^2D)8f$	$8f {}^1P^\circ$	1	1167800
		1	904500	$3d^9({}^2D)8f$	$8f {}^3D^\circ$	3	
		0				2	
$3d^9({}^2D)4f$	$4f {}^1P^\circ$	1	909100			1	1174700
$3d^9({}^2D)4f$	$4f {}^3D^\circ$	3					
		2					
		1	917300				
				Se VIII ( ${}^2D_{3/2}$ )	Limit		1253300

August 1950.



## BROMINE

## Br I

35 electrons

 $Z=35$ Ground States  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^5 {}^2P_{1/2}^{\circ}$  $4p^5 {}^2P_{1/2}^{\circ}$  95550  $\text{cm}^{-1}$ 

I. P. 11.84 volts

This spectrum has been analyzed by Kiess and de Bruin, who have observed more than 300 lines between 3735 Å and 9320 Å. By utilizing the ultraviolet observations by Turner in the interval 1232 Å to 1633 Å, they have classified a total of 208 lines as combinations among terms of the doublet and quartet systems. The terms of these two systems are connected by observed intersystem combinations.

They have determined the limit from a Rydberg formula representing 11 sets of terms of the  $ns$ ,  $np$ , and  $nd$  configurations. This limit depends on series of two members each.

Two changes have been made in the published analysis. Revised tables have recently been prepared, which give the maximum binding energies of electrons in the first and second spectra of the elements H through Nb. From an examination of these data Russell has pointed out that the known  $nd$  terms are from  $6d$  and  $7d$ , and that the terms from  $4d$  and  $5d$  are not yet known because the observed lines lie beyond the range of the present observations.

In compiling the table the writer has assumed that the  ${}^1S$  limit in Br II is higher than the  ${}^1D$  limit, although the  $5s {}^2S$  and  $5s {}^2D$  terms of Br I from these respective limits are in the reverse order. Further analysis of Br II is required to settle this question; the term  $4p^4 {}^1S$  in Br II has not been found.

## REFERENCES

- L. A. Turner, Phys. Rev. **27**, 400 (1926).  
 C. C. Kiess, and T. L. de Bruin, Bur. Std. J. Research **4**, 667, RP 172 (1930). (I P) (T) (C L) (G D)  
 P. Lacroute, Ann. de Phys. [11] **3**, 59 [1934]. (Z E).  
 J. E. Mack, Rev. Mod. Phys. **22**, No. 1, 64 (1950). (Summary hfs)

## Br I

## Br I

Config.	Desig.	$J$	Level	Interval	Obs. $g$	Config.	Desig.	$J$	Level	Interval	Obs. $g$
$4s^2 4p^5$	$4p^5 {}^2P^{\circ}$	$1\frac{1}{2}$ $0\frac{1}{2}$	$0$ 3685	—3685		$4s^2 4p^4 ({}^1D) 5s$	$5s' {}^2D$	$1\frac{1}{2}$ $2\frac{1}{2}$	77305. 93 77324. 11	18. 18	
$4s^2 4p^4 ({}^3P) 5s$	$5s {}^4P$	$2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	63429. 82 64900. 50 66877. 16	—1470. 68 —1976. 66	1. 60 1. 50 2. 60	$4s^2 4p^4 ({}^3P) 5p$	$5p {}^2D^{\circ}$	$2\frac{1}{2}$ $1\frac{1}{2}$	78504. 88 79689. 16	—1184. 28	
$4s^2 4p^4 ({}^3P) 5s$	$5s {}^2P$	$1\frac{1}{2}$ $0\frac{1}{2}$	67176. 87 68963. 52	—1786. 65	1. 49 0. 75:	$4s^2 4p^4 ({}^3P) 5p$	$5p {}^4S^{\circ}$	$1\frac{1}{2}$	78669. 92		
$4s^2 4p^4 ({}^3P) 5p$	$5p {}^4P^{\circ}$	$2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	74665. 67 75002. 52 75807. 33	—336. 85 —804. 81		$4s^2 4p^4 ({}^3P) 5p$	$5p {}^2P^{\circ}$	$0\frac{1}{2}$ $1\frac{1}{2}$	78858. 98 79171. 64	312. 66	
$4s^2 4p^4 ({}^3P) 5p$	$5p {}^4D^{\circ}$	$3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	75514. 82 75690. 44 76736. 45 78069. 29	—175. 62 —1046. 01 —1332. 84		$4s^2 4p^4 ({}^3P) 6p$	$6p {}^4P^{\circ}$	$2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	85520. 14 85579. 60 85792. 56	—59. 46 —212. 96	1. 46 1. 54
$4s^2 4p^4 ({}^1S) 5s$	$5s'' {}^2S$	$0\frac{1}{2}$	75901. 89			$4s^2 4p^4 ({}^3P) 6p$	$6p {}^4D^{\circ}$	$3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	85756. 22 85813. 82 85937. 22 86429. 88	—57. 60 —123. 40 —492. 66	1. 43 1. 23 1. 62 2. 26

## Br I—Continued

## Br I—Continued

Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>	Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>
$4s^2 4p^4(^3P)6p$	$6p \ ^2P^\circ$	$1\frac{1}{2}$ $0\frac{1}{2}$	87252. 57 87492. 36	—239. 79	1. 29 1. 06	$4s^2 4p^4(^3P)6d$	$6d \ ^4P$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$	90186. 50 90559. 12 90782. 20	372. 62 223. 08	
$4s^2 4p^4(^3P)7s$	$7s \ ^2P$	$1\frac{1}{2}$ $0\frac{1}{2}$	87748. 30 90102. 93	—2354. 63		$4s^2 4p^4(^3P)6d$	$6d \ ^4F$	$4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$	90238. 19 90261. 16 90348. 33 90421. 50	—22. 97 —87. 17 —73. 17	
$4s^2 4p^4(^3P)7s$	$7s \ ^4P$	$2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	88128. 33 88268. 77 90285. 62	—140. 44 —2016. 85		$4s^2 4p^4(^3P)6d$	$6d \ ^2F$	$2\frac{1}{2}$ $3\frac{1}{2}$	91432. 00 91462. 44	30. 44	
$4s^2 4p^4(^1D)5p$	$5p' \ ^2P^\circ$	$1\frac{1}{2}$ $0\frac{1}{2}$	88476. 73 88552. 92	—76. 19		$4s^2 4p^4(^3P)6d$	$6d \ ^2D$	$2\frac{1}{2}$ $1\frac{1}{2}$	91646. 58 91811. 64	—165. 06	
$4s^2 4p^4(^1D)5p$	$5p' \ ^2F^\circ$	$3\frac{1}{2}$ $2\frac{1}{2}$	88658. 93 88674. 92	—15. 99		$4s^2 4p^4(^3P)7d$	$7d \ ^4D$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$	91733. 24 91793. 40 91803. 62 91748. 84	60. 16 10. 22 —54. 78	
$4s^2 4p^4(^3P)6p$	$6p \ ^2D^\circ$	$1\frac{1}{2}$ $2\frac{1}{2}$	88841. 29 89025. 05	183. 76		$4s^2 4p^4(^3P)6d$	$6d \ ^2P$	$1\frac{1}{2}$ $0\frac{1}{2}$	91785. 35		
$4s^2 4p^4(^3P)6p$	$6p \ ^4S^\circ$	$1\frac{1}{2}$	88947. 12		1. 36	$4s^2 4p^4(^3P)7d$	$7d \ ^4F$	$4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$	91844. 52 91874. 41 91949. 83	—29. 89 —75. 42	
$4s^2 4p^4(^3P)6p$	$6p \ ^2S^\circ$	$0\frac{1}{2}$	89140. 50		0. 47	$4s^2 4p^4(^3P)7d$	$7d \ ^4P$	$2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	92722. 87 92746. 84 92736. 30	—23. 97 10. 54	
$4s^2 4p^4(^3P)7p$	$7p \ ^4P^\circ$	$2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	89541. 96 89779. 48 89941. 14	—237. 52 —161. 66	1. 40: 1. 56:	-----	-----	-----	-----	-----	-----
$4s^2 4p^4(^3P)6d$	$6d \ ^4D$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$	89722. 68 89861. 13 89941. 29 89854. 02	138. 45 80. 16 —87. 27		Br II ( $^3P_2$ )	<i>Limit</i>	-----	95550		
$4s^2 4p^4(^1S)5p$	$5p'' \ ^2P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	89758. 04 89899. 16	141. 12							
$4s^2 4p^4(^1D)5p$	$5p' \ ^2D^\circ$	$2\frac{1}{2}$ $1\frac{1}{2}$	89786. 97 89854. 34	—67. 37							

January 1950.

## Br I OBSERVED TERMS\*

Config. $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} +$	Observed Terms					
$4s^2 4p^5$	$4p^5 \ ^2P^\circ$					
	$ns \ (n \geq 5)$		$np \ (n \geq 5)$			$nd \ (n \geq 4)$
$4s^2 4p^4(^3P)nx$	{	5,7s $^4P$ 5,7s $^2P$	5,6p $^4S^\circ$ 5,6p $^2S^\circ$	5,6,7p $^4P^\circ$ 5,6p $^2P^\circ$	5,6p $^4D^\circ$ 5,6p $^2D^\circ$	6,7d $^4P$ 6d $^2P$ 6,7d $^4D$ 6d $^2D$ 6,7d $^4F$ 6d $^2F$
$4s^2 4p^4(^1D)nx'$		5s' $^2D$		5p' $^2P^\circ$ 5p' $^2D^\circ$ 5p' $^2F^\circ$		
$4s^2 4p^4(^1S)nx''$		5s'' $^2S$		5p'' $^2P^\circ$		

\*For predicted terms in the spectra of the Br I isoelectronic sequence, see Vol. II, Introduction.



## Br II

(Se I sequence; 34 electrons)

 $Z=35$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^4 {}^3P_2$  $4p^4 {}^3P_2$  174119  $\text{cm}^{-1}$ 

I. P. 21.6 volts

This spectrum would well repay further observation; the analysis is far from complete. L. Bloch, E. Bloch, and P. Lacroute have given absolute values for 23 terms from the two limits  ${}^4S^\circ$  and  ${}^2D^\circ$  in Br III. The limit quoted here is from their paper, which gives no details about its derivation. The writer derives the limit 175870 (I P 21.8) from the  $ns {}^4S^\circ$  and  $ns {}^3S^\circ$  series ( $n=5,6$ ) by using a Rydberg formula. This value is probably too high.

R. Ramanadham and K. R. Rao have extended the earlier analysis and revised the  $4d {}^3D^\circ$ ,  $5d {}^3D^\circ$ , and  $5s' {}^1D^\circ$  terms. In general their terms have been used in preparing the table; although the writer has made adjustments in the values of the  $6s {}^4S^\circ$ ,  $6s {}^3S^\circ$ ,  $5d {}^5D^\circ$ , and  $5d {}^3D^\circ$  terms by utilizing unpublished wave lengths by Kiess. The level they list as  $6s' {}^3D_2^\circ$  has been corrected and entered in the table as  $2_2^\circ$ . The two levels listed as  $4d {}^3D_{2,1}^\circ$  by the Blochs and Lacroute, and rejected by Ramanadham and Rao, are included in the table as  $4p^5 {}^3P^\circ$ . This designation is tentatively suggested by the writer.

The observed  $g$ -values are from the 1934 paper except for the following, which have been determined by the writer from Lacroute's observed Zeeman patterns:

$4p^5 {}^3P^\circ$ ,  $5p' {}^3D_{2,3}$ ,  $5p' {}^3F_4$ ,  $5d' {}^1D^\circ$ ,  $5d' {}^1P^\circ$ ,  $5d' {}^1G^\circ$ ,  $6s' {}^1D^\circ$ ,  $5d' {}^3F_3^\circ$ ,  $5d' {}^3G^\circ$ ,  $5d' {}^3P^\circ$ ,  $5d' {}^3S^\circ$ ,  $5d' {}^1F^\circ$ .

Approximately 260 lines are classified in the interval between 711 Å and 6352 Å. Observed intersystem combinations connect the terms of all multiplicities.

## REFERENCES

- P. Lacroute, Ann. de Phys. [11] **3**, 5-96 (1935). (T) (C L) (Z E)  
 L. Bloch, E. Bloch, et P. Lacroute, Compt. Rend. **199**, 41 (1934). (I P) (T) (C L) (Z E)  
 R. Ramanadham and K. R. Rao, Ind. J. Phys. **18**, 317 (1944). (T) (C L)  
 C. C. Kiess, unpublished material (1940).  
 J. D. Ranade, Phil. Mag. **42**, No. 326, 284 (1951). (hfs)

## Br II

## Br II

Config.	Desig.	$J$	Level	Interval	Obs. $g$	Config.	Desig.	$J$	Level	Interval	Obs. $g$
$4p^4$	$4p^4 {}^3P$	2	0	-3139 -701		$4p^3({}^4S^\circ)4d$	$4d {}^3D^\circ$	1	112395.86	-865.34 930.03	0.52
		1	3139					2	111530.52		1.10
		0	3840					3	112460.55		1.29
$4p^4$	$4p^4 {}^1D$	2	11409	-2367.96	2.02	$4p^3({}^2D^\circ)5s$	$5s' {}^1D^\circ$	2	112939.46	135.36 358.05	1.06
$4p^3({}^4S^\circ)5s$	$5s {}^4S^\circ$	2	93927.48			$4p^3({}^4S^\circ)5p$	$5p {}^5P$	1	114682.76		2.51
$4s 4p^5$	$4p^5 {}^3P^\circ$	2	96439.39					2	114818.12		1.83
		1	98807.35					3	115176.17		1.69
		0				$4p^3({}^3P^\circ)5s$	$5s'' {}^1P^\circ$	1	116786.0		
$4p^3({}^4S^\circ)5s$	$5s {}^3S^\circ$	1	98476.38		1.99						
$4p^3({}^2D^\circ)5s$	$5s' {}^3D^\circ$	1	109428.2	154.3 695.7	0.55 1.14 1.29	$4p^3({}^4S^\circ)5p$	$5p {}^3P$	2	117767.56	206.06 -272.84	1.51
		2	109682.5					1	117561.50		1.49
		3	110378.2					0	117834.34		0/0



## Br II—Continued

## Br II—Continued

Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>	Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>
$4p^3(^2P^o)5s$	$5s''\ ^3P^o$	0 1 2	121154.0 121558.0 122629.0	404.0 1071.0		$4p^3(^2D^o)5d$	$5d'\ ^3D^o$	1 2 3	151357.8 151502.27 152380.58	144.5 878.31	1.30 1.28
$4p^3(^2D^o)5p$	$5p'\ ^3D$	1 2 3	128676.26 129965.86 130653.88	1289.60 688.02	0.67 1.19 1.31		$2^o$	2	151459.30		
$4p^3(^2D^o)5p$	$5p'\ ^3F$	2 3 4	130609.88 131308.75 131745.7	698.87 437.0	0.86 1.18 1.31	$4p^3(^2D^o)5d$	$5d'\ ^1D^o$	2	152832.3		1.06
$4p^3(^2D^o)5p$	$5p'\ ^1P$	1	130823.82		1.08	$4p^3(^2D^o)5d$	$5d'\ ^1P^o$	1	154088.7		1.04
$4p^3(^2D^o)5p$	$5p'\ ^1F$	3	131688.75		1.06	$4p^3(^2D^o)5d$	$5d'\ ^1G^o$	4	154984.6		1.20
$4p^3(^2D^o)5p$	$5p'\ ^3P$	2 1 0	133278.13 133601.14 133574.63	-323.01 26.51	1.42 1.48 0/0	$4p^3(^2D^o)6s$	$6s'\ ^1D^o$	2	155001.5		1.07
$4p^3(^4S^o)6s$	$6s\ ^5S^o$	2	135794.2		2.02			1 2 3	156025.0		
$4p^3(^2D^o)5p$	$5p'\ ^1D$	2	136607.73		1.01	$4p^3(^2D^o)5d$	$5d'\ ^3G^o$	3 4 5	156116.1 156152.3 156275.6	36.2 123.3	0.88 1.13 1.23
$4p^3(^4S^o)6s$	$6s\ ^3S^o$	1	137608.1			$4p^3(^2D^o)5d$	$5d'\ ^3P^o$	2 1 0	158234.3 157633.7 159257.9	600.6 -1624.2	1.52 1.40
$4p^3(^4S^o)5d$	$5d\ ^3D^o$	3 2 1	139257.5 140123.6 139450.2	-866.1 673.4	1.50	$4p^3(^2D^o)5d$	$5d'\ ^3S^o$	1	157725.9		1.64
$4p^3(^4S^o)5d$	$5d\ ^5D^o$	0 1 2 3 4	140223.09 140222.66 140506.63 140294.19 140291.94	-0.43 283.97 -212.44 -2.25	0/0 1.49 1.51 1.50 1.51	$4p^3(^2D^o)5d$	$5d'\ ^1F^o$	3	160887.7		1.07
						Br III ( $^4S_{1/2}$ )	Limit	-----	174119		

October 1950.

## Br II OBSERVED TERMS\*

Config. $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} +$	Observed Terms			
$4s^2 4p^4$	{ $4p^4\ ^3P$ $4p^4\ ^1D$			
$4s 4p^5$	$4p^5\ ^3P^o$			
	$ns(n \geq 5)$	$np(n \geq 5)$	$nd(n \geq 4)$	
$4s^2 4p^3(^4S^o)nx$	{ $5, 6s\ ^5S^o$ $5, 6s\ ^3S^o$	$5p\ ^5P$ $5p\ ^3P$	$5d\ ^5D^o$ $4, 5d\ ^3D^o$	
$4s^2 4p^3(^2D^o)nx'$	{ $5, 6s'\ ^3D^o$ $5, 6s'\ ^1D^o$	$5p'\ ^3P$ $5p'\ ^1P$	$5p'\ ^3D$ $5p'\ ^1D$	$5p'\ ^3F$ $5p'\ ^1F$
$4s^2 4p^3(^2P^o)nx''$	{ $5s''\ ^3P^o$ $5s''\ ^1P^o$		$5d'\ ^3S^o$ $5d'\ ^1P^o$	$5d'\ ^3P^o$ $5d'\ ^1D^o$ $5d'\ ^3F^o$ $5d'\ ^1G^o$

\*For predicted terms in the spectra of the Se I isoelectronic sequence, see Vol. II, Introduction.

## Br III

(As I sequence; 33 electrons)

 $Z=35$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^3 {}^4S_{1\frac{1}{2}}^{\circ}$  $4p^3 {}^4S_{1\frac{1}{2}}^{\circ}$  289529  $\text{cm}^{-1}$ 

I. P. 35.9 volts

The analysis is from K. R. Rao and Krishnamurty, who revised the early work of Deb, and published 128 classified lines between 665 Å and 4519 Å. Rao has since (1944) reported that "a further investigation of the spectrum has led to the identification of many intercombination lines . . ." He states that the interval between  $4p^3 {}^4S_{1\frac{1}{2}}^{\circ}$  and  $4p^3 {}^2D_{1\frac{1}{2}}^{\circ}$  is  $15042 \text{ cm}^{-1}$ . This correction has been added to the doublet terms in the 1937 paper, starting with  $4p^3 {}^2D_{1\frac{1}{2}}^{\circ}$  as zero. The six miscellaneous levels of the odd set, labeled  $a, b, \dots, f$  by the authors, are here called  $1^{\circ}, 2^{\circ}, \dots, 6^{\circ}$ .

The limit is from the two series terms 5, 6s  ${}^4P$ .

## REFERENCES

K. R. Rao and S. G. Krishnamurty, Proc. Roy. Soc. London [A] **161**, 38 (1937). (I P) (T) (C L)

K. R. Rao, Current Sci. **13**, 72 (L) (1944). (T)

## Br III

## Br III

Config.	Desig.	$J$	Level	Interval	Config.	Desig.	$J$	Level	Interval
$4s^2 4p^3$	$4p^3 {}^4S^{\circ}$	$1\frac{1}{2}$	0. 0		$4s^2 4p^2({}^3P)5p$	$5p {}^2D^{\circ}$	$1\frac{1}{2}$ $2\frac{1}{2}$	180695. 7 184178. 9	3483. 2
$4s^2 4p^3$	$4p^3 {}^2D^{\circ}$	$1\frac{1}{2}$ $2\frac{1}{2}$	15042. 0 16301. 0	1259. 0	$4s^2 4p^2({}^3P)5p$	$5p {}^4S^{\circ}$	$1\frac{1}{2}$	182017. 8	
$4s^2 4p^3$	$4p^3 {}^2P^{\circ}$	$0\frac{1}{2}$ $1\frac{1}{2}$	26915. 0 28579. 0	1664. 0	$4s^2 4p^2({}^3P)5p$	$5p {}^2S^{\circ}$	$0\frac{1}{2}$	182871. 5	
$4s^2 4p^2(?)4d$	$4d$ 1	$1\frac{1}{2}$	137483. 2		$4s^2 4p^2(?)5p$	$5p$ $1^{\circ}$		184627. 4	
$4s^2 4p^2(?)4d$	$4d$ 2	$1\frac{1}{2}, 2\frac{1}{2}$	137531. 1		$4s^2 4p^2(?)5p$	$5p$ $2^{\circ}$		185422. 2	
$4s^2 4p^2(?)4d$	$4d$ 3	$1\frac{1}{2}$	139792. 0		$4s^2 4p^2({}^3P)5p$	$5p {}^2P^{\circ}$	$0\frac{1}{2}$ $1\frac{1}{2}$	185432. 4	
$4s^2 4p^2(?)4d$	$4d$ 4	$2\frac{1}{2}$	141996. 6		$4s^2 4p^2(?)5p$	$5p$ $3^{\circ}$		187768. 1	
$4s^2 4p^2(?)4d$	$4d$ 5	$0\frac{1}{2}, 1\frac{1}{2}$	143994. 9		$4s^2 4p^2(?)5p$	$5p$ $4^{\circ}$		188043. 1	
$4s^2 4p^2(?)4d$	$4d$ 6	$1\frac{1}{2}$	145174. 6		$4s^2 4p^2(?)5p$	$5p$ $5^{\circ}$		191903. 3	
$4s^2 4p^2({}^3P)5s$	$5s$ ${}^4P$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$	145416. 9 147670. 4 150259. 8	2253. 5 2589. 4	$4s^2 4p^2(?)5p$	$5p$ $6^{\circ}$		192109. 7	
$4s^2 4p^2(?)4d$	$4d$ 7	$1\frac{1}{2}$	147557. 5		$4s^2 4p^2(?)5d$	$5d$ 10	$2\frac{1}{2}$	209006. 1	
$4s^2 4p^2({}^3P)5s$	$5s$ ${}^2P$	$0\frac{1}{2}$ $1\frac{1}{2}$	149199. 5 152109. 8	2910. 3	$4s^2 4p^2({}^3P)6s$	$6s$ ${}^4P$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$	210256. 5 213015. 3 215924. 1	2758. 8 2908. 8
$4s^2 4p^2(?)4d$	$4d$ 8	$2\frac{1}{2}$	150917. 8		$4s^2 4p^2(?)5d$	$5d$ 11	$1\frac{1}{2}$	212451. 6	
$4s^2 4p^2(?)4d$	$4d$ 9	$1\frac{1}{2}$	151063. 2		$4s^2 4p^2(?)5d$	$5d$ 12	$1\frac{1}{2}$	212586. 2	
$4s^2 4p^2({}^1D)5s$	$5s'$ ${}^2D$	$2\frac{1}{2}$ $1\frac{1}{2}$	157746. 7 158512. 4	-765. 7	$4s^2 4p^2(?)5d$	$5d$ 13	$1\frac{1}{2}$	214882. 6	
$4s^2 4p^2({}^3P)5p$	$5p$ ${}^4D^{\circ}$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$	173181. 8 173840. 0 175910. 4 178322. 5	658. 2 2070. 4 2412. 1	$4s^2 4p^2(?)5d$	$5d$ 14	$2\frac{1}{2}$	215470. 3	
$4s^2 4p^2({}^3P)5p$	$5p$ ${}^4P^{\circ}$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$	176670. 6 178130. 4 180253. 8	1459. 8 2123. 4	$4s^2 4p^2(?)5d$	$5d$ 15	$1\frac{1}{2}, 2\frac{1}{2}$	219987. 2	
					$4s^2 4p^2(?)5d$	$5d$ 16	$1\frac{1}{2}$	222868. 3	
					Br IV ( ${}^3P_0$ )	Limit		289529	



OBSERVED TERMS\*

Config. 1s <sup>2</sup> 2s <sup>2</sup> 2p <sup>6</sup> 3s <sup>2</sup> 3p <sup>6</sup> 3d <sup>10</sup> +	Observed Terms		
4s <sup>2</sup> 4p <sup>3</sup>	{ 4p <sup>3</sup> <sup>4</sup> S <sup>o</sup> 4p <sup>3</sup> <sup>2</sup> P <sup>o</sup> 4p <sup>3</sup> <sup>2</sup> D <sup>o</sup>		
	ns (n ≥ 5)		np (n ≥ 5)
	{ 5,6s <sup>4</sup> P 5s <sup>2</sup> P		5p <sup>4</sup> S <sup>o</sup> 5p <sup>4</sup> P <sup>o</sup> 5p <sup>4</sup> D <sup>o</sup> 5p <sup>2</sup> S <sup>o</sup> 5p <sup>2</sup> P <sup>o</sup> 5p <sup>2</sup> D <sup>o</sup>
4s <sup>2</sup> 4p <sup>2</sup> ( <sup>3</sup> P)nx			
4s <sup>2</sup> 4p <sup>2</sup> ( <sup>1</sup> D)nx'	5s' <sup>2</sup> D		

\*For predicted terms in the spectra of the As I isoelectronic sequence, see Vol. II, Introduction.

Br IV

(Ge I sequence; 32 electrons)

Z=35

Ground state 1s<sup>2</sup> 2s<sup>2</sup> 2p<sup>6</sup> 3s<sup>2</sup> 3p<sup>6</sup> 3d<sup>10</sup> 4s<sup>2</sup> 4p<sup>2</sup> <sup>3</sup>P<sub>0</sub>

4p<sup>2</sup> <sup>3</sup>P<sub>0</sub>      cm<sup>-1</sup>      I. P.      volts

This spectrum seriously needs further investigation. The authors have revised Deb's early work and published 47 classified lines in the interval 538 Å to 3041 Å. From combinations of 5s <sup>1,3</sup>P with terms of the 4p<sup>2</sup> and 5p configurations, they derive absolute term values with the limit equal to 404890 cm<sup>-1</sup>, giving an ionization potential of about 50 volts. No regular series have been observed and this estimate requires further confirmation.

Observed intersystem combinations connect the singlet and triplet systems of terms.

REFERENCE

A. S. Rao and S. G. Krishnamurty, Proc. Phys. Soc. London **46**, 531 (1934). (IP) (T) (CL)

Br IV

Br IV

Config.	Desig.	J	Level	Interval	Config.	Desig.	J	Level	Interval
4s <sup>2</sup> 4p <sup>3</sup>	4p <sup>3</sup> <sup>3</sup> P	0	0	3247 2990	4s <sup>2</sup> 4p( <sup>2</sup> P <sup>o</sup> )4d	4d <sup>3</sup> P <sup>o</sup>	2	176686	-1892 1625
		1	3247				1	180578	
		2	6237				0	178953	
4s <sup>2</sup> 4p <sup>3</sup>	4p <sup>3</sup> <sup>1</sup> D	2	18115			b <sup>o</sup>	1, 2	177993	
		a <sup>o</sup>	0, 1	139179					
4s 4p <sup>3</sup>	4p <sup>3</sup> <sup>3</sup> D <sup>o</sup>	1	153897	8053 10608	4s <sup>2</sup> 4p( <sup>2</sup> P <sup>o</sup> )5s	5s <sup>3</sup> P <sup>o</sup>	0	180619	1281 4688
		2	161950				1	181900	
		3	172558				2	186588	
4s 4p <sup>3</sup>	4p <sup>3</sup> <sup>3</sup> P <sup>o</sup>	2	167568	-419 -348	4s <sup>2</sup> 4p( <sup>2</sup> P <sup>o</sup> )5s	5s <sup>1</sup> P <sup>o</sup>	1	189034	
		1	167987						
		0	168335						
4s <sup>2</sup> 4p( <sup>2</sup> P <sup>o</sup> )4d	4d <sup>3</sup> D <sup>o</sup>	1	168910	1115 2856	4s <sup>2</sup> 4p( <sup>2</sup> P <sup>o</sup> )5p	5p <sup>3</sup> P	0	216786	2677 2567
		2	170025				1	219463	
		3	172881				2	222030	
					4s <sup>2</sup> 4p( <sup>2</sup> P <sup>o</sup> )5p	5p <sup>1</sup> D	2	227763	



## Br IV OBSERVED TERMS\*

Config. $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} +$	Observed Terms		
$4s^2 4p^2$	$\left\{ \begin{array}{l} 4p^2 \ ^3P \\ 4p^2 \ ^1D \\ 4p^3 \ ^3P^\circ \ 4p^3 \ ^1D^\circ \end{array} \right.$		
$4s \ 4p^3$			
	$ns(n \geq 5)$	$np(n \geq 5)$	$nd(n \geq 4)$
$4s^2 4p(^2P^\circ)nz$	$\left\{ \begin{array}{l} 5s \ ^3P^\circ \\ 5s \ ^1P^\circ \end{array} \right.$	$5p \ ^3P$ $5p \ ^1D$	$4d \ ^3P^\circ$ $4d \ ^1D^\circ$

\*For predicted terms in the spectra of the Ge I isoelectronic sequence, see Vol. II, Introduction.

## Br V

(Ga I sequence; 31 electrons)

$Z=35$

Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p \ ^2P_0^\circ$

$4p \ ^2P_{0,1,2}$        $\text{cm}^{-1}$

I. P.      volts

This spectrum needs investigation. From a study of isoelectronic sequence data, A. S. Rao and K. R. Rao have reported five terms and 12 classified lines in the range between 468 Å and 855 Å. Their term values are quoted in the table. The term  $4p^2 \ ^2D$  has been added by the writer with the value derived from its combination with  $4p \ ^2P^\circ$ , which they give.

## REFERENCE

A. S. Rao and K. R. Rao, Proc. Phys. Soc. London **46**, 164 (1934). (T) (C L)

## Br V

Config.	Desig.	$J$	Level	Interval
$4s^2(^1S)4p$	$4p \ ^2P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	$0$ $6090$	6090
$4s \ 4p^2$	$4p^2 \ ^2D$	$1\frac{1}{2}$ $2\frac{1}{2}$	122941 123628	687
$4s \ 4p^2$	$4p^2 \ ^2P$	$0\frac{1}{2}$ $1\frac{1}{2}$	158158 161011	2853
$4s^2(^1S)4d$	$4d \ ^2D$	$1\frac{1}{2}$ $2\frac{1}{2}$	187970 188592	622
$4s^2(^1S)5s$	$5s \ ^2S$	$0\frac{1}{2}$	213510	

May 1950.

Br VI

(Zn I sequence; 30 electrons)

Z=35

Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 \ ^1S_0$

$4s^2 \ ^1S_0$        $\text{cm}^{-1}$       I. P.      volts

Little is known about this spectrum. Rao and Rao have classified 14 lines between 499 Å and 939 Å. They list one dubious intersystem combination connecting the singlet and triplet terms. The singlet term  $4p \ ^1P_1^\circ$  needs further confirmation since it is based upon only one combination.

REFERENCE

A. S. Rao and K. R. Rao, Proc. Phys. Soc. London **46**, 166 (1934). (T) (C L)

Br VI

Config.	Desig.	<i>J</i>	Level	Interval
$4s^2$	$4s^2 \ ^1S$	0	0	
$4s(^2S)4p$	$4p \ ^3P^\circ$	0	104316	2115 4905
		1	106431	
		2	111336	
$4s(^2S)4p$	$4p \ ^1P^\circ$	1	151274	
$4p^2$	$4p^2 \ ^3P$	0	244136	3270 6486
		1	247406	
		2	253892	
$4s(^2S)4d$	$4d \ ^3D$	1	304648	319 484
		2	304967	
		3	305451	

March 1950.

## Br VII

(Cu I sequence; 29 electrons)

 $Z=35$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 S_{0\frac{1}{2}}$  $4s^2 S_{0\frac{1}{2}}$   $\text{cm}^{-1}$ 

I. P. volts

This spectrum is incompletely known. In 1931 Mack reported that the lines of the principal doublet were very intense on his plates. Subsequently Rao and Rao classified five lines between 502 Å and 779 Å. The terms given in the table are from their paper.

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## Br VII

Config.	Desig.	$J$	Level	Interval
$4s$	$4s^2 S$	$0\frac{1}{2}$	0	
$4p$	$4p^2 P^o$	$0\frac{1}{2}$ $1\frac{1}{2}$	$128274$ $135854$	7580
$4d$	$4d^2 D$	$1\frac{1}{2}$ $2\frac{1}{2}$	$327205$ $328066$	861

March 1950.

## Br VIII

(Ni I sequence; 28 electrons)

 $Z=35$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 1S_0$  $3d^{10} 1S_0$  1554700  $\text{cm}^{-1}$ 

I. P. 193 volts

Kruger and Shoupp have observed two lines near 139 Å, and classified them as combinations of the ground term with terms from  $3d^9 4p$ .

From preliminary measurements Edlén has confirmed these results, extended the analysis, and derived provisional absolute term values from the Rydberg  $nf$ -series. All of the values in the table except those from  $3d^9 4p$  are from his unpublished manuscript. His unit,  $10^3 \text{ cm}^{-1}$ , has here been changed to  $\text{cm}^{-1}$ .

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B. Edlén, letter (July 1950). (I P) (T)



## Br VIII

## Br VIII

Config.	Desig.	<i>J</i>	Level	Config.	Desig.	<i>J</i>	Level
$3d^{10}$	$3d^{10} {}^1S$	0	0	$3d^9({}^3D)4f$	$4f {}^3D^\circ$	3 2 1	1115900
$3d^9({}^3D)4p$	$4p {}^3P^\circ$	2 1 0	701900	$3d^9({}^3D)5f$	$5f {}^3P^\circ$	1	1266900
$3d^9({}^3D)4p$	$4p {}^1P^\circ$	1	715300	$3d^9({}^3D)5f$	$5f {}^3D^\circ$	3 2 1	1276700
$3d^9({}^3D)4p$	$4p {}^3D^\circ$	3 2 1	719800	$3d^9({}^3D)6f$	$6f {}^3P^\circ$	1	1355400
$3d^9({}^3D)4f$	$4f {}^3P^\circ$	2 1 0	1098300	$3d^9({}^3D)6f$	$6f {}^3D^\circ$	3 2 1	1364100
$3d^9({}^3D)4f$	$4f {}^1P^\circ$	1	1104500	Br IX ( ${}^2D_{3/2}$ )	Limit	-----	1554700

August 1950.

## Br IX

(Co I sequence; 27 electrons)

 $Z=35$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^9 {}^2D_{3/2}$  $3d^9 {}^2D_{3/2}$  cm<sup>-1</sup>

I. P. volts

Edlén has observed three lines due to the transition  $3p^6 3d^9 {}^2D - 3p^5 3d^{10} {}^2P^\circ$ . From preliminary unpublished measurements he has furnished the provisional term values quoted in the table. His unit, 10<sup>3</sup> cm<sup>-1</sup>, has here been changed to cm<sup>-1</sup>.

## REFERENCE

B. Edlén, letter (July 1950). (T)

## Br IX

Config.	Desig.	<i>J</i>	Level	Interval
$3p^6 3d^9$	$3d^9 {}^3D$	2½ 1½	0 8600	-8600
$3p^5 3d^{10}$	$3d^{10} {}^3P^\circ$	1½ 0½	912500 962300	-49800

July 1950.

## KRYPTON

## Kr I

36 electrons

Z=36

Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 {}^1S_0$  $4p^6 {}^1S_0$  112915.2  $\text{cm}^{-1}$ 

I. P. 13.996 volts

The Kr I spectrum has now been observed from 850A to 22000A. The observations in the infrared beyond the photographic limit are listed in the 1947 and 1949 references below, by Humphreys and Plyler, and Sittner and Peck, respectively.

The present list of energy levels has been compiled from an unpublished manuscript kindly furnished by Edlén, who has made a careful study of the spectrum and interpreted it with the aid of present atomic theory. Many of the levels are from the papers published at the National Bureau of Standards, which, in turn, contain revisions and extensions of the earlier work on Kr I. Three place entries are from interferometer measurements. Edlén's predicted value for one level of the  $6f[4\frac{1}{2}]$  pair is entered in brackets in the table.

The observed  $g$ -values are from the 1940 and 1943 references by J. B. Green and others. Those for the  $4f[1\frac{1}{2}]_1$ , and  $5f[1\frac{1}{2}]_2$  have been added by the writer from Table 1 in the 1940 paper. Pogány has also published a shorter list of  $g$ -values of Kr I.

White has discussed the effect of autoionization on the spectra of the inert gases, as an explanation of the lack of higher series members having the higher limit ( ${}^2P_{0\frac{1}{2}}^{\circ}$ ). Beutler has observed a number of these lines. The levels  $ns'[0\frac{1}{2}]_1^{\circ}$ , ( $n=8$  to 12) and  $nd'[1\frac{1}{2}]_1^{\circ}$ , ( $n=6$  to 14) have been determined by the writer from Beutler's observations of absorption series in the region 850 A to 900 A, and added to Edlén's list.

Edlén has determined the revised series limits quoted here. Boyce's value, 112915.7, has been used for the compilation of the energy levels. This value is 1.53  $\text{cm}^{-1}$  higher than the earlier value adopted in the 1931 paper by Meggers, de Bruin, and Humphreys.

The Paschen notation is entered in column one of the table in the same form as for Ne I and Ar I. The letters X, Z, U, T, Y, and W, adopted when configurations involving  $f$ -electrons were found, are also entered in this column.

Edlén suggested that a pair-coupling notation be adopted for Ne I-like spectra to take into account the departure from  $LS$ -coupling. According to Shortley,  $LS$ -designations can be significantly assigned in only a few cases. The writer suggests them provisionally for the following groups of levels:

Paschen	Desig.	Paschen	Desig.	Paschen	Desig.	Paschen	Desig.	Paschen	Desig.
$(n-4)s_5$	$ns {}^3P_2^{\circ}$	$2p_{10}$	$5p {}^3S_1$	$2p_5$	$5p {}^3P_0$	$4d_6$	$5d {}^3P_0^{\circ}$	$4d_1''$	$5d {}^3F_2^{\circ}$
$(n-4)s_4$	$ns {}^3P_1^{\circ}$	$2p_9$	$5p {}^3D_3$	$2p_4$	$5p {}^1P_1$	$4d_5$	$5d {}^3P_1^{\circ}$	$4d_1'$	$5d {}^1F_3^{\circ}$
$(n-4)s_3$	$ns {}^3P_0^{\circ}$	$2p_8$	$5p {}^3D_2$	$2p_3$	$5p {}^3P_1$	$4, 5d_4'$	$5, 6d {}^3F_1^{\circ}$	$4s_1'''$	$5d {}^1D_2^{\circ}$
$(n-4)s_2$	$ns {}^1P_1^{\circ}$	$2p_7$	$5p {}^3D_1^?$	$2p_2$	$5p {}^3P_2$	$4, 5d_4$	$5, 6d {}^3F_3^{\circ}$	$4s_1''$	$5d {}^3D_3^{\circ}$
		$2p_6$	$5p {}^1D_2^?$	$2p_1$	$5p {}^1S_0$	$4d_3$	$5d {}^3P_2^{\circ}$	$4s_1'$	$5d {}^3D_2^{\circ}$
						$4d_2$	$5d {}^1P_1^{\circ}$	$4s_1$	$5d {}^3D_1^{\circ}$

Consequently, the  $j\bar{l}$ -coupling notation in the general form suggested by Racah is here introduced, as for Ne I and Ar I. The present arrangement has been suggested by Shortley, who has made a detailed study of the theoretical arrangement of the "pairs", to be used as a guide in preparing the present table.

Twenty lines of Kr I between 4273 A and 6456 A were recommended by the International Astronomical Union (1935) as secondary standards of wavelength. All but two are regarded as accurate to eight figures. This Union (1935) listed, also, 25 lines between 3424 A and 3845 A measured to four decimal places. Further observations are required before these can be adopted as secondary standards.



## Kr I—Continued

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## Kr I

## Kr I

Authors	Config.	Desig.	<i>J</i>	Level	Obs. <i>g</i>	Authors	Config.	Desig.	<i>J</i>	Level	Obs. <i>g</i>
$1p_0$	$4p^6$	$4p^6 \ ^1S$	0	0. 0		$3d_1''$ $3d_1'$	$4p^5(^2P_{1/2})4d$	$4d \ [2\frac{1}{2}]^\circ$	2 3	98868. 22 99080. 19	
$1s_5$ $1s_4$	$4p^5(^2P_{1/2})5s$	$5s \ [1\frac{1}{2}]^\circ$	2 1	79972. 535 80917. 561	1. 502 1. 242	$3s_1''''$ $3s_1'''$	$4p^5(^2P_{0/2})4d$	$4d' \ [2\frac{1}{2}]^\circ$	2 3	103443. 46 103702. 239	
$1s_3$ $1s_2$	$4p^5(^2P_{0/2})5s$	$5s' \ [0\frac{1}{2}]^\circ$	0 1	85192. 414 85847. 501	1. 259	$3s_1''$ $3s_1'$	"	$4d' \ [1\frac{1}{2}]^\circ$	2 1	103267. 12 104888. 114	1. 018
$2p_{10}$	$4p^5(^2P_{1/2})5p$	$5p \ [0\frac{1}{2}]$	1	91169. 313	1. 898	$2s_5$ $2s_4$	$4p^5(^2P_{1/2})6s$	$6s \ [1\frac{1}{2}]^\circ$	2 1	99627. 67 99894. 83	
$2p_9$ $2p_8$	"	$5p \ [2\frac{1}{2}]$	3 2	92295. 199 92308. 177	1. 336 1. 099	$2s_3$ $2s_2$	$4p^5(^2P_{0/2})6s$	$6s' \ [0\frac{1}{2}]^\circ$	0 1	105092. 14 105147. 13	
$2p_7$ $2p_6$	"	$5p \ [1\frac{1}{2}]$	1 2	92965. 194 93124. 140	1. 004 1. 388	$3p_{10}$	$4p^5(^2P_{1/2})6p$	$6p \ [0\frac{1}{2}]$	1	102888. 002	1. 834
$2p_5$	"	$5p \ [0\frac{1}{2}]$	0	94093. 662		$3p_9$ $3p_8$	"	$6p \ [2\frac{1}{2}]$	3 2	103116. 449 103121. 953	1. 333 1. 107
$2p_4$ $2p_3$	$4p^5(^2P_{0/2})5p$	$5p' \ [1\frac{1}{2}]$	1 2	97596. 718 97945. 970	0. 647 1. 181	$3p_7$ $3p_6$	"	$6p \ [1\frac{1}{2}]$	1 2	103314. 284 103363. 425	1. 034 1. 403
$2p_2$ $2p_1$	"	$5p' \ [0\frac{1}{2}]$	1 0	97919. 951 98855. 871	1. 452	$3p_5$	"	$6p \ [0\frac{1}{2}]$	0	103762. 446	
$3d_6$ $3d_5$	$4p^5(^2P_{1/2})4d$	$4d \ [0\frac{1}{2}]^\circ$	0 1	96772. 31 97086. 00		$3p_4$ $3p_3$	$4p^5(^2P_{0/2})6p$	$6p' \ [1\frac{1}{2}]$	1 2	108439. 074 108568. 583	0. 648 1. 158
$3d_4'$ $3d_4$	"	$4d \ [3\frac{1}{2}]^\circ$	4 3	97798. 15 98227. 08		$3p_2$ $3p_1$	"	$6p' \ [0\frac{1}{2}]$	1 0	108514. 999 108822. 382	1. 401
$3d_3$ $3d_2$	"	$4d \ [1\frac{1}{2}]^\circ$	2 1	97688. 58 99647. 02		$4d_6$ $4d_5$	$4p^5(^2P_{1/2})5d$	$5d \ [0\frac{1}{2}]^\circ$	0 1	104074. 276 103802. 598	1. 098



## Kr I—Continued

## Kr I—Continued

Authors	Config.	Desig.	<i>J</i>	Level	Obs. <i>g</i>	Authors	Config.	Desig.	<i>J</i>	Level	Obs. <i>g</i>
4d' <sub>4</sub> 4d <sub>4</sub>	4p <sup>5</sup> ( <sup>2</sup> P <sub>i<sub>1/2</sub></sub> )5d	5d [3½]°	4 3	104631. 87 104917. 282	1. 050	5U	4p <sup>5</sup> ( <sup>2</sup> P <sub>i<sub>1/2</sub></sub> )5f	5f [4½]	5 4	108487. 73 108487. 88	
4d <sub>3</sub> 4d <sub>2</sub>	"	5d [1½]°	2 1	105008. 054 105649. 25	1. 295 0. 935	5T 5Y	"	5f [2½]	3 2	108504. 045 108504. 62	
4d' <sub>1</sub> 4d <sub>1</sub>	"	5d [2½]°	2 3	105164. 302 105209. 278	1. 006 1. 243	5W	"	5f [3½]	3, 4	108517. 77	
4s <sub>1</sub> <sup>'''</sup> 4s <sub>1</sub> <sup>'''</sup>	4p <sup>5</sup> ( <sup>2</sup> P <sub>o<sub>1/2</sub></sub> )5d	5d' [2½]°	2 3	110122. 88 110238. 22	0. 899 1. 140	5p <sub>10</sub>	4p <sup>5</sup> ( <sup>2</sup> P <sub>i<sub>1/2</sub></sub> )8p	8p [0½]	1	109083. 580	1. 795
4s <sub>1</sub> <sup>''</sup> 4s <sub>1</sub>	"	5d' [1½]°	2 1	110104. 05 110734. 07	1. 169	5p <sub>9</sub> 5p <sub>8</sub>	"	8p [2½]	3 2	109104. 106 109106. 58	
3s <sub>5</sub> 3s <sub>4</sub>	4p <sup>5</sup> ( <sup>2</sup> P <sub>i<sub>1/2</sub></sub> )7s	7s [1½]°	2 1	105648. 254 105771. 50	1. 496 1. 097	5p <sub>7</sub> 5p <sub>6</sub>	"	8p [1½]	1 2	109150. 501 109161. 762	1. 014 1. 411
3s <sub>2</sub>	4p <sup>5</sup> ( <sup>2</sup> P <sub>o<sub>1/2</sub></sub> )7s	7s' [0½]°	0 1	111003. 79	1. 208	5p <sub>5</sub>	"	8p [0½]	0	109296. 997	
4X 4Z	4p <sup>5</sup> ( <sup>2</sup> P <sub>i<sub>1/2</sub></sub> )4f	4f [1½]	1 2	105965. 258 105966. 379	0. 52	6d <sub>6</sub> 6d <sub>5</sub>	4p <sup>5</sup> ( <sup>2</sup> P <sub>i<sub>1/2</sub></sub> )7d	7d [0½]°	0 1	109331. 75 109343. 75	1. 355
4U	"	4f [4½]	5	105989. 60		6d' <sub>4</sub> 6d <sub>4</sub>	"	7d [3½]°	4 3	109434. 716 109472. 27	1. 228 1. 094
4T 4Y	"	4f [2½]	3 2	106021. 657 106022. 425		6d <sub>3</sub> 6d <sub>2</sub>	"	7d [1½]°	2 1	109376. 14 109689. 56	1. 315 0. 797
4W	"	4f [3½]	3, 4	106048. 19		6d' <sub>1</sub> 6d <sub>1</sub>	"	7d [2½]°	2 3	109528. 36 109579. 82	0. 954 1. 231
	4p <sup>5</sup> ( <sup>2</sup> P <sub>o<sub>1/2</sub></sub> )4f	4f' [3½]	4 3	111378. 7 111379. 21		6s' <sub>1</sub>	4p <sup>5</sup> ( <sup>2</sup> P <sub>o<sub>1/2</sub></sub> )7d	7d' [1½]°	2 1	115010	
	"	4f' [2½]	3 2	111381. 10 111381. 98		5s <sub>5</sub> 5s <sub>4</sub>	4p <sup>5</sup> ( <sup>2</sup> P <sub>i<sub>1/2</sub></sub> )9s	9s [1½]°	2 1	109752. 74 109780. 11	1. 495 1. 174
4p <sub>10</sub>	4p <sup>5</sup> ( <sup>2</sup> P <sub>i<sub>1/2</sub></sub> )7p	7p [0½]	1	107006. 184	1. 795	5s <sub>2</sub>	4p <sup>5</sup> ( <sup>2</sup> P <sub>o<sub>1/2</sub></sub> )9s	9s' [0½]°	0 1	115128	
4p <sub>9</sub> 4p <sub>8</sub>	"	7p [2½]	3 2	107141. 983 107141. 611		6X 6Z	4p <sup>5</sup> ( <sup>2</sup> P <sub>i<sub>1/2</sub></sub> )6f	6f [1½]	1 2	109836. 94 109837. 56	
4p <sub>7</sub> 4p <sub>6</sub>	"	7p [1½]	1 2	107222. 145 107247. 499	1. 041 1. 403		"	6f [4½]	5 4	[109843. 8] 109843. 91	
4p <sub>5</sub>	"	7p [0½]	0	107411. 191		6U	"	6f [2½]	3 2	109853. 01 109853. 55	
5d <sub>6</sub> 5d <sub>5</sub>	4p <sup>5</sup> ( <sup>2</sup> P <sub>i<sub>1/2</sub></sub> )6d	6d [0½]°	0 1	107604. 43 107676. 953	1. 348	6T 6Y	"	6f [3½]	3, 4	109861. 12	
5d' <sub>4</sub> 5d <sub>4</sub>	"	6d [3½]°	4 3	107779. 701 107877. 712	1. 231 1. 073	6W	"	6f [3½]	3, 4	109861. 12	
5d <sub>3</sub> 5d <sub>2</sub>	"	6d [1½]°	2 1	107797. 681 108259. 59	1. 318 0. 823	6p <sub>10</sub>	4p <sup>5</sup> ( <sup>2</sup> P <sub>i<sub>1/2</sub></sub> )9p	9p [0½]	1	110180. 87	
5d' <sub>1</sub> 5d <sub>1</sub>	"	6d [2½]°	2 3	107993. 585 108047. 121	0. 965 1. 254	6p <sub>9</sub> 6p <sub>8</sub>	"	9p [2½]	3 2	110210. 35 110210. 64	
5s' <sub>1</sub>	4p <sup>5</sup> ( <sup>2</sup> P <sub>o<sub>1/2</sub></sub> )6d	6d' [1½]°	2 1	113500		6p <sub>7</sub> 6p <sub>6</sub>	"	9p [1½]	1 2	110235. 64 110243. 62	
4s <sub>5</sub> 4s <sub>4</sub>	4p <sup>5</sup> ( <sup>2</sup> P <sub>i<sub>1/2</sub></sub> )8s	8s [1½]°	2 1	108325. 81 108373. 87	1. 506 1. 171	6p <sub>5</sub>	"	9p [0½]	0	110308. 93	
4s <sub>3</sub> 4s <sub>2</sub>	4p <sup>5</sup> ( <sup>2</sup> P <sub>o<sub>1/2</sub></sub> )8s	8s' [0½]°	0 1	113711		7d <sub>6</sub> 7d <sub>5</sub>	4p <sup>5</sup> ( <sup>2</sup> P <sub>i<sub>1/2</sub></sub> )8d	8d [0½]°	0 1	110336. 47 110291. 15	1. 294
5X 5Z	4p <sup>5</sup> ( <sup>2</sup> P <sub>i<sub>1/2</sub></sub> )5f	5f [1½]	1 2	108481. 562 108471. 937	0. 61 1. 09	7d' <sub>4</sub> 7d <sub>4</sub>	"	8d [3½]°	4 3	110404. 42 110471. 70	1. 236 1. 037
						7d <sub>3</sub> 7d <sub>2</sub>	"	8d [1½]°	2 1	110513. 57 110514. 84	

## Kr I—Continued

## Kr I—Continued

Authors	Config.	Desig.	<i>J</i>	Level	Obs. <i>g</i>	Authors	Config.	Desig.	<i>J</i>	Level	Obs. <i>g</i>
$7d_1''$ $7d_1'$	$4p^5(^2P_{1/2})8d$	$8d [2\frac{1}{2}]^\circ$	2 3	110497. 47 110508. 89	1. 005 1. 227	$9d_3$	$4p^5(^2P_{1/2})10d$	$10d [1\frac{1}{2}]^\circ$	2 1	111446. 18	
$7s_1'$	$4p^5(^2P_{0/2})8d$	$8d' [1\frac{1}{2}]^\circ$	2 1	115910		$9d_1''$ $9d_1'$	"	$10d [2\frac{1}{2}]^\circ$	2 3	111468. 14 111474. 87	
$6s_5$ $6s_4$	$4p^5(^2P_{1/2})10s$	$10s [1\frac{1}{2}]^\circ$	2 1	110609. 13 110619. 78	1. 161	$9s_1'$	$4p^5(^2P_{0/2})10d$	$10d' [1\frac{1}{2}]^\circ$	2 1	116870	
$6s_2$	$4p^5(^2P_{0/2})10s$	$10s' [0\frac{1}{2}]^\circ$	0 1	115961		$8s_5$ $8s_4$	$4p^5(^2P_{1/2})12s$	$12s [1\frac{1}{2}]^\circ$	2 1	111528. 62 111537. 42	
$7X$ $7Z$	$4p^5(^2P_{1/2})7f$	$7f [1\frac{1}{2}]$	1 2	110656. 24 110656. 80		$8s_2$	$4p^5(^2P_{0/2})12s$	$12s' [0\frac{1}{2}]^\circ$	0 1	116904	
$7U$	"	$7f [4\frac{1}{2}]$	4, 5	110660. 69		$9X$	$4p^5(^2P_{1/2})9f$	$9f [1\frac{1}{2}]$	1 2	111551. 3	
$7T$ $7Y$	"	$7f [2\frac{1}{2}]$	3 2	110666. 24 110666. 54		$9U$	"	$9f [4\frac{1}{2}]$	5 4	111553. 16	
$7W$	"	$7f [3\frac{1}{2}]$	3, 4	110671. 46		$9T$	"	$9f [2\frac{1}{2}]$	3	111556. 56	
$7p_{10}$	$4p^5(^2P_{1/2})10p$	$10p [0\frac{1}{2}]$	1	110873. 22		$10d_6$ $10d_5$	$4p^5(^2P_{1/2})11d$	$11d [0\frac{1}{2}]^\circ$	0 1	111709. 11 111718. 95	
$7p_6$	"	$10p [1\frac{1}{2}]$	1 2	110916. 86		$10d_4'$ $10d_4$	"	$11d [3\frac{1}{2}]^\circ$	4 3	111726. 00 111737. 65	
$7p_5$	"	$10p [0\frac{1}{2}]$	0	110957. 03		$10d_3$	"	$11d [1\frac{1}{2}]^\circ$	2 1	111731. 93	
$8d_6$	$4p^5(^2P_{1/2})9d$	$9d [0\frac{1}{2}]^\circ$	0	110934. 16		$10d_1'$	"	$11d [2\frac{1}{2}]^\circ$	2 3	111755. 14	
$8d_4'$ $8d_4$	"	$9d [3\frac{1}{2}]^\circ$	4 3	111019. 65 111047. 90		$10s_1'$	$4p^5(^2P_{0/2})11d$	$11d' [1\frac{1}{2}]^\circ$	2 1	117145	
$8d_3$ $8d_2$	"	$9d [1\frac{1}{2}]^\circ$	2 1	111047. 86 111143		$10X$	$4p^5(^2P_{1/2})10f$	$10f [1\frac{1}{2}]$	1 2	111810. 4	
$8d_1''$ $8d_1'$	"	$9d [2\frac{1}{2}]^\circ$	2 3	111072. 24 111079. 85		$10U$	"	$10f [4\frac{1}{2}]$	5 4	111812. 3	
$8s_1'$	$4p^5(^2P_{0/2})9d$	$9d' [1\frac{1}{2}]^\circ$	2 1	116480		$10T$	"	$10f [2\frac{1}{2}]$	3 2	111814. 2	
$7s_5$ $7s_4$	$4p^5(^2P_{1/2})11s$	$11s [1\frac{1}{2}]^\circ$	2 1	111155. 19 111171. 62		$11d_4'$ $11d_4$	$4p^5(^2P_{1/2})12d$	$12d [3\frac{1}{2}]^\circ$	4 3	111939. 50 111947. 70	
$7s_2$	$4p^5(^2P_{0/2})11s$	$11s' [0\frac{1}{2}]^\circ$	0 1	116527		$11s_1'$	$4p^5(^2P_{0/2})12d$	$12d' [1\frac{1}{2}]^\circ$	2 1	117345	
$8X$	$4p^5(^2P_{1/2})8f$	$8f [1\frac{1}{2}]$	1 2	111187. 33		$12d_4'$	$4p^5(^2P_{1/2})13d$	$13d [3\frac{1}{2}]^\circ$	4 3	112100. 54	
$8U$	"	$8f [4\frac{1}{2}]$	4, 5	111190. 29		$12s_1'$	$4p^5(^2P_{0/2})13d$	$13d' [1\frac{1}{2}]^\circ$	2 1	117497	
$8T$ $8Y$	"	$8f [2\frac{1}{2}]$	3 2	111193. 45 111193. 78							
$8p_5$	$4p^5(^2P_{1/2})11p$	$11p [0\frac{1}{2}]$	0	111391. 1							
$9d_6$ $9d_5$	$4p^5(^2P_{1/2})10d$	$10d [0\frac{1}{2}]^\circ$	0 1	111413. 23 111429. 36			Kr II ( $^2P_{1/2}^\circ$ )	<b>Limit</b>	-----	112915. 2	
$9d_4'$ $9d_4$	"	$10d [3\frac{1}{2}]^\circ$	4 3	111433. 88 111451. 22		$13s_1'$	$4p^5(^2P_{0/2})14d$	$14d' [1\frac{1}{2}]^\circ$	2 1	117625	
							Kr II ( $^2P_{0/2}^\circ$ )	<b>Limit</b>	-----	118284. 7	

June 1951.



## Kr I OBSERVED LEVELS\*

Config. $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 +$	Observed Terms			
$4p^6$	$4p^6 \ ^1S$			
	$ns \ (n \geq 5)$	$np \ (n \geq 5)$		$nd \ (n \geq 4)$
	$\left\{ \begin{array}{l} 5-12s \ ^3P^\circ \\ 5-12s \ ^1P^\circ \end{array} \right.$	$\begin{array}{l} 5p \ ^3S \\ 5p \ ^1S \end{array}$	$\begin{array}{l} 5p \ ^3P \\ 5p \ ^1P \end{array}$	$\begin{array}{l} 5p \ ^3D \\ 5p \ ^1D \end{array}$
$4p^5(^2P^\circ)nx$		$\begin{array}{l} 5d \ ^3P^\circ \\ 5d \ ^1P^\circ \end{array}$	$\begin{array}{l} 5d \ ^3D^\circ \\ 5d \ ^1D^\circ \end{array}$	$\begin{array}{l} 5, 6d \ ^3F^\circ \\ 5, 6d \ ^1F^\circ \end{array}$
<i>jl</i> -Coupling Notation				
$4p^5(^2P_{1/2})nx$	Observed Pairs			
	$ns \ (n \geq 5)$	$np \ (n \geq 5)$		$nd \ (n \geq 4)$
	$5-12s \ [1\frac{1}{2}]^\circ$	$\begin{array}{l} 5-11p \ [0\frac{1}{2}] \\ 5-9p \ [2\frac{1}{2}] \\ 5-10p \ [1\frac{1}{2}] \end{array}$		$\begin{array}{l} 4-11d \ [0\frac{1}{2}]^\circ \\ 4-13d \ [3\frac{1}{2}]^\circ \\ 4-11d \ [1\frac{1}{2}]^\circ \\ 4-11d \ [2\frac{1}{2}]^\circ \end{array}$
$4p^5(^2P_{3/2})nx'$	$5-12s' \ [0\frac{1}{2}]^\circ$	$\begin{array}{l} 5-6p' \ [1\frac{1}{2}] \\ 5-6p' \ [0\frac{1}{2}] \end{array}$		$\begin{array}{l} 4-5d' \ [2\frac{1}{2}]^\circ \\ 4-14d' \ [1\frac{1}{2}]^\circ \end{array}$
				$\begin{array}{l} 4-10f \ [1\frac{1}{2}] \\ 4-10f \ [4\frac{1}{2}] \\ 4-10f \ [2\frac{1}{2}] \\ 4-7f \ [3\frac{1}{2}] \end{array}$
				$\begin{array}{l} 4f' \ [3\frac{1}{2}] \\ 4f' \ [2\frac{1}{2}] \end{array}$

\*For predicted levels in the spectra of the Kr I isoelectronic sequence, see Introduction.

## Kr II

(Br I sequence; 35 electrons)

$Z=36$

Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^5 \ ^2P_{1/2}^\circ$

$4p^5 \ ^2P_{1/2}^\circ$  198182.00  $\text{cm}^{-1}$

I. P. 24.56 volts

A detailed analysis of this spectrum has been published by de Bruin, Humphreys, and Meggers, who have observed 1050 lines between 2080 Å and 10659 Å. Of these, 750, or 71 percent, are classified. In the extreme ultraviolet, Boyce has extended the work of Abbink and Dorgelo to include 82 classified lines between 559 Å and 964 Å, of which 31 are newly classified. No new terms are added from this ultraviolet work.

The doublet and quartet systems of terms are connected by observed intersystem combinations.

The limit is derived by applying the Rydberg series formula to the first two members of the  $ns \ ^4P_{3/2}$  series ( $n=5,6$ ).

Most of the observed  $g$ -values are from the 1931 paper listed below. A few additional values, based on unpublished observations furnished by Bakker, Zeeman, and de Bruin are also included in the 1933 paper containing the analysis of Kr II.

## REFERENCES

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 T. L. de Bruin, C. J. Humphreys, and W. F. Meggers, Bur. Std. J. Research **11**, 409, RP 599 (1933). (I P)  
 (T) (C L) (Z E)  
 J. C. Boyce, Phys. Rev. **47**, 718 (1935). (C L)



## Kr II

## Kr II

Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>	Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>
$4s^2 4p^5$	$4p^5 \ ^2P^\circ$	$1\frac{1}{2}$ $0\frac{1}{2}$	0. 00 5371. 00	-5371. 00		$4s^2 4p^4(^1D)4d$	$4d' \ ^2F$	$3\frac{1}{2}$ $2\frac{1}{2}$	149860. 27? 150814. 24?	-953. 97	
$4s 4p^6$	$4p^6 \ ^2S$	$0\frac{1}{2}$	109002. 06			$4s^2 4p^4(^1D)5p$	$5p' \ ^2P^\circ$	$1\frac{1}{2}$ $0\frac{1}{2}$	150203. 48 152240. 97	-2037. 49	1. 33 0. 70
$4s^2 4p^4(^3P)5s$	$5s \ ^4P$	$2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	112830. 00 115093. 71 117604. 73	-2263. 71 -2511. 02	1. 60 1. 54 2. 64	$4s^2 4p^4(^1D)4d$	$4d' \ ^2P$	$1\frac{1}{2}$ $0\frac{1}{2}$	151828. 00 152186. 70	-358. 70	
$4s^2 4p^4(^3P)5s$	$5s \ ^2P$	$1\frac{1}{2}$ $0\frac{1}{2}$	118476. 07 121003. 87	-2527. 80	1. 52 0. 70	$4s^2 4p^4(^1D)5p$	$5p' \ ^2D^\circ$	$1\frac{1}{2}$ $2\frac{1}{2}$	152191. 86 152316. 20	124. 34	0. 80 1. 20
$4s^2 4p^4(^3P)4d$	$4d \ ^4D$	$3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	120211. 59 120428. 65 121002. 10 121781. 28	-217. 06 -573. 45 -779. 18	0. 00	$4s^2 4p^4(^3P)6s$	$6s \ ^4P$	$2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	157079. 07 157885. 41 161877. 37	-806. 34 -3991. 96	1. 60 1. 39 2. 34
$4s^2 4p^4(^3P)4d$	$4d \ ^4F$	$4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$	126002. 57 127931. 20 129698. 98 129743. 56	-1928. 63 -1767. 78 -44. 58		$4s^2 4p^4(^3P)5d$	$5d \ ^4P$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$	160796. 68 161409. 29 161013. 56	612. 61 -395. 73	2. 07 2. 47
$4s^2 4p^4(^1D)5s$	$5s' \ ^2D$	$1\frac{1}{2}$ $2\frac{1}{2}$	127599. 19 127863. 23	264. 04	0. 80 1. 20	$4s^2 4p^4(^3P)5d$	$5d \ ^4D$	$3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	161285. 31 161451. 83 161801. 92 163033. 48	-166. 52 -350. 09 -1231. 56	1. 40 1. 37 0. 88
$4s^2 4p^4(^3P)4d$	$4d \ ^4P$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$	130514. 59 130895. 28 131377. 24	380. 69 481. 96		$4s^2 4p^4(^3P)6s$	$6s \ ^2P$	$1\frac{1}{2}$ $0\frac{1}{2}$	162059. 03 162566. 16	-507. 13	1. 33 0. 92
$4s^2 4p^4(^3P)4d$	$4d \ ^2F$	$3\frac{1}{2}$ $2\frac{1}{2}$	131633. 86 137099. 98	-5466. 12		$4s^2 4p^4(^3P)5d$	$5d \ ^4F$	$4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$	162208. 84 162531. 91 165077. 35 167047. 13	-323. 07 -2545. 44 -1969. 78	1. 33 1. 17 1. 12 0. 52
$4s^2 4p^4(^3P)4d$	$4d \ ^2D$	$1\frac{1}{2}$ $2\frac{1}{2}$	132967. 28 134568. 82	1601. 54		$4s^2 4p^4(^1S)6s$	$6s'' \ ^2S$	$0\frac{1}{2}$	164439. 16?		1. 94
	1	$2\frac{1}{2}$	132972. 50			$4s^2 4p^4(^3P)5d$	$5d \ ^2P$	$1\frac{1}{2}$ $0\frac{1}{2}$	165141. 91 166953. 31	-1811. 40	1. 40 0. 51
$4s^2 4p^4(^3P)5p$	$5p \ ^4P^\circ$	$2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	133925. 65 134288. 44 135783. 03	-362. 79 -1494. 59	1. 58 1. 67 1. 98	$4s^2 4p^4(^3P)5d$	$5d \ ^2F$	$3\frac{1}{2}$ $2\frac{1}{2}$	165397. 72 167518. 91	-2121. 19	1. 24 1. 04
$4s^2 4p^4(^3P)4d$	$4d \ ^2P$	$0\frac{1}{2}$ $1\frac{1}{2}$	134623. 17				$1^\circ$	$1\frac{1}{2}$	166155. 50?		
$4s^2 4p^4(^3P)5p$	$5p \ ^4D^\circ$	$3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	135783. 18 136071. 00 138381. 35 140163. 25	-287. 82 -2310. 35 -1781. 90	1. 43 1. 23 1. 26 0. 00	$4s^2 4p^4(^3P)5d$	$5d \ ^2D$	$1\frac{1}{2}$ $2\frac{1}{2}$	167913. 11 169704. 85	1791. 74	1. 18 1. 15
	2	$1\frac{1}{2}$	138495. 02			$4s^2 4p^4(^3P)5f$	$5f \ ^4F^\circ$	$4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$	168085. 49 168118. 00 168183. 20 168385. 12	-32. 51 -65. 20 -201. 92	
$4s^2 4p^4(^3P)5p$	$5p \ ^2P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	139103. 36 140137. 15	1033. 79	1. 78 1. 26	$4s^2 4p^4(^3P)5d$	$5d \ ^2D$	$1\frac{1}{2}$ $2\frac{1}{2}$	167913. 11 169704. 85		
$4s^2 4p^4(^3P)5p$	$5p \ ^2D^\circ$	$2\frac{1}{2}$ $1\frac{1}{2}$	140118. 99 141995. 68	-1876. 69	1. 34 1. 33	$4s^2 4p^4(^3P)5f$	$5f \ ^2F^\circ$	$3\frac{1}{2}$ $2\frac{1}{2}$	168260. 43 168462. 53	-202. 10	
$4s^2 4p^4(^3P)5p$	$5p \ ^4S^\circ$	$1\frac{1}{2}$	141722. 72		1. 54	$4s^2 4p^4(^1S)5p$	$5p'' \ ^2P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	168262. 90 168939. 35	676. 45	1. 24 0. 90
$4s^2 4p^4(^3P)5p$	$5p \ ^2S^\circ$	$0\frac{1}{2}$	142363. 55		1. 50		$2^\circ$	$3\frac{1}{2}$	168490. 67		
$4s^2 4p^4(^1S)5s$	$5s'' \ ^2S$	$0\frac{1}{2}$	145813. 61		2. 00	$4s^2 4p^4(^3P)5f$	$5f \ ^2D^\circ$	$2\frac{1}{2}$ $1\frac{1}{2}$	168630. 36		1. 02
$4s^2 4p^4(^1D)4d$	$4d' \ ^2G$	$4\frac{1}{2}$ $3\frac{1}{2}$	146892. 32?			$4s^2 4p^4(^3P)5f$	$5f \ ^4D^\circ$	$3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	168718. 90		
$4s^2 4p^4(^1D)5p$	$5p' \ ^2F^\circ$	$2\frac{1}{2}$ $3\frac{1}{2}$	149173. 42 149704. 55	531. 13	0. 86 1. 14	$4s^2 4p^4(^1D)6s$	$6s' \ ^2D$	$2\frac{1}{2}$ $1\frac{1}{2}$	170571. 12		1. 00
$4s^2 4p^4(^1D)4d$	$4d' \ ^2D$	$2\frac{1}{2}$ $1\frac{1}{2}$	149515. 90 150179. 87	-663. 97							

## Kr II—Continued

## Kr II—Continued

Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>	Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>
$4s^2 4p^4(^1S)4d$	$3^\circ$	$1\frac{1}{2}$	170887. 53			$4s^2 4p^4(^1D)5d$	$5d' ^2P$	$1\frac{1}{2}$ $0\frac{1}{2}$	177683. 83 178787. 63	-1103. 80	1. 18
	$4^\circ$	$2\frac{1}{2}$	171295. 70			$4s^2 4p^4(^1D)5d$	$5d' ^2F$	$2\frac{1}{2}$ $3\frac{1}{2}$	177710. 28 177909. 00	198. 72	0. 89 1. 14
	$5^\circ$	$2\frac{1}{2}$	171886. 32			$4s^2 4p^4(^3P)7s$	$7s ^2P$	$1\frac{1}{2}$ $0\frac{1}{2}$	177956. 88 178507. 45	-550. 57	
	$6^\circ$	$3\frac{1}{2}$	171560. 00			$4s^2 4p^4(^3P)5g$	$5g ^4G$	$5\frac{1}{2}$ $4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$	178842. 39 178811. 30 178815. 51 178860. 88	31. 09 -4. 21 -45. 37	
$4s^2 4p^4(^1D)5f$	$5f' ^2D^\circ$	$1\frac{1}{2}$ $2\frac{1}{2}$	172714. 72 172773. 37	58. 65			$8^\circ$	$1\frac{1}{2}$	182464. 85		
$4s^2 4p^4(^1D)5f$	$7^\circ$	$2\frac{1}{2}$	172734. 15				$9^\circ$	$0\frac{1}{2}?$	182479. 27		
	$5f' ^2F^\circ$	$3\frac{1}{2}$ $2\frac{1}{2}$	173131. 03 173156. 42	-25. 39			$10^\circ$	$1\frac{1}{2}$	182811. 90		
$4s^2 4p^4(^3P)7s$	$7s ^4P$	$2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	173309. 68 173640. 02 178054. 79	-330. 34 -4414. 77			$11^\circ$	$2\frac{1}{2}$	182841. 19		
$4s^2 4p^4(^1D)5f$	$5f' ^2P^\circ$	$1\frac{1}{2}$ $0\frac{1}{2}$	173687. 88 174503. 00	-815. 12			$12^\circ$	$1\frac{1}{2}$	182965. 59		
$4s^2 4p^4(^1D)5d$	$5d' ^2G$	$3\frac{1}{2}$ $4\frac{1}{2}$	175891. 74 176592. 97	701. 23	0. 89 1. 11		$13^\circ$	$2\frac{1}{2}$	183308. 55		
$4s^2 4p^4(^1D)5d$	$5d' ^2D$	$1\frac{1}{2}$ $2\frac{1}{2}$	176110. 96 178320. 63	2209. 67	1. 20	Kr III ( $^3P_2$ )	Limit		198182. 00		

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## Kr II OBSERVED TERMS\*

Config. $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} +$	Observed Terms		
$4s^2 4p^5$	$4p^5 ^2P^\circ$		
$4s 4p^6$	$4p^6 ^1S$		
$4s^2 4p^4(^3P)nx$ $4s^2 4p^4(^1D)nx''$ $4s^2 4p^4(^1S)nx''$	$ns (n \geq 5)$	$np (n \geq 5)$	
	$\left\{ \begin{array}{l} 5,6,7s ^4P \\ 5,6,7s ^2P \end{array} \right.$	$5p ^4S^\circ$ $5p ^2S^\circ$	$5p ^4P^\circ$ $5p ^2P^\circ$ $5p ^4D^\circ$ $5p ^2D^\circ$
	$5, 6s' ^2D$	$5p' ^2P^\circ$	$5p' ^2D^\circ$ $5p' ^2F^\circ$
	$5, 6s'' ^2S$	$5p'' ^2P^\circ$	
$4s^2 4p^4(^3P)nx$ $4s^2 4p^4(^1D)nx'$ $4s^2 4p^4(^1S)nx''$	$nd (n \geq 4)$	$nf (n \geq 4)$	$ng (n \geq 5)$
	$\left\{ \begin{array}{l} 4, 5d ^4P \quad 4,5d ^4D \quad 4,5d ^4F \\ 4, 5d ^2P \quad 4,5d ^2D \quad 4,5d ^2F \end{array} \right.$	$5f ^4D^\circ$ $5f ^2D^\circ$	$5f ^4F^\circ$ $5f ^2F^\circ$ $5g ^4G$
	$4, 5d' ^2P \quad 4,5d' ^2D \quad 4,5d' ^2F \quad 4,5d' ^2G$	$5f' ^2P^\circ$ $5f' ^2D^\circ$ $5f' ^2F^\circ$	
	$4d'' ^2D$		

\*For predicted terms in the spectra of the Br I isoelectronic sequence, see Vol. II, Introduction.



## Kr III

(Se I sequence; 34 electrons)

 $Z=36$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^4 {}^3P_2$  $4p^4 {}^3P_2$  298020  $\text{cm}^{-1}$ 

I. P. 36.9 volts

The analysis is from Humphreys, who has discussed the earlier work on this spectrum. He lists 369 classified lines in the interval between 2116 Å and 7353 Å. In addition, Boyce has classified 138 lines between 516 Å and 1923 Å. Observed intersystem combinations connect the terms of all multiplicities.

The limit is based on the  $nd {}^5D_3^\circ$ ,  $nd {}^3D_3^\circ$  ( $n=4,5$ ), and  $ns {}^3S_1^\circ$  ( $n=5,6$ ) series.

The Zeeman effect for two lines, 3507.42 Å and 3564.23 Å has been observed by Bakker and de Bruin. The resulting  $g$ -values are:

Desig.	Obs. $g$
$5s {}^3S_1^\circ$	1.99
$5p {}^3P_2$	1.50
$5p {}^3P_1$	1.55

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## Kr III

## Kr III

Config.	Desig.	$J$	Level	Interval	Config.	Desig.	$J$	Level	Interval
$4s^2 4p^4$	$4p^4 {}^3P$	2 1 0	0 4548 5313	—4548 —765	$4s^2 4p^3({}^2D^\circ)4d$	$4d' {}^1D^\circ$	2	165464.45	
					$4s^2 4p^3({}^2D^\circ)4d$	$4d' {}^3D^\circ$	1 2 3	170203.38 172466.51 174452.05	2263.13 1985.54
$4s^2 4p^4$	$4p^4 {}^1D$	2	14644						
$4s^2 4p^4$	$4p^4 {}^1S$	0	33079		$4s^2 4p^3({}^2D^\circ)5s$	$5s' {}^1D^\circ$	2	170900.02	
$4s 4p^5$	$4p^5 {}^3P^\circ$	2 1 0	115932 119381 121544	—3449 —2163	$4s^2 4p^3({}^2D^\circ)4d$	$4d' {}^1P^\circ?$	1	171996.91	
					$4s^2 4p^3({}^2D^\circ)4d$	$4d' {}^3S^\circ?$	1	172984.33	
$4s^2 4p^3({}^4S^\circ)4d$	$4d {}^5D^\circ$	0 1 2 3 4	138447.68 138472.12 138481.92 138493.78 138650.27	24.44 9.80 11.86 156.49	$4s^2 4p^3({}^2P^\circ)4d$	$4d'' {}^3F^\circ$	4 3 2	175043.98 174831.66 175212.28	212.32 —380.62
$4s 4p^5$	$4p^5 {}^1P^\circ$	1	141876		$4s^2 4p^3({}^4S^\circ)5p$	$5p {}^5P$	1 2 3	175545.05 175779.74 176521.18	234.69 741.44
$4s^2 4p^3({}^4S^\circ)5s$	$5s {}^5S^\circ$	2	145720.00						
$4s^3 4p^3({}^4S^\circ)4d$	$4d {}^3D^\circ$	3 2 1	148736.44 147805.70 149072.99	930.74 —1267.29	$4s^2 4p^3({}^2P^\circ)4d$	$4d'' {}^3D^\circ$	1 2 3	182266.00 176791.83 184892.85	—5474.17 8101.02
$4s^2 4p^3({}^4S^\circ)5s$	$5s {}^3S^\circ$	1	151581.26		$4s^2 4p^3({}^2P^\circ)5s$	$5s'' {}^3P^\circ$	0 1 2	178244.46 178260.12 180248.10	15.66 1987.98
$4s^2 4p^3({}^2D^\circ)4d$	$4d' {}^3F^\circ$	2 3 4	153564.18 154701.05 156082.96	1136.87 1381.91					
$4s^3 4p^3({}^2D^\circ)4d$	$4d' {}^3G^\circ$	3 4 5	159997.52 160415.88 161109.55	418.36 693.67	$4s^2 4p^3({}^4S^\circ)5p$	$5p {}^3P$	0 1 2	179629.83 180084.12	454.29
$4s^2 4p^3({}^2D^\circ)4d$	$4d' {}^1G^\circ$	4	162842.07		$4s^2 4p^3({}^2P^\circ)5s$	$5s'' {}^1P^\circ$	1	181264.53	
$4s^2 4p^3({}^2D^\circ)5s$	$5s' {}^3D^\circ$	1 2 3	163270.01 163636.83 165054.55	366.82 1417.72	$4s^2 4p^3({}^2P^\circ)4d$	$4d'' {}^1F^\circ$	3	182968.27	
					$4s^2 4p^3({}^2P^\circ)4d$	$4d'' {}^1P^\circ$	1	188234.28	



## Kr III—Continued

Config.	Desig.	<i>J</i>	Level	Interval
$4s^2 4p^3(^2P^o)4d$	$4d'' ^1D^o$	2	188570. 30	
$4s^2 4p^3(^2P^o)4d$	$4d'' ^3P^o$	0		
		1	190227. 24	
		2	193652. 80	3425. 56
$4s^2 4p^3(^2D^o)5p$	$5p' ^3D$	1	190724. 64	
		2	192702. 93	1978. 29
		3	193826. 24	1123. 31
$4s^2 4p^3(^2D^o)5p$	$5p' ^3F$	2	193856. 49	
		3	194963. 87	1107. 38
		4	195675. 44	711. 57
$4s^2 4p^3(^2D^o)5p$	$5p' ^1P$	1	194121. 20	
$4s^2 4p^3(^2D^o)5p$	$5p' ^1F$	3	195478. 99	
$4s^2 4p^3(^2D^o)5p$	$5p' ^3P$	2	198108. 88	
		1	198825. 49	-716. 61
		0	198790. 11	35. 38
$4s^2 4p^3(^2D^o)5p$	$5p' ^1D$	2	202897. 08	
$4s^2 4p^3(^2P^o)5p$	$5p'' ^3D$	1	207248. 18	
		2	208511. 04	1262. 86
		3	209869. 57	1358. 53
$4s^2 4p^3(^2D^o)5p$	$5p'' ^3S$	1	208610. 74	
$4s^2 4p^3(^2P^o)5p$	$5p'' ^1P$	1	209285. 43	
$4s^2 4p^3(^2P^o)5p$	$5p'' ^3P$	0	209787. 45	
		1	212264. 81	2477. 36
		2	213058. 56	793. 75
$4s^2 4p^3(^2P^o)5p$	$5p'' ^1D$	2	212124. 52	
$4s^2 4p^3(^4S^o)6s$	$6s ^5S^o$	2	215522. 57	
$4s^2 4p^3(^4S^o)5d$	$5d ^5D^o$	0	216501. 29	
		1	216515. 30	14. 01
		2	216529. 32	14. 02
		3	216545. 64	16. 32
		4	216605. 16	59. 52
$4s^2 4p^3(^4S^o)5d$	$5d ^3D^o$	1	219295. 44	
		2	217376. 66	-1918. 78
		3	220759. 93	3383. 27
$4s^2 4p^3(^4S^o)6s$	$6s ^3S^o$	1	221843. 40	
$4s^2 4p^3(^2D^o)6s$	$6s' ^3D^o$	1		
		2	233111. 63	
		3	234567. 20	1455. 57
$4s^2 4p^3(^2D^o)5d$	$5d' ^1D^o?$	2	233347. 38	
$4s^2 4p^3(^2D^o)5d$	$5d' ^1G^o$	4	235357. 36	
$4s^2 4p^3(^2D^o)6s$	$6s' ^1D^o?$	2	236183. 67	
$4s^2 4p^3(^2D^o)5d$	$5d' ^1^o$	1	237971. 13	
$4s^2 4p^3(^2D^o)5d$	$5d' ^2^o$	2	238608. 32	
$4s^2 4p^3(^2P^o)6s$	$6s'' ^3P^o$	0		
		1	249167. 98	
		2	250911. 83	1743. 85
$4s^2 4p^3(^2P^o)6s$	$6s'' ^1P^o$	1	252461. 12	
Kr IV ( $4S_{1\frac{1}{2}}$ )	Limit	-----	298020	

November 1950.

## Kr III OBSERVED TERMS\*

Config.	Observed Terms		
$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} +$			
$4s^2 4p^4$	$4p^4 ^1S$	$4p^4 ^3P$	$4p^4 ^1D$
$4s 4p^5$		$4p^5 ^3P^o$ $4p^5 ^1P^o$	
$4s^2 4p^3(^4S^o)nx$	$\{ \begin{smallmatrix} 5,6s \\ 5,6s \end{smallmatrix} \} ^5S^o$ $\{ \begin{smallmatrix} 5,6s \\ 5,6s \end{smallmatrix} \} ^3S^o$	$ns (n \geq 5)$	$ns (n \geq 5)$
$4s^2 4p^3(^2D^o)nx'$	$\{ \begin{smallmatrix} 5,6s' \\ 5,6s' \end{smallmatrix} \} ^5S^o$ $\{ \begin{smallmatrix} 5,6s' \\ 5,6s' \end{smallmatrix} \} ^3S^o$	$np (n \geq 5)$	$np (n \geq 5)$
$4s^2 4p^3(^2P^o)nx''$	$\{ \begin{smallmatrix} 5,6s'' \\ 5,6s'' \end{smallmatrix} \} ^5S^o$ $\{ \begin{smallmatrix} 5,6s'' \\ 5,6s'' \end{smallmatrix} \} ^3S^o$	$nd (n \geq 4)$	$nd (n \geq 4)$

\*For predicted terms in the spectra of the Se I isoelectronic sequence, see Vol. II, Introduction.

## Kr IV

(As I sequence; 33 electrons)

 $Z=36$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^3 {}^4S_{1/2}$  $4p^3 {}^4S_{1/2}$  cm<sup>-1</sup>

I. P. volts

This spectrum has not been satisfactorily analyzed. Boyce has observed the three ultimate lines, 805 Å to 842 Å, having the transition  $4p^3 {}^4S^\circ - 4p^4 {}^4P$ . These observations have been used to calculate the recorded value of  $4p^4 {}^4P$ .

Rao and Krishnamurty have reported 61 additional lines in the interval from 2237 Å to 3934 Å, as combinations among four terms and a number of miscellaneous levels. Their terms start with  $5s {}^4P_{0/2}=0$ . By comparison with As I and Se II the writer has estimated that this level is approximately  $166100 \text{ cm}^{-1}$  above the ground state zero. This value, entered in brackets in the table, has been added to all levels taken from the 1939 reference,  $x$  denoting that they are not connected with the rest by observed combinations. The writer has also assigned numbers to the miscellaneous levels. The levels here designated as 1, 2, and 3 have been corrected to fit the observed combinations, because they are incorrectly tabulated in the published paper.

All but the two lowest terms in the table need confirmation.

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## Kr IV

## Kr IV

Config.	Desig.	$J$	Level	Interval	Config.	Desig.	$J$	Level	Interval
$4s^2 4p^3$	$4p^3 {}^4S^\circ$	$1\frac{1}{2}$	0. 0		$4s^2 4p^2({}^3P)4d$	9	$0\frac{1}{2}, 1\frac{1}{2}$	172999 $+x$	
$4s 4p^4$	$4p^4 {}^4P$	$2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	118760 122426 124108	-3666 -1682	$4s^2 4p^2({}^3P)4d$	10	$1\frac{1}{2}, 2\frac{1}{2}$	173552 $+x$	
$4s^2 4p^2({}^3P)5s$	$5s {}^4P$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$	[166100] $+x$ 169200 $+x$ 172423 $+x$	3100 3223	$4s^2 4p^2({}^3P)4d$	11	$1\frac{1}{2}, 2\frac{1}{2}$	177800 $+x$	
$4s^2 4p^2({}^3P)4d$	1	$1\frac{1}{2}, 2\frac{1}{2}$	164416 $+x$		$4s^2 4p^2({}^3P)4d$	12	$1\frac{1}{2}$	182553 $.5+x$	
$4s^2 4p^2({}^3P)4d$	2	$1\frac{1}{2}, 2\frac{1}{2}$	165881 $+x$		$4s^2 4p^2({}^3P)5p$	$5p {}^4D^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$	202711 $.8+x$ 204240 $.9+x$ 207424 $.5+x$ 210732 $+x$	1529. 1 3183. 6 3308
$4s^2 4p^2({}^3P)4d$	3	$1\frac{1}{2}, 2\frac{1}{2}$	166062 $+x$		$4s^2 4p^2({}^3P)5p$	$5p {}^4P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$	207962 $+x$ 208450 $+x$ 208798 $.5+x$	488 348
$4s^2 4p^2({}^3P)4d$	4	$2\frac{1}{2}$	167708 $+x$		$4s^2 4p^2({}^3P)5p$	$5p {}^4S^\circ$	$1\frac{1}{2}$	208881 $+x$	
$4s^2 4p^2({}^3P)4d$	5	$2\frac{1}{2}, 3\frac{1}{2}$	168025 $+x$		$4s^2 4p^2({}^3P)5p$	1 $^\circ$	$1\frac{1}{2}, 2\frac{1}{2}$	210126 $.9+x$	
$4s^2 4p^2({}^3P)4d$	6	$2\frac{1}{2}, 3\frac{1}{2}$	168159 $+x$		$4s^2 4p^2({}^3P)5p$	2 $^\circ$	$1\frac{1}{2}, 2\frac{1}{2}$	210563 $.4+x$	
$4s^2 4p^2({}^3P)4d$	7	$1\frac{1}{2}, 2\frac{1}{2}$	170862 $+x$		$4s^2 4p^2({}^3P)5p$	3 $^\circ$	$1\frac{1}{2}, 2\frac{1}{2}$	212831 $.3+x$	
$4s^2 4p^2({}^3P)4d$	8	$2\frac{1}{2}$	171482 $+x$						

October 1950.

## Kr IX

(Ni I sequence; 28 electrons)

 $Z=36$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} {}^1S_0$  $3d^{10} {}^1S_0$        $\text{cm}^{-1}$ 

I. P.      volts

This spectrum has not been analyzed, but Paul has observed three lines as follows:

I A	Int.	Wave No.
114. 948	75	869958
115. 741	100	863998
117. 710	20	849546

By analogy with the related isoelectronic spectra Se VII to Y XII, he has classified these lines as combinations of the ground term with terms from the  $3d^9 4p$  configuration, as given in the table. He has examined this spectrum and furnished these results especially for inclusion here.

## REFERENCE

F. W. Paul (letter, November 1950). (T) (C L)

## Kr IX

Config.	Desig.	$J$	Level
$3d^{10}$	$3d^{10} {}^1S$	0	0
$3d^9({}^2D)4p$	$4p {}^3P^\circ$	2 1 0	849546
$3d^9({}^2D)4p$	$4p {}^1P^\circ$	1	863998
$3d^9({}^2D)4p$	$4p {}^3D^\circ$	3 2 1	869958

November 1950.



## RUBIDIUM

## Rb I

37 electrons

 $Z=37$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 5s^2 S_{0\frac{1}{2}}$  $5s^2 S_{0\frac{1}{2}} \text{ Rb}^{85} 33691.02 \pm 0.03 \text{ cm}^{-1}$ 

I. P. 4.176 volts

 $5s^2 S_{0\frac{1}{2}} \text{ Rb}^{87} 33691.10 \pm 0.03 \text{ cm}^{-1}$ 

I. P. 4.176 volts

The well known series of Rb I reported in the classical publications of Paschen-Götze and Fowler have recently been extended. Kratz has observed in absorption the principal series ( $np^2P^\circ$ ) to  $n=77$ .

Mack has furnished in advance of publication his observations of forbidden absorption lines, all of which are combinations of the ground term,  $5s^2S$ , with higher series members  $nd^2D$  and  $ns^2S$ . The series called  $nf^2F^\circ$  in the table is labeled by Mack  $n^2Q$  to indicate that the terms are  $nf^2F^\circ$ ,  $ng^2G$ ,  $nh^2H^\circ$ , etc.

Ramb has observed with the interferometer 33 lines between 5169.651 Å and 10075.711 Å. The inverted terms of the Bergmann series have been discussed in detail by Meissner and Masaki. From these and other papers Mack has prepared the list of terms as far as  $12s^2S$ , and furnished his manuscript for inclusion here. He notes that the values of the terms  $6s^2S$ ,  $4d^2D$ , 4 to  $8f^2F^\circ$ , 5,  $6g^2G$ , and  $6h^2H^\circ$  need further adjustment from more accurate wave lengths. He suggests, also, the following improved values of intervals:

Term	Interval	Term	Interval
$5p^2P^\circ$	237.598	$7d^2D$	1.507
$5d^2D$	2.960	$8d^2D$	1.013
$6d^2D$	2.262	$9d^2D$	0.697

Brackets denote that the tabular entries have been derived from series calculations.

Kratz derives the limit  $33690.96 \pm 0.03 \text{ cm}^{-1}$ , from the long  $np^2P^\circ$  series, and calculates the limit of the lowest hyperfine structure sublevel as  $33691.02 \pm 0.03$ . Mack confirms this calculation for  $\text{Rb}^{85}$  and adds the value quoted above for  $\text{Rb}^{87}$ .

Beutler has observed in absorption 39 lines between 594.61 Å and 809.72 Å, and classified all but 3 as transitions from the ground term to levels above the ionization limit. His rounded-off wave numbers have been entered in the table. These levels have as limits, two higher terms  $^3P^\circ$  and  $^1P^\circ$  in Rb II. The miscellaneous levels have been assigned numbers by the writer. The double entries of  $J$  for these levels (unlike those for unresolved terms) indicate that the existing data are insufficient to distinguish which value of  $J$  is correct.

The Quadratic Zeeman Effect in the principal series of Rb I is discussed by Harting and Klinkenberg.

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## Rb I

## Rb I

Config.	Desig.	$J$	Level	Interval	Config.	Desig.	$J$	Level	Interval
$4p^6(^1S)5s$	$5s\ ^2S$	$0\frac{1}{2}$	0. 00		$4p^6(^1S)11d$	$11d\ ^2D$	$1\frac{1}{2}$ $2\frac{1}{2}$	32514. 63 32514. 93	0. 30
$4p^6(^1S)5p$	$5p\ ^2P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	12578. 96 12816. 56	237. 60	$4p^6(^1S)13p$	$13p\ ^2P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	32665. 03 32667. 63	2. 60
$4p^6(^1S)4d$	$4d\ ^2D$	$2\frac{1}{2}$ $1\frac{1}{2}$	19355. 01 19355. 45	-0. 44	$4p^6(^1S)12d$	$12d\ ^2D$	$1\frac{1}{2}$ $2\frac{1}{2}$	32724. 68 32724. 93	0. 25
$4p^6(^1S)6s$	$6s\ ^2S$	$0\frac{1}{2}$	20133. 6		$4p^6(^1S)14p$	$14p\ ^2P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	32838. 02 32840. 02	2. 00
$4p^6(^1S)6p$	$6p\ ^2P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	23715. 19 23792. 69	77. 50	$4p^6(^1S)13d$	$13d\ ^2D$	$1\frac{1}{2}$ $2\frac{1}{2}$	32883. 21 32883. 41	0. 20
$4p^6(^1S)5d$	$5d\ ^2D$	$1\frac{1}{2}$ $2\frac{1}{2}$	25700. 56 25703. 52	2. 96	$4p^6(^1S)15p$	$15p\ ^2P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	32970. 66 32972. 19	1. 53
$4p^6(^1S)7s$	$7s\ ^2S$	$0\frac{1}{2}$	26311. 46		$4p^6(^1S)14d$	$14d\ ^2D$	$1\frac{1}{2}, 2\frac{1}{2}$	33005. 84	
$4p^6(^1S)4f$	$4f\ ^2F^\circ$	$2\frac{1}{2}, 3\frac{1}{2}$	26791. 98		$4p^6(^1S)16p$	$16p\ ^2P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	33074. 59 33076. 83	1. 24
$4p^6(^1S)7p$	$7p\ ^2P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	27835. 05 27870. 14	35. 09	$4p^6(^1S)15d$	$15d\ ^2D$	$1\frac{1}{2}, 2\frac{1}{2}$	33102. 39	
$4p^6(^1S)6d$	$6d\ ^2D$	$1\frac{1}{2}$ $2\frac{1}{2}$	28687. 15 28689. 41	2. 26	$4p^6(^1S)17p$	$17p\ ^2P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	33157. 54 33158. 54	1. 00
$4p^6(^1S)8s$	$8s\ ^2S$	$0\frac{1}{2}$	29046. 84		$4p^6(^1S)16d$	$16d\ ^2D$	$1\frac{1}{2}, 2\frac{1}{2}$	33180. 03	
$4p^6(^1S)5f$	$5f\ ^2F^\circ$	$3\frac{1}{2}$ $2\frac{1}{2}$	29277. 58 29277. 59	-0. 01	$4p^6(^1S)18p$	$18p\ ^2P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	33224. 83 33225. 67	0. 84
$4p^6(^1S)5g$	$5g\ ^2G$	$3\frac{1}{2}, 4\frac{1}{2}$	29297. 6		$4p^6(^1S)17d$	$17d\ ^2D$	$1\frac{1}{2}, 2\frac{1}{2}$	33244. 23	
$4p^6(^1S)8p$	$8p\ ^2P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	29834. 96 29853. 82	18. 86	$4p^6(^1S)19p$	$19p\ ^2P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	33280. 13 33280. 81	0. 68
$4p^6(^1S)7d$	$7d\ ^2D$	$1\frac{1}{2}$ $2\frac{1}{2}$	30280. 18 30281. 69	1. 51	$4p^6(^1S)18d$	$18d\ ^2D$	$1\frac{1}{2}, 2\frac{1}{2}$	33295. 28	
$4p^6(^1S)9s$	$9s\ ^2S$	$0\frac{1}{2}$	30499. 06		$4p^6(^1S)20p$	$20p\ ^2P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	33326. 13 33326. 70	0. 57
$4p^6(^1S)6f$	$6f\ ^2F^\circ$	$3\frac{1}{2}$ $2\frac{1}{2}$	30627. 77 30627. 78	-0. 01	$4p^6(^1S)19d$	$19d\ ^2D$	$1\frac{1}{2}, 2\frac{1}{2}$	33338. 80	
$4p^6(^1S)6g$	$6g\ ^2G$	$3\frac{1}{2}, 4\frac{1}{2}$	30636. 9		$4p^6(^1S)21p$	$21p\ ^2P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	33364. 81 33365. 29	0. 48
$4p^6(^1S)6h$	$6h\ ^2H^\circ$	$4\frac{1}{2}, 5\frac{1}{2}$	30643. 5		$4p^6(^1S)20d$	$20d\ ^2D$	$1\frac{1}{2}, 2\frac{1}{2}$	33375. 4	
$4p^6(^1S)9p$	$9p\ ^2P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	30958. 94 30970. 22	11. 28	$4p^6(^1S)22p$	$22p\ ^2P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	33397. 66 33398. 09	0. 43
$4p^6(^1S)8d$	$8d\ ^2D$	$1\frac{1}{2}$ $2\frac{1}{2}$	31221. 47 31222. 48	1. 01	$4p^6(^1S)21d$	$21d\ ^2D$	$1\frac{1}{2}, 2\frac{1}{2}$	33406. 86	
$4p^6(^1S)10s$	$10s\ ^2S$	$0\frac{1}{2}$	31362. 36		$4p^6(^1S)23p$	$23p\ ^2P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	33425. 76 33426. 15	0. 39
$4p^6(^1S)7f$	$7f\ ^2F^\circ$	$3\frac{1}{2}$ $2\frac{1}{2}$	31441. 52 31441. 53	-0. 01	$4p^6(^1S)22d$	$22d\ ^2D$	$1\frac{1}{2}, 2\frac{1}{2}$	33433. 88	
$4p^6(^1S)10p$	$10p\ ^2P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	31653. 88 31661. 19	7. 31	$4p^6(^1S)24p$	$24p\ ^2P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	33450. 03 33450. 38	0. 35
$4p^6(^1S)9d$	$9d\ ^2D$	$1\frac{1}{2}$ $2\frac{1}{2}$	31821. 88 31822. 58	0. 70	$4p^6(^1S)23d$	$23d\ ^2D$	$1\frac{1}{2}, 2\frac{1}{2}$	33457. 06	
$4p^6(^1S)11s$	$11s\ ^2S$	$0\frac{1}{2}$	31917. 25		$4p^6(^1S)25p$	$25p\ ^2P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	33471. 11 33471. 43	0. 32
$4p^6(^1S)8f$	$8f\ ^2F^\circ$	$2\frac{1}{2}, 3\frac{1}{2}$	31969. 43		$4p^6(^1S)24d$	$24d\ ^2D$	$1\frac{1}{2}, 2\frac{1}{2}$	33477. 0	
$4p^6(^1S)11p$	$11p\ ^2P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	32113. 53 32118. 55	4. 97	$4p^6(^1S)26p$	$26p\ ^2P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	33489. 53 33489. 79	0. 26
$4p^6(^1S)10d$	$10d\ ^2D$	$1\frac{1}{2}$ $2\frac{1}{2}$	[32227. 68] 32228. 16	[0. 48]	$4p^6(^1S)25d$	$25d\ ^2D$	$1\frac{1}{2}, 2\frac{1}{2}$	33494. 8	
$4p^6(^1S)12s$	$12s\ ^2S$	$0\frac{1}{2}$	[32295. 04]		$4p^6(^1S)27p$	$27p\ ^2P^\circ$	$0\frac{1}{2}, 1\frac{1}{2}$	33505. 92	
$4p^6(^1S)12p$	$12p\ ^2P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	32433. 50 32437. 04	3. 54	$4p^6(^1S)26d$	$26d\ ^2D$	$1\frac{1}{2}, 2\frac{1}{2}$	33510. 1	
					$4p^6(^1S)28p$	$28p\ ^2P^\circ$	$0\frac{1}{2}, 1\frac{1}{2}$	33520. 22	



## Rb I—Continued

## Rb I—Continued

Config.	Desig.	<i>J</i>	Level	Interval	Config.	Desig.	<i>J</i>	Level	Interval
$4p^6(^1S)27d$	$27d\ ^2D$	$1\frac{1}{2}, 2\frac{1}{2}$	33524. 01		$4p^6(^1S)40p$	$40p\ ^2P^\circ$	$0\frac{1}{2}, 1\frac{1}{2}$	33612. 34	
$4p^6(^1S)29p$	$29p\ ^2P^\circ$	$0\frac{1}{2}, 1\frac{1}{2}$	33532. 91		$4p^6(^1S)39d$	$39d\ ^2D$	$1\frac{1}{2}, 2\frac{1}{2}$	33613. 38	
$4p^6(^1S)28d$	$28d\ ^2D$	$1\frac{1}{2}, 2\frac{1}{2}$	33535. 9		$4p^6(^1S)41s$	$41s\ ^2S$	$0\frac{1}{2}$	33614. 23	
$4p^6(^1S)30p$	$30p\ ^2P^\circ$	$0\frac{1}{2}, 1\frac{1}{2}$	33544. 26		$4p^6(^1S)38f$	$38f\ ^2F^\circ$	$2\frac{1}{2}, \text{etc.}$	33614. 55	
$4p^6(^1S)29d$	$29d\ ^2D$	$1\frac{1}{2}, 2\frac{1}{2}$	33547. 3		$4p^6(^1S)41p$	$41p\ ^2P^\circ$	$0\frac{1}{2}, 1\frac{1}{2}$	33616. 38	
$4p^6(^1S)31p$	$31p\ ^2P^\circ$	$0\frac{1}{2}, 1\frac{1}{2}$	33554. 47		$4p^6(^1S)40d$	$40d\ ^2D$	$1\frac{1}{2}, 2\frac{1}{2}$	33617. 34	
$4p^6(^1S)30d$	$30d\ ^2D$	$1\frac{1}{2}, 2\frac{1}{2}$	33557. 02		$4p^6(^1S)42s$	$42s\ ^2S$	$0\frac{1}{2}$	33618. 26	
$4p^6(^1S)32s$	$32s\ ^2S$	$0\frac{1}{2}$	33559. 2		$4p^6(^1S)39f$	$39f\ ^2F^\circ$	$2\frac{1}{2}, \text{etc.}$	33619. 5	
$4p^6(^1S)29f$	$29f\ ^2F^\circ$	$2\frac{1}{2}, \text{etc.}$	33559. 9		$4p^6(^1S)42p$	$42p\ ^2P^\circ$	$0\frac{1}{2}, 1\frac{1}{2}$	33620. 15	
$4p^6(^1S)32p$	$32p\ ^2P^\circ$	$0\frac{1}{2}, 1\frac{1}{2}$	33563. 57		$4p^6(^1S)41d$	$41d\ ^2D$	$1\frac{1}{2}, 2\frac{1}{2}$	33621. 00	
$4p^6(^1S)31d$	$31d\ ^2D$	$1\frac{1}{2}, 2\frac{1}{2}$	33565. 95		$4p^6(^1S)43s$	$43s\ ^2S$	$0\frac{1}{2}$	33621. 62	
$4p^6(^1S)33s$	$33s\ ^2S$	$0\frac{1}{2}$	33567. 7		$4p^6(^1S)40f$	$40f\ ^2F^\circ$	$2\frac{1}{2}, \text{etc.}$	33622. 05	
$4p^6(^1S)30f$	$30f\ ^2F^\circ$	$2\frac{1}{2}, \text{etc.}$	33568. 5		$4p^6(^1S)43p$	$43p\ ^2P^\circ$	$0\frac{1}{2}, 1\frac{1}{2}$	33623. 61	
$4p^6(^1S)33p$	$33p\ ^2P^\circ$	$0\frac{1}{2}, 1\frac{1}{2}$	33571. 85		$4p^6(^1S)42d$	$42d\ ^2D$	$1\frac{1}{2}, 2\frac{1}{2}$	33624. 41	
$4p^6(^1S)32d$	$32d\ ^2D$	$1\frac{1}{2}, 2\frac{1}{2}$	33574. 06		$4p^6(^1S)44s$	$44s\ ^2S$	$0\frac{1}{2}$	33625. 08	
$4p^6(^1S)34s$	$34s\ ^2S$	$0\frac{1}{2}$	[33575. 6]		$4p^6(^1S)41f$	$41f\ ^2F^\circ$	$2\frac{1}{2}, \text{etc.}$	33625. 56	
$4p^6(^1S)31f$	$31f\ ^2F^\circ$	$2\frac{1}{2}, \text{etc.}$	[33576. 7]		$4p^6(^1S)44p$	$44p\ ^2P^\circ$	$0\frac{1}{2}, 1\frac{1}{2}$	33626. 83	
$4p^6(^1S)34p$	$34p\ ^2P^\circ$	$0\frac{1}{2}, 1\frac{1}{2}$	33579. 34		$4p^6(^1S)43d$	$43d\ ^2D$	$1\frac{1}{2}, 2\frac{1}{2}$	33627. 55	
$4p^6(^1S)33d$	$33d\ ^2D$	$1\frac{1}{2}, 2\frac{1}{2}$	33581. 21		$4p^6(^1S)45s$	$45s\ ^2S$	$0\frac{1}{2}$	33628. 23	
$4p^6(^1S)35s$	$35s\ ^2S$	$0\frac{1}{2}$	33582. 7		$4p^6(^1S)42f$	$42f\ ^2F^\circ$	$2\frac{1}{2}, \text{etc.}$	33628. 76	
$4p^6(^1S)32f$	$32f\ ^2F^\circ$	$2\frac{1}{2}, \text{etc.}$	33583. 8		$4p^6(^1S)45p$	$45p\ ^2P^\circ$	$0\frac{1}{2}, 1\frac{1}{2}$	33629. 80	
$4p^6(^1S)35p$	$35p\ ^2P^\circ$	$0\frac{1}{2}, 1\frac{1}{2}$	33586. 11		$4p^6(^1S)44d$	$44d\ ^2D$	$1\frac{1}{2}, 2\frac{1}{2}$	33630. 51	
$4p^6(^1S)34d$	$34d\ ^2D$	$1\frac{1}{2}, 2\frac{1}{2}$	33587. 87		$4p^6(^1S)46s$	$46s\ ^2S$	$0\frac{1}{2}$	33631. 13	
$4p^6(^1S)36s$	$36s\ ^2S$	$0\frac{1}{2}$	33589. 09		$4p^6(^1S)43f$	$43f\ ^2F^\circ$	$2\frac{1}{2}, \text{etc.}$	[33631. 6]	
$4p^6(^1S)33f$	$33f\ ^2F^\circ$	$2\frac{1}{2}, \text{etc.}$	33589. 93		$4p^6(^1S)46p$	$46p\ ^2P^\circ$	$0\frac{1}{2}, 1\frac{1}{2}$	33632. 60	
$4p^6(^1S)36p$	$36p\ ^2P^\circ$	$0\frac{1}{2}, 1\frac{1}{2}$	33592. 31		$4p^6(^1S)45d$	$45d\ ^2D$	$1\frac{1}{2}, 2\frac{1}{2}$	33633. 23	
$4p^6(^1S)35d$	$35d\ ^2D$	$1\frac{1}{2}, 2\frac{1}{2}$	33593. 83		$4p^6(^1S)47s$	$47s\ ^2S$	$0\frac{1}{2}$	33633. 93	
$4p^6(^1S)37s$	$37s\ ^2S$	$0\frac{1}{2}$	33595. 02		$4p^6(^1S)44f$	$44f\ ^2F^\circ$	$2\frac{1}{2}, \text{etc.}$	[33634. 28]	
$4p^6(^1S)34f$	$34f\ ^2F^\circ$	$2\frac{1}{2}, \text{etc.}$	33595. 9		$4p^6(^1S)47p$	$47p\ ^2P^\circ$	$0\frac{1}{2}, 1\frac{1}{2}$	33635. 21	
$4p^6(^1S)37p$	$37p\ ^2P^\circ$	$0\frac{1}{2}, 1\frac{1}{2}$	33597. 96		$4p^6(^1S)46d$	$46d\ ^2D$	$1\frac{1}{2}, 2\frac{1}{2}$	33635. 83	
$4p^6(^1S)36d$	$36d\ ^2D$	$1\frac{1}{2}, 2\frac{1}{2}$	33599. 42		$4p^6(^1S)48s$	$48s\ ^2S$	$0\frac{1}{2}$	33636. 33	
$4p^6(^1S)38s$	$38s\ ^2S$	$0\frac{1}{2}$	33600. 57		$4p^6(^1S)45f$	$45f\ ^2F^\circ$	$2\frac{1}{2}, \text{etc.}$	33636. 86	
$4p^6(^1S)35f$	$35f\ ^2F^\circ$	$2\frac{1}{2}, \text{etc.}$	33601. 44		$4p^6(^1S)48p$	$48p\ ^2P^\circ$	$0\frac{1}{2}, 1\frac{1}{2}$	33637. 63	
$4p^6(^1S)38p$	$38p\ ^2P^\circ$	$0\frac{1}{2}, 1\frac{1}{2}$	33603. 14		$4p^6(^1S)47d$	$47d\ ^2D$	$1\frac{1}{2}, 2\frac{1}{2}$	33638. 17	
$4p^6(^1S)37d$	$37d\ ^2D$	$1\frac{1}{2}, 2\frac{1}{2}$	33604. 43		$4p^6(^1S)49s$	$49s\ ^2S$	$0\frac{1}{2}$	33638. 80	
$4p^6(^1S)39s$	$39s\ ^2S$	$0\frac{1}{2}$	33605. 26		$4p^6(^1S)46f$	$46f\ ^2F^\circ$	$2\frac{1}{2}, \text{etc.}$	[33639. 10]	
$4p^6(^1S)36f$	$36f\ ^2F^\circ$	$2\frac{1}{2}, \text{etc.}$	33605. 97		$4p^6(^1S)49p$	$49p\ ^2P^\circ$	$0\frac{1}{2}, 1\frac{1}{2}$	33639. 89	
$4p^6(^1S)39p$	$39p\ ^2P^\circ$	$0\frac{1}{2}, 1\frac{1}{2}$	33607. 96		$4p^6(^1S)48d$	$48d\ ^2D$	$1\frac{1}{2}, 2\frac{1}{2}$	33640. 46	
$4p^6(^1S)38d$	$38d\ ^2D$	$1\frac{1}{2}, 2\frac{1}{2}$	33609. 08		$4p^6(^1S)50s$	$50s\ ^2S$	$0\frac{1}{2}$	33640. 95	
$4p^6(^1S)40s$	$40s\ ^2S$	$0\frac{1}{2}$	33610. 09		$4p^6(^1S)47f$	$47f\ ^2F^\circ$	$2\frac{1}{2}, \text{etc.}$	33641. 32	
$4p^6(^1S)37f$	$37f\ ^2F^\circ$	$2\frac{1}{2}, \text{etc.}$	33610. 41		$4p^6(^1S)50p$	$50p\ ^2P^\circ$	$0\frac{1}{2}, 1\frac{1}{2}$	33642. 01	



## Rb I—Continued

## Rb I—Continued

Config.	Desig.	<i>J</i>	Level	Interval	Config.	Desig.	<i>J</i>	Level	Interval
4p <sup>6</sup> ( <sup>1</sup> S)49d	49d <sup>2</sup> D	1½, 2½	33642. 7		4p <sup>5</sup> 5s( <sup>3</sup> P <sub>1</sub> )4d	4d 2°	0½, 1½	139910	
4p <sup>6</sup> ( <sup>1</sup> S)51s	51s <sup>2</sup> S	0½	33643. 98		4p <sup>5</sup> 5s( <sup>3</sup> P <sub>2</sub> )4d	4d 3°	0½, 1½	145540	
4p <sup>6</sup> ( <sup>1</sup> S)51p	51p <sup>2</sup> P°	0½, 1½	33644. 02		4p <sup>5</sup> 5s( <sup>3</sup> P <sub>2</sub> )4d	4d 4°	0½, 1½	146050	
4p <sup>6</sup> ( <sup>1</sup> S)50d	50d <sup>2</sup> D	1½, 2½	33644. 5		4p <sup>5</sup> 5s( <sup>3</sup> P <sub>1</sub> )4d	4d 5°	0½, 1½	146780	
4p <sup>6</sup> ( <sup>1</sup> S)52s	52s <sup>2</sup> S	0½	33644. 95		4p <sup>5</sup> 5s( <sup>3</sup> P <sub>2</sub> )4d	4d 6°	0½, 1½	147330	
4p <sup>6</sup> ( <sup>1</sup> S)52p	52p <sup>2</sup> P°	0½, 1½	33645. 96		4p <sup>5</sup> 5s( <sup>3</sup> P <sub>0</sub> )4d	4d 7°	0½, 1½	147580	
4p <sup>6</sup> ( <sup>1</sup> S)51d	51d <sup>2</sup> D	1½, 2½	33646. 54		4p <sup>5</sup> 5s( <sup>3</sup> P <sub>1</sub> )4d	4d 8°	0½, 1½	148910	
4p <sup>6</sup> ( <sup>1</sup> S)53s	53s <sup>2</sup> S	0½	33646. 84?		4p <sup>5</sup> 5s( <sup>3</sup> P <sub>2</sub> )6s	6s <sup>2</sup> P°	1½ 0½?	151760 152980	—1220
4p <sup>6</sup> ( <sup>1</sup> S)53p	53p <sup>2</sup> P°	0½, 1½	33647. 72		4p <sup>5</sup> 5s( <sup>3</sup> P <sub>1</sub> )6s				
4p <sup>6</sup> ( <sup>1</sup> S)52d	52d <sup>2</sup> D	1½, 2½	33648. 29		4p <sup>5</sup> 5s( <sup>3</sup> P°)6s	6s <sup>4</sup> P°	2½ 1½? 0½?	152380 158520	—6140
4p <sup>6</sup> ( <sup>1</sup> S)54p	54p <sup>2</sup> P°	0½, 1½	33649. 33		4p <sup>5</sup> 5s( <sup>3</sup> P <sub>0</sub> )6s				
4p <sup>6</sup> ( <sup>1</sup> S)53d	53d <sup>2</sup> D	1½, 2½	33650. 03		4p <sup>5</sup> 5s( <sup>1</sup> P <sub>1</sub> )4d	4d' 9°	0½, 1½	152690	
4p <sup>6</sup> ( <sup>1</sup> S)55p	55p <sup>2</sup> P°	0½, 1½	33650. 95		4p <sup>5</sup> 5s( <sup>1</sup> P <sub>1</sub> )4d	4d' 10°	0½, 1½	154040	
4p <sup>6</sup> ( <sup>1</sup> S)54d	54d <sup>2</sup> D	1½, 2½	33651. 36		4p <sup>5</sup> 5s( <sup>3</sup> P <sub>2</sub> )5d	5d 11°	0½, 1½	154260	
4p <sup>6</sup> ( <sup>1</sup> S)56p	56p <sup>2</sup> P°	0½, 1½	33652. 41		4p <sup>5</sup> 5s( <sup>1</sup> P <sub>1</sub> )4d?	4d' 12°	0½, 1½	154950	
4p <sup>6</sup> ( <sup>1</sup> S)57p	57p <sup>2</sup> P°	0½, 1½	33653. 80		4p <sup>5</sup> 5s( <sup>3</sup> P <sub>1</sub> )5d	5d 13°	0½, 1½	156310	
4p <sup>6</sup> ( <sup>1</sup> S)58p	58p <sup>2</sup> P°	0½, 1½	33655. 11		4p <sup>5</sup> 5s( <sup>3</sup> P <sub>2</sub> )5d	5d 14°	0½, 1½	156980	
4p <sup>6</sup> ( <sup>1</sup> S)59p	59p <sup>2</sup> P°	0½, 1½	33656. 39		4p <sup>5</sup> 5s( <sup>3</sup> P <sub>1</sub> )5d	5d 15°	0½, 1½	157380	
4p <sup>6</sup> ( <sup>1</sup> S)60p	60p <sup>2</sup> P°	0½, 1½	33657. 55		4p <sup>5</sup> 5s( <sup>3</sup> P <sub>1</sub> )5d	5d 16°	0½, 1½	157750	
4p <sup>6</sup> ( <sup>1</sup> S)61p	61p <sup>2</sup> P°	0½, 1½	33658. 69		4p <sup>5</sup> 5s( <sup>3</sup> P <sub>1</sub> )5d	5d 17°	0½, 1½	159070	
4p <sup>6</sup> ( <sup>1</sup> S)62p	62p <sup>2</sup> P°	0½, 1½	33659. 80		4p <sup>5</sup> 5s( <sup>1</sup> P <sub>1</sub> )6s	6s' <sup>2</sup> P°	0½ 1½	159210 160990	1780
4p <sup>6</sup> ( <sup>1</sup> S)63p	63p <sup>2</sup> P°	0½, 1½	33660. 82		4p <sup>5</sup> 5s( <sup>3</sup> P <sub>2</sub> )7s	7s <sup>2</sup> P°	1½ 0½	159210	
4p <sup>6</sup> ( <sup>1</sup> S)64p	64p <sup>2</sup> P°	0½, 1½	33661. 81						
4p <sup>6</sup> ( <sup>1</sup> S)65p	65p <sup>2</sup> P°	0½, 1½	33662. 73		4p <sup>5</sup> 5s( <sup>3</sup> P°)7s	7s <sup>4</sup> P°	2½ 1½? 0½?	160060 166830	—6770
4p <sup>6</sup> ( <sup>1</sup> S)66p	66p <sup>2</sup> P°	0½, 1½	33663. 63		4p <sup>5</sup> 5s( <sup>3</sup> P <sub>1</sub> )7s?				
4p <sup>6</sup> ( <sup>1</sup> S)67p	67p <sup>2</sup> P°	0½, 1½	33664. 48		4p <sup>5</sup> 5s( <sup>3</sup> P <sub>0</sub> )7s?				
4p <sup>6</sup> ( <sup>1</sup> S)68p	68p <sup>2</sup> P°	0½, 1½	33665. 28		4p <sup>5</sup> 5s( <sup>3</sup> P <sub>2</sub> )6d	6d 18°	0½, 1½	161210	
4p <sup>6</sup> ( <sup>1</sup> S)69p	69p <sup>2</sup> P°	0½, 1½	33666. 04		4p <sup>5</sup> 5s( <sup>3</sup> P <sub>2</sub> )6d	6d 19°	0½, 1½	161450	
4p <sup>6</sup> ( <sup>1</sup> S)70p	70p <sup>2</sup> P°	0½, 1½	33666. 78		4p <sup>5</sup> 5s( <sup>3</sup> P <sub>1</sub> )6d	6d 20°	0½, 1½	162820	
4p <sup>6</sup> ( <sup>1</sup> S)71p	71p <sup>2</sup> P°	0½, 1½	33667. 49		4p <sup>5</sup> 5s( <sup>3</sup> P <sub>2</sub> )7d	7d 21°	0½, 1½	162820	
4p <sup>6</sup> ( <sup>1</sup> S)72p	72p <sup>2</sup> P°	0½, 1½	33668. 11		4p <sup>5</sup> 5s( <sup>3</sup> P <sub>0</sub> )5d	5d 22°	0½, 1½	163380	
4p <sup>6</sup> ( <sup>1</sup> S)73p	73p <sup>2</sup> P°	0½, 1½	33668. 79		4p <sup>5</sup> 5s( <sup>3</sup> P°)8s	8s <sup>4</sup> P°	2½ 1½? 0½	163500	
4p <sup>6</sup> ( <sup>1</sup> S)74p	74p <sup>2</sup> P°	0½, 1½	33669. 36		4p <sup>5</sup> 5s( <sup>3</sup> P <sub>1</sub> )8s				
4p <sup>6</sup> ( <sup>1</sup> S)75p	75p <sup>2</sup> P°	0½, 1½	33670. 01		4p <sup>5</sup> 5s( <sup>1</sup> P <sub>1</sub> )5d	5d' 23°	0½, 1½	164700	
4p <sup>6</sup> ( <sup>1</sup> S)76p	76p <sup>2</sup> P°	0½, 1½	33670. 61		4p <sup>5</sup> 5s( <sup>1</sup> P <sub>1</sub> )5d	5d' 24°	0½, 1½	165080	
4p <sup>6</sup> ( <sup>1</sup> S)77p	77p <sup>2</sup> P°	0½, 1½	33671. 07		4p <sup>5</sup> 5s( <sup>1</sup> P <sub>1</sub> )5d	5d' 25°	0½, 1½	166060	
					4p <sup>5</sup> 5s( <sup>1</sup> P <sub>1</sub> )7s	7s' <sup>2</sup> P°	0½? 1½	168180	
Rb II ( <sup>1</sup> S <sub>0</sub> )	Limit	-----	33691. 02		Rb II (5s <sup>3</sup> P <sub>2</sub> )	Limit	-----	167040	
4p <sup>5</sup> ( <sup>3</sup> P <sub>2</sub> )5s <sup>2</sup>	5s <sup>2</sup> <sup>2</sup> P°	1½	123500	—6820	Rb II (5s <sup>3</sup> P <sub>1</sub> )	Limit	-----	168570	
4p <sup>5</sup> ( <sup>1</sup> P <sub>1</sub> )5s <sup>2</sup>		0½	130320		Rb II (5s <sup>3</sup> P <sub>0</sub> )	Limit	-----	175570	
					Rb II (5s <sup>1</sup> P <sub>1</sub> )	Limit	-----	177160	
4p <sup>5</sup> 5s( <sup>3</sup> P <sub>2</sub> )4d	4d 1°	0½, 1½	138780						

## Rb II

(Kr I sequence; 36 electrons)

 $Z=37$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 {}^1S_0$  $4p^6 {}^1S_0$  221852  $\text{cm}^{-1}$ 

I. P. 27.5 volts

Laporte, Miller, and Sawyer have published a list of 102 classified lines extending from 697.04 Å to 7698.57 Å. They have utilized earlier data by Reinheimer and Otsuka together with their own additional observations. Their limit is from the  $ns {}^3P_{2,1}$  series ( $n=5,6$ ) fitted to a Rydberg formula. The higher limit given in the table has been obtained by adding to their ionization limit the interval of the ground term of Rb III.

The author's notation is entered in column one of the table. The writer has provisionally assigned to the miscellaneous levels the pair-coupling notation, used in these volumes for spectra of the inert gases. These assignments require further confirmation.

## REFERENCES

O. Laporte, G. R. Miller, and R. A. Sawyer, Phys. Rev. **38**, 843 (1931). (I P) (T) (C L)  
J. E. Mack, Rev. Mod. Phys. **22**, No. 1, 64 (1950). (Summary hfs)

## Rb II

## Rb II

Authors	Config.	Desig.	$J$	Level	Authors	Config.	Desig.	$J$	Level
$4p^6 {}^1S_0$	$4p^6$	$4p^6 {}^1S$	0	0.00	$5p \begin{smallmatrix} 7_1 \\ 8_2 \end{smallmatrix}$	$4p^5({}^2P_{3/2}^o)5p$	$5p' [1\frac{1}{2}]$	$\begin{smallmatrix} 1 \\ 2 \end{smallmatrix}$	$\begin{smallmatrix} 163929.47 \\ 164972.81 \end{smallmatrix}$
$4d \begin{smallmatrix} 1_1^o \\ 4_0^o \end{smallmatrix}$	$4p^5({}^2P_{1/2})4d$	$4d [0\frac{1}{2}]^o$	$\begin{smallmatrix} 1 \\ 0 \end{smallmatrix}$	$\begin{smallmatrix} 126453.53 \\ 138799.56 \end{smallmatrix}$	$5p \begin{smallmatrix} 9_1 \\ 10_0 \end{smallmatrix}$	"	$5p' [0\frac{1}{2}]$	$\begin{smallmatrix} 1 \\ 0 \end{smallmatrix}$	$\begin{smallmatrix} 165094.55 \\ 167637.30 \end{smallmatrix}$
$4d \begin{smallmatrix} 2_2^o \\ 5_1^o \end{smallmatrix}$	"	$4d [1\frac{1}{2}]^o$	$\begin{smallmatrix} 2 \\ 1 \end{smallmatrix}$	$\begin{smallmatrix} 128693.70 \\ 140615.18 \end{smallmatrix}$	$6s \begin{smallmatrix} {}^3P_2^o \\ {}^3P_1^o \end{smallmatrix}$	$4p^5({}^2P_{1/2})6s$	$6s [1\frac{1}{2}]^o$	$\begin{smallmatrix} 2 \\ 1 \end{smallmatrix}$	$\begin{smallmatrix} 179740.11 \\ 180173.33 \end{smallmatrix}$
$4d \begin{smallmatrix} 3_2^o \\ 6_{1,2} \end{smallmatrix}$	"	$4d [2\frac{1}{2}]^o$	$\begin{smallmatrix} 2 \\ 3 \end{smallmatrix}$	$\begin{smallmatrix} 136665.21 \\ 143027.39 \end{smallmatrix}$	$6s \begin{smallmatrix} {}^1P_1^o \\ 1 \end{smallmatrix}$	$4p^5({}^2P_{3/2}^o)6s$	$6s' [0\frac{1}{2}]^o$	$\begin{smallmatrix} 0 \\ 1 \end{smallmatrix}$	$\begin{smallmatrix} 188622.28 \\ 184205.27 \end{smallmatrix}$
$4d \begin{smallmatrix} 7_2^o \\ 8_{1,2} \end{smallmatrix}$	"	$4d' [1\frac{1}{2}]^o$	$\begin{smallmatrix} 2 \\ 1 \end{smallmatrix}$	$\begin{smallmatrix} 143960.94 \\ 145630.06 \end{smallmatrix}$	$5d \begin{smallmatrix} 1_1^o \\ 3_2^o \end{smallmatrix}$	$4p^5({}^2P_{1/2})5d$	$5d [0\frac{1}{2}]^o$	$\begin{smallmatrix} 1 \\ 0 \end{smallmatrix}$	$\begin{smallmatrix} 184205.27 \\ 185131.62 \end{smallmatrix}$
$5s \begin{smallmatrix} {}^3P_2^o \\ {}^3P_1^o \end{smallmatrix}$	$4p^5({}^2P_{1/2})5s$	$5s [1\frac{1}{2}]^o$	$\begin{smallmatrix} 2 \\ 1 \end{smallmatrix}$	$\begin{smallmatrix} 133347.29 \\ 134875.14 \end{smallmatrix}$	$5d \begin{smallmatrix} 2_2^o \\ 6_1^o \end{smallmatrix}$	"	$5d [1\frac{1}{2}]^o$	$\begin{smallmatrix} 2 \\ 1 \end{smallmatrix}$	$\begin{smallmatrix} 184841.65 \\ 187340.37 \end{smallmatrix}$
$5s \begin{smallmatrix} {}^3P_0^o \\ {}^1P_1^o \end{smallmatrix}$	$4p^5({}^2P_{3/2}^o)5s$	$5s' [0\frac{1}{2}]^o$	$\begin{smallmatrix} 0 \\ 1 \end{smallmatrix}$	$\begin{smallmatrix} 141879.24 \\ 143467.00 \end{smallmatrix}$	$5d \begin{smallmatrix} 4_2^o \\ 5_3^o \end{smallmatrix}$	"	$5d [2\frac{1}{2}]^o$	$\begin{smallmatrix} 2 \\ 3 \end{smallmatrix}$	$\begin{smallmatrix} 185622.53 \\ 186010.87 \end{smallmatrix}$
$5p \begin{smallmatrix} 1_1 \\ 2_2 \\ 3_3 \end{smallmatrix}$	$4p^5({}^2P_{1/2})5p$	$5p [0\frac{1}{2}]$	1	154279.25	$5d \begin{smallmatrix} 7_1^o \\ 8_{1,2}^o \end{smallmatrix}$	$4p^5({}^2P_{3/2}^o)5d$	$5d' [1\frac{1}{2}]^o$	$\begin{smallmatrix} 1 \\ 2 \end{smallmatrix}$	$\begin{smallmatrix} 189006.27 \\ 192380.15 \end{smallmatrix}$
$5p \begin{smallmatrix} 4_1 \\ 5_2 \end{smallmatrix}$	"	$5p [2\frac{1}{2}]$	$\begin{smallmatrix} 2 \\ 3 \end{smallmatrix}$	$\begin{smallmatrix} 156742.20 \\ 156900.72 \end{smallmatrix}$		Rb III ( ${}^2P_{1/2}$ )	Limit	-----	221852
$5p \begin{smallmatrix} 6_0 \end{smallmatrix}$	"	$5p [1\frac{1}{2}]$	$\begin{smallmatrix} 1 \\ 2 \end{smallmatrix}$	$\begin{smallmatrix} 158156.66 \\ 158717.04 \end{smallmatrix}$		Rb III ( ${}^2P_{3/2}^o$ )	Limit	-----	229232
	"	$5p [0\frac{1}{2}]$	0	161205.13					

May 1951.



Rb II OBSERVED LEVELS\*

Config. 1s <sup>2</sup> 2s <sup>2</sup> 2p <sup>6</sup> 3s <sup>2</sup> 3p <sup>6</sup> 3d <sup>10</sup> 4s <sup>2</sup> +	Observed Terms		
4p <sup>6</sup>	4p <sup>6</sup> 1S		
	ns (n ≥ 5)		
	{ 5, 6s 3P° 5, 6s 1P°		
4p <sup>5</sup> (2P°) nx			
j <i>l</i> -Coupling Notation			
	Observed Pairs		
	ns (n ≥ 5)	np (n ≥ 5)	nd (n ≥ 4)
	5, 6s [1½]°	5p [0½] 5p [2½] 5p [1½]	4,5d [0½]° 5d [3½]° 4,5d [1½]° 4,5d [2½]°
	5, 6s' [0½]°	5p' [1½] 5p' [0½]	4d' [2½]° 4,5d' [1½]°

\*For predicted levels in the spectra of the Kr I isoelectronic sequence, see Introduction.

Rb III

(Br I sequence; 35 electrons)

Z=37

Ground state 1s<sup>2</sup> 2s<sup>2</sup> 2p<sup>6</sup> 3s<sup>2</sup> 3p<sup>6</sup> 3d<sup>10</sup> 4s<sup>2</sup> 4p<sup>5</sup> 2P°<sub>1/2</sub>

4p<sup>5</sup> 2P°<sub>1/2</sub> 320000 cm<sup>-1</sup>

I. P. 40 volts

The analysis is incomplete. Tombouliau has classified 30 lines of Rb III in the region between 482 Å and 815 Å as due to transitions from the ground term to 11 higher terms.

He has estimated the value of the limit by extrapolation of isoelectronic sequence data.

REFERENCE

D. H. Tombouliau, Phys. Rev. 54, 350 (1938). (I P) (T) (C L)

Rb III

Rb III

Config.	Desig.	J	Level	Interval	Config.	Desig.	J	Level	Interval
4s <sup>2</sup> 4p <sup>5</sup>	4p <sup>5</sup> 2P°	1½ 0½	0 7380	— 7380	4s <sup>2</sup> 4p <sup>4</sup> (3P) 4d	4d 2D	1½ 2½	173475	
4s 4p <sup>6</sup>	4p <sup>6</sup> 2S	0½	130036		4s <sup>2</sup> 4p <sup>4</sup> (3P) 4d	4d 2P	0½ 1½	177044	
4s <sup>2</sup> 4p <sup>4</sup> (3P) 4d	4d 4D	3½ 2½ 1½ 0½	152353 154403	— 2050	4s <sup>2</sup> 4p <sup>4</sup> (1D) 5s	5s' 2D	1½ 2½	182963	
4s <sup>2</sup> 4p <sup>4</sup> (3P) 5s	5s 4P	2½ 1½ 0½	164507 168085	— 3578	4s <sup>2</sup> 4p <sup>4</sup> (1D) 4d	4d' 2D	2½ 1½	200883	
4s <sup>2</sup> 4p <sup>4</sup> (3P) 4d	4d 4P	0½ 1½ 2½	170423 170847	424	4s <sup>2</sup> 4p <sup>4</sup> (1D) 4d	4d' 2P	1½ 0½	204104	
4s <sup>2</sup> 4p <sup>4</sup> (3P) 5s	5s 2P	1½ 0½	172045 175396	— 3351	4s <sup>2</sup> 4p <sup>4</sup> (1S) 5s	5s'' 2S	0½	207277	
					Rb IV (3P <sub>2</sub> )	Limit	-----	[320000]	



## Rb III OBSERVED TERMS\*

Config. $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} +$	Observed Terms	
$4s^2 4p^5$	$4p^5 \ ^1P^o$	
$4s 4p^6$	$4p^6 \ ^1S$	
	$ns \ (n \geq 5)$	$nd \ (n \geq 4)$
$4s^2 4p^4(^3P)nx$	{ $5s \ ^4P$ $5s \ ^2P$ $5s' \ ^2D$ $5s'' \ ^2S$	$4d \ ^4P \quad 4d \ ^4D$
$4s^2 4p^4(^1D)nx'$		$4d \ ^2P \quad 4d \ ^2D$
$4s^2 4p^4(^1S)nx''$		$4d' \ ^2P \quad 4d' \ ^2D$

\*For predicted terms in the spectra of the Br I isoelectronic sequence, see Vol. II, Introduction.

## Rb IX

(Cu I sequence; 29 electrons)

$Z=37$

Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s \ ^2S_{0\frac{1}{2}}$

$4s \ ^2S_{0\frac{1}{2}} \quad \text{cm}^{-1}$

I. P. volts

This spectrum has not been analyzed, but Mack has observed the principal doublet, as follows:

I A	Wave No.	Desig.
583. 37	171417	$4s \ ^2S_{0\frac{1}{2}} - 4p \ ^2P_{\frac{1}{2}}$
628. 62	159078	$4s \ ^2S_{0\frac{1}{2}} - 4p \ ^2P_{\frac{3}{2}}$

## REFERENCE

J. E. Mack, Phys. Rev. **38**, 193 (L) (1931). (I P) (T) (C L)  
March 1950.

## Rb X

(Ni I sequence; 28 electrons)

$Z=37$

Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} \ ^1S_0$

$3d^{10} \ ^1S_0 \ 2235100 \text{ cm}^{-1}$

I. P. 277 volts

Edlén has observed lines from the  $3d^{10} - 3d^9np$  ( $n=4,5$ ) and  $3d^{10} - 3d^9nf$  ( $n=4-6$ ) configurations. In figure 2 of his paper on the spectra of highly ionized atoms, some lines from each group are indicated on the photograph of vacuum spark spectra of Rb observed between 50 Å and 100 Å.

From preliminary unpublished measurements he has derived provisional absolute term values from the Rydberg  $nf$ -series. The terms in the table are from his manuscript. His unit,  $10^3 \text{ cm}^{-1}$ , has here been changed to  $\text{cm}^{-1}$ .

## REFERENCES

B. Edlén, Physica **13**, No. 9, 547 (1947).  
B. Edlén, letter (July 1950). (I P) (T)

## Rb x

## Rb x

Config.	Desig.	<i>J</i>	Level	Config.	Desig.	<i>J</i>	Level
$3d^{10}$	$3d^{10} {}^1S$	0	0	$3d^9({}^1D)5p$	$5p {}^1D^\circ$	$\begin{smallmatrix} 3 \\ 2 \\ 1 \end{smallmatrix}$	
$3d^9({}^2D)4p$	$4p {}^1P^\circ$	1	1023400				1568400
$3d^9({}^2D)4p$	$4p {}^3D^\circ$	$\begin{smallmatrix} 3 \\ 2 \\ 1 \end{smallmatrix}$	1031100	$3d^9({}^2D)5f$	$5f {}^1P^\circ$	1	1733800
				$3d^9({}^2D)5f$	$5f {}^3D^\circ$	$\begin{smallmatrix} 3 \\ 2 \\ 1 \end{smallmatrix}$	1799200
$3d^9({}^2D)4f$	$4f {}^3P^\circ$	$\begin{smallmatrix} 2 \\ 1 \\ 0 \end{smallmatrix}$	1517200				1922300
$3d^9({}^2D)4f$	$4f {}^1P^\circ$	1	1527700	$3d^9({}^2D)6f$	$6f {}^1P^\circ$	1	
$3d^9({}^2D)4f$	$4f {}^3D^\circ$	$\begin{smallmatrix} 3 \\ 2 \\ 1 \end{smallmatrix}$	1548000	$3d^9({}^2D)6f$	$4f {}^3D^\circ$	$\begin{smallmatrix} 3 \\ 2 \\ 1 \end{smallmatrix}$	1935400
$3d^9({}^2D)5p$	$5p {}^1P^\circ$	1	1559600	-----			-----
				Rb xi ( ${}^2D_{3/2}$ )	<b>Limit</b>	-----	2235100

August 1950.

## Rb xi

(Co I sequence; 27 electrons)

 $Z=37$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^9 {}^2D_{3/2}$  $3d^9 {}^2D_{3/2}$  cm<sup>-1</sup>

I. P. volts

Edlén has observed three lines due to the transition  $3p^6 3d^9 {}^2D - 3p^5 3d^{10} {}^2P^\circ$ . From preliminary unpublished measurements he has furnished the provisional term values quoted in the table. In figure 2 of his paper on the spectra of highly ionized atoms, the lines are indicated on the photograph of the vacuum spark spectra of Rb observed between 50 Å and 100 Å. Another group of lines from  $3d^9 - 3d^8 4p$  is also indicated in the figure.

Edlén's unit, 10<sup>3</sup> cm<sup>-1</sup>, has here been changed to cm<sup>-1</sup>.

## REFERENCES

- B. Edlén, *Physica*, **13**, No. 9, 547 (1947).  
 B. Edlén, letter (July 1950). (T)

## Rb xi

Config.	Desig.	<i>J</i>	Level	Interval
$3p^6 3d^9$	$3d^9 {}^2D$	$\begin{smallmatrix} 2\frac{1}{2} \\ 1\frac{1}{2} \end{smallmatrix}$	$\begin{smallmatrix} 0 \\ 12300 \end{smallmatrix}$	-12300
$3p^5 3d^{10}$	$3d^{10} {}^2P^\circ$	$\begin{smallmatrix} 1\frac{1}{2} \\ 0\frac{1}{2} \end{smallmatrix}$	$\begin{smallmatrix} 1028700 \\ 1101400 \end{smallmatrix}$	-72700

July 1950.

**Rb XII**

(Fe I sequence; 26 electrons)

 $Z=37$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^8 {}^3F_4$  $3d^8 {}^3F_4$        $\text{cm}^{-1}$ 

I. P.      volts

This spectrum has not been analyzed, but Edlén has observed a group of lines due to terms from the  $3d^8-3d^7 4p$  configurations. In figure 2 of his paper on the spectra of highly ionized atoms, the lines are indicated on the photograph of vacuum spark spectra of Rb observed between 50 Å and 100 Å.

The writer has assumed the ground state indicated above, by analogy with Ni III.

## REFERENCE

B. Edlén, *Physica* **13**, No. 9, 547 (1947).

February 1950.

**Rb XIII**

(Mn I sequence; 25 electrons)

 $Z=37$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^7 {}^4F_{4\frac{1}{2}}$  $3d^7 {}^4F_{4\frac{1}{2}}$        $\text{cm}^{-1}$ 

I. P.      volts

This spectrum has not been analyzed, but Edlén has observed a group of lines due to terms from the  $3d^7-3d^6 4p$  configurations. In figure 2 of his paper on the spectra of highly ionized atoms, the lines are indicated on the photograph of vacuum spark spectra of Rb observed between 50 Å and 100 Å.

The writer has assumed the ground state indicated above, by analogy with Co III.

## REFERENCE

B. Edlén, *Physica* **13**, No. 9, 547 (1947).

February 1950.

**Rb XIV**

(Cr I sequence; 24 electrons)

 $Z=37$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^6 {}^5D_4$  $3d^6 {}^5D_4$        $\text{cm}^{-1}$ 

I. P.      volts

This spectrum has not been analyzed, but Edlén has observed a group of lines due to terms from the  $3d^6-3d^5 4p$  configurations. In figure 2 of his paper on the spectra of highly ionized atoms the lines are indicated on the photograph of vacuum spark spectra of Rb observed between 50 Å and 100 Å.

The writer has assumed the ground state indicated above, by analogy with Fe III.

## REFERENCE

B. Edlén, *Physica* **13**, No. 9, 547 (1947).

February 1950.



## STRONTIUM

## Sr I

38 electrons

 $Z=38$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 5s^2 {}^1S_0$  $5s^2 {}^1S_0$  45925.6  $\text{cm}^{-1}$ 

I. P. 5.692 volts

The Sr I spectrum, like Ca I, has played an important part in the development of a satisfactory theory for atomic spectra. In addition to the "regular" series, terms involving two excited electrons were found in Sr I as well as in Ca I, and were first discussed in the classical paper by Russell and Saunders in 1925. White discusses these terms further in his paper on "Auto-Ionization in the Alkaline Earth Metals and the Inert Gases."

The regular series terms, i. e., those having the limit  ${}^2S$  in Sr II, have been taken from the paper by Saunders, except for  $5d {}^1D_2$ . Other terms are from the papers by Russell and Saunders and by Meggers. The writer has also had at her disposal Russell's unpublished line list and multiplet arrays.

Sullivan has observed 102 Sr I lines with the interferometer. From these observations he has improved a number of the term values. All of the three-place entries in the table, except that of  $6p {}^3P_0^\circ$ ; and the two-place values for the terms 6, 7,  $10p {}^1P^\circ$ ; 4,  $5f {}^1F^\circ$ ; 7,  $8d {}^3D$ ; and  $4d^2 {}^3P$ , are from his paper. The rest have been adjusted to these by the writer with the aid of the best available line list. The resolution of the terms 6,  $7f {}^3F^\circ$  is dubious, owing to the inaccuracy of the existing wavelengths.

Although long series are well known, and all of the terms are well connected by observed intersystem combinations, a number of Sr I lines remain unclassified, and many of the observed lines should be remeasured. Humphreys has recently remeasured two lines, 20764.19 Å and 20778.14 Å, which are designated as  $6s {}^3S_1-6p {}^3P_0^\circ$  and  $5d {}^1D_2-4f {}^1F_3^\circ$ , respectively. He expects to extend the analysis from further observations in the far infrared. A monograph containing a homogeneous list of lines and term values is seriously needed as soon as his work is completed.

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 C. J. Humphreys, unpublished material (April 1951). (C L)

## Sr I

## Sr I

Config.	Desig.	<i>J</i>	Level	Interval	Config.	Desig.	<i>J</i>	Level	Interval
5s <sup>2</sup>	5s <sup>2</sup> 1S	0	0. 000		5s(2S)8p	8p 1P°	1	41172. 15	
5s(2S)5p	5p 3P°	0	14317. 520	186. 831	5s(2S)5f	5f 3F°	2	41364. 614	0. 918
		1	14504. 351	394. 212			3	41365. 532	1. 163
		2	14898. 563				4	41366. 695	
5s(2S)4d	4d 3D	1	18159. 056	59. 739	5s(2S)5f	5f 1F°	3	41518. 91	
		2	18218. 795	100. 472	5s(2S)7d	7d 1D	2	41831. 7	
		3	18319. 267		5s(2S)7d	7d 3D	1	41864. 40	4. 92
5s(2S)4d	4d 1D	2	20149. 700				2	41869. 32	5. 58
5s(2S)5p	5p 1P°	1	21698. 482				3	41874. 90	
5s(2S)6s	6s 3S	1	29038. 795		5s(2S)9s	9s 3S	1	42451. 2	
5s(2S)6s	6s 1S	0	30591. 8		5s(2S)9p	9p 1P°	1	42462. 36	
4d(2D)5p	5p' 3F°	2	33266. 872	322. 852	5s(2S)9s	9s 1S	0	42596. 0	
		3	33589. 724	329. 606	5s(2S)6f	6f 3F°	2	42776. 2?	0. 4?
		4	33919. 330				3	42776. 6?	1. 6?
4d(2D)5p	5p' 1D°	2	33826. 927				4	42778. 155	
5s(2S)6p	6p 3P°	0	33853. 516	14. 817	5s(2S)6f	6f 1F°	3	42839. 4	
		1	33868. 333	104. 748	5s(2S)8d	8d 1D	2	43020. 9	
		2	33973. 081		5s(2S)8d	8d 3D	1	43066. 7	3. 6
5s(2S)6p	6p 1P°	1	34098. 44				2	43070. 31	4. 46
5s(2S)5d	5d 1D	2	34727. 483				3	43074. 77	
5s(2S)5d	5d 3D	1	35006. 943	15. 072	5s(2S)10p	10p 1P°	1	43327. 94	
		2	35022. 015	23. 040	5s(2S)10s	10s 3S	1	43427. 6	
		3	35045. 055		5s(2S)10s	10s 1S	0	43512. 6	
5p <sup>2</sup>	5p <sup>2</sup> 3P	0	35193. 47	206. 67	5s(2S)7f	7f 3F°	2, 3	43624. 0	0. 5?
		1	35400. 138	274. 530			4	43624. 513	
		2	35674. 668		5s(2S)7f	7f 1F°	3	43656. 1	
4d(2D)5p	5p' 3D°	1	36264. 181	117. 588	5s(2S)9d	9d 1D	2	43780. 6	
		2	36381. 769	177. 745	5s(2S)9d	9d 3D	1, 2	43807. 8	4. 8
		3	36559. 514				3	43812. 6	
5p <sup>2</sup>	5p <sup>2</sup> 1D	2	36960. 881		5s(2S)11p	11p 1P°	1	43938. 26	
5p <sup>2</sup>	5p <sup>2</sup> 1S	0	37160. 278		5s(2S)11s	11s 3S	1	44043. 4	
4d(2D)5p	5p' 3P°	0	37292. 106	10. 654	5s(2S)11s	11s 1S	0	44097. 1	
		1	37302. 760	33. 856	5s(2S)8f	8f 3F°	2, 3, 4	44171. 8	
		2	37336. 616		5s(2S)8f	8f 1F°	3	44190. 1	
5s(2S)7s	7s 3S	1	37424. 713		5s(2S)10d	10d 3D	1	44283. 8	3. 3?
4d(2D)5p	5p' 1F°	3	38008. 0				2	44287. 1	12. 6
5s(2S)7s	7s 1S	0	38444. 054				3	44299. 7	
5s(2S)4f	4f 3F°	2	38750. 454	1. 986	5s(2S)12p	12p 1P°	1	44365. 9	
		3	38752. 440	2. 759	5s(2S)12s	12s 3S	1	44457. 3	
		4	38755. 199		4d <sup>2</sup>	4d <sup>2</sup> 3P	0	44525. 88	70. 09
5s(2S)7p	7p 1P°	1	38906. 90				1	44595. 97	133. 70
5s(2S)7p	7p 3P°	0	39411. 703	14. 768	5s(2S)9f	9f 3F°	2, 3, 4	44544. 6	
		1	39426. 471	30. 938	5s(2S)9f	9f 1F°	3	44556. 1	
		2	39457. 409		5s(2S)11d	11d 3D	1	44618. 4	6. 7
5s(2S)4f	4f 1F°	3	39539. 04				2	44625. 1	
5s(2S)6d	6d 3D	1	39685. 903	4. 946			3	44675. 1	
		2	39690. 849	12. 305					
		3	39703. 154						
5s(2S)6d	6d 1D	2	39733. 114						
5s(2S)8s	8s 3S	1	40761. 440						
5s(2S)8s	8s 1S	0	41052. 5						



Sr I—Continued

Sr I—Continued

Config.	Desig.	<i>J</i>	Level	Interval	Config.	Desig.	<i>J</i>	Level	Interval
5s(²S)10f	10f ³F°	2, 3, 4	44809. 8	4. 9	5s(²S)12f	12f ¹F°	3	45160. 4	148. 4 107. 5
5s(²S)10f	10f ¹F°	3	44819. 1		5s(²S)13f	13f ³F°	2, 3, 4	45274. 1	
5s(²S)12d	12d ³D	1 2 3	44860. 0 44864. 9		5s(²S)13f	13f ¹F°	3	45277. 9	
5s(²S)14p	14p ¹P°	1	44903. 5		5s(²S)15d	15d ³D	1, 2, 3	45287. 4	
5s(²S)11f	11f ³F°	2, 3, 4	45005. 6		5s(²S)16d	16d ³D	1, 2, 3	45372. 6	
5s(²S)11f	11f ¹F°	3	45012. 0		Sr II(²S <sub>0½</sub> )	Limit		45925. 6	
5s(²S)13d	13d ³D	1, 2, 3	45043. 9		4d(²D)6p	6p' ³F°	2 3 4	49409. 9 49558. 3 49665. 8	
5s(²S)12f	12f ³F°	2, 3, 4	45155. 6						

April 1951.

Sr I OBSERVED TERMS\*

Config. 1s² 2s² 2p⁶ 3s² 3p⁶ 3d¹⁰ 4s² 4p⁶ +	Observed Terms			
5s²	5s² ¹S			
4d²	4d² ³P			
5p²	{ 5p² ¹S      5p² ³P      5p² ¹D			
	ns (n ≥ 5)	np (n ≥ 5)	nd (n ≥ 4)	nf (n ≥ 4)
5s(²S)nx	{ 6-12s ³S 6-11s ¹S	5- 7p ³P° 5-14p ¹P°	4-13, 15, 16d ³D 4-9d ¹D	4-13f ³F° 4-13f ¹F°
4d(²D)nx'	{	5p' ³P°    5p' ³D°    5, 6p' ³F° 5p' ¹D°    5p' ¹F°		

\*For predicted terms in the spectra of the Sr I isoelectronic sequence, see Vol. II, Introduction.

Sr. II

(Rb I sequence; 37 electrons)

Z=38

Ground state 1s² 2s² 2p⁶ 3s² 3p⁶ 3d¹⁰ 4s² 4p⁶ 5s ²S<sub>0½</sub>

5s ²S<sub>0½</sub> 88964.0 cm<sup>-1</sup>

I. P. 11.027 volts

The analysis is from the paper by Saunders, Schneider, and Buckingham, who list 93 classified lines between 1482 Å and 13124 Å, including the infrared observations by Meggers and by Randall, in addition to their own observations. Sullivan has observed 14 of these lines with the interferometer, and derived improved term values for the six terms given to two decimal places in the table. Brackets denote calculated values.

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## Sr II

## Sr II

Config.	Desig.	$J$	Level	Interval	Config.	Desig.	$J$	Level	Interval
$4p^6(^1S)5s$	$5s\ ^2S$	$0\frac{1}{2}$	0. 00		$4p^6(^1S)10s$	$10s\ ^2S$	$0\frac{1}{2}$	80701. 8	
$4p^6(^1S)4d$	$4d\ ^2D$	$1\frac{1}{2}$ $2\frac{1}{2}$	14555. 90 14836. 24	280. 34	$4p^6(^1S)9d$	$9d\ ^2D$	$1\frac{1}{2}$ $2\frac{1}{2}$	81240. 2 [81249. 0]	[8. 8]
$4p^6(^1S)5p$	$5p\ ^2P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	23715. 19 24516. 65	801. 46	$4p^6(^1S)8f$	$8f\ ^2F^\circ$	$\left\{ \begin{matrix} 2\frac{1}{2} \\ 3\frac{1}{2} \end{matrix} \right\}$	82005. 9	
$4p^6(^1S)6s$	$6s\ ^2S$	$0\frac{1}{2}$	47736. 53		$4p^6(^1S)7g$	$7g\ ^2G$	$\left\{ \begin{matrix} 3\frac{1}{2} \\ 4\frac{1}{2} \end{matrix} \right\}$	82090. 4	
$4p^6(^1S)5d$	$5d\ ^2D$	$1\frac{1}{2}$ $2\frac{1}{2}$	53286. 31 53372. 97	86. 66	$4p^6(^1S)11s$	$11s\ ^2S$	$0\frac{1}{2}$	82576. 1	
$4p^6(^1S)6p$	$6p\ ^2P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	55769. 7 56057. 9	288. 2	$4p^6(^1S)10d$	$10d\ ^2D$	$2\frac{1}{2}$ $1\frac{1}{2}$	82951. 5 82953. 9	-2. 4
$4p^6(^1S)4f$	$4f\ ^2F^\circ$	$\left\{ \begin{matrix} 2\frac{1}{2} \\ 3\frac{1}{2} \end{matrix} \right\}$	60991. 7		$4p^6(^1S)9f$	$9f\ ^2F^\circ$	$\left\{ \begin{matrix} 2\frac{1}{2} \\ 3\frac{1}{2} \end{matrix} \right\}$	83472. 7	
$4p^6(^1S)7s$	$7s\ ^2S$	$0\frac{1}{2}$	64964. 10		$4p^6(^1S)8g$	$8g\ ^2G$	$\left\{ \begin{matrix} 3\frac{1}{2} \\ 4\frac{1}{2} \end{matrix} \right\}$	[83533. 8]	
$4p^6(^1S)6d$	$6d\ ^2D$	$1\frac{1}{2}$ $2\frac{1}{2}$	67522. 87 67563. 15	40. 28	$4p^6(^1S)12s$	$12s\ ^2S$	$0\frac{1}{2}$	83879. 9	
$4p^6(^1S)7p$	$7p\ ^2P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	68645. 2 68793. 6	148. 4	$4p^6(^1S)11d$	$11d\ ^2D$	$1\frac{1}{2}$ $2\frac{1}{2}$	84142. 0 84146. 9	4. 9
$4p^6(^1S)5f$	$5f\ ^2F^\circ$	$\left\{ \begin{matrix} 2\frac{1}{2} \\ 3\frac{1}{2} \end{matrix} \right\}$	71065. 8		$4p^6(^1S)10f$	$10f\ ^2F^\circ$	$\left\{ \begin{matrix} 2\frac{1}{2} \\ 3\frac{1}{2} \end{matrix} \right\}$	84521. 0	
$4p^6(^1S)4g$	$4g\ ^2G$	$\left\{ \begin{matrix} 3\frac{1}{2} \\ 4\frac{1}{2} \end{matrix} \right\}$	71357. 8		$4p^6(^1S)9g$	$9g\ ^2G$	$\left\{ \begin{matrix} 3\frac{1}{2} \\ 4\frac{1}{2} \end{matrix} \right\}$	84567. 0	
$4p^6(^1S)8s$	$8s\ ^2S$	$0\frac{1}{2}$	73237. 1		$4p^6(^1S)13s$	$13s\ ^2S$	$0\frac{1}{2}$	84819. 1	
$4p^6(^1S)7d$	$7d\ ^2D$	$1\frac{1}{2}$ $2\frac{1}{2}$	74621. 3 74643. 1	21. 8	$4p^6(^1S)12d$	$12d\ ^2D$	$\left\{ \begin{matrix} 1\frac{1}{2} \\ 2\frac{1}{2} \end{matrix} \right\}$	85015. 5	
$4p^6(^1S)8p$	$8p\ ^2P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	75311. 8		$4p^6(^1S)11f$	$11f\ ^2F^\circ$	$\left\{ \begin{matrix} 2\frac{1}{2} \\ 3\frac{1}{2} \end{matrix} \right\}$	85294. 8	
$4p^6(^1S)6f$	$6f\ ^2F^\circ$	$\left\{ \begin{matrix} 2\frac{1}{2} \\ 3\frac{1}{2} \end{matrix} \right\}$	76553. 4		$4p^6(^1S)10g$	$10g\ ^2G$	$\left\{ \begin{matrix} 3\frac{1}{2} \\ 4\frac{1}{2} \end{matrix} \right\}$	85330. 3	
$4p^6(^1S)5g$	$5g\ ^2G$	$\left\{ \begin{matrix} 3\frac{1}{2} \\ 4\frac{1}{2} \end{matrix} \right\}$	76737. 7		$4p^6(^1S)13d$	$13d\ ^2D$	$\left\{ \begin{matrix} 1\frac{1}{2} \\ 2\frac{1}{2} \end{matrix} \right\}$	85668. 8	
$4p^6(^1S)9s$	$9s\ ^2S$	$0\frac{1}{2}$	77857. 6		$4p^6(^1S)12f$	$12f\ ^2F^\circ$	$\left\{ \begin{matrix} 2\frac{1}{2} \\ 3\frac{1}{2} \end{matrix} \right\}$	85883. 9	
$4p^6(^1S)8d$	$8d\ ^2D$	$1\frac{1}{2}$ $2\frac{1}{2}$	78688. 8 78702. 4	13. 6	$4p^6(^1S)14d$	$14d\ ^2D$	$\left\{ \begin{matrix} 1\frac{1}{2} \\ 2\frac{1}{2} \end{matrix} \right\}$	86174. 6	
$4p^6(^1S)7f$	$7f\ ^2F^\circ$	$\left\{ \begin{matrix} 2\frac{1}{2} \\ 3\frac{1}{2} \end{matrix} \right\}$	79861. 3						
$4p^6(^1S)6g$	$6g\ ^2G$	$\left\{ \begin{matrix} 3\frac{1}{2} \\ 4\frac{1}{2} \end{matrix} \right\}$	79984. 3						
					Sr III( $^1S_0$ )	Limit	-----	88964. 0	

March 1951.

## Sr IV

(Br I sequence; 35 electrons)

Z=38

Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^5 {}^2P_{1/2}^{\circ}$  $4p^5 {}^2P_{1/2}^{\circ}$  460000  $\text{cm}^{-1}$ 

I. P. 57 volts

The analysis is incomplete. Tombouliau has classified 29 lines of Sr IV in the region between 367 Å and 710 Å as due to transitions from the ground term to 11 higher terms.

He has estimated the value of the limit by extrapolation of isoelectronic sequence data.

## REFERENCE

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## Sr IV

## Sr IV

Config.	Desig.	<i>J</i>	Level	Interval	Config.	Desig.	<i>J</i>	Level	Interval
$4s^2 4p^5$	$4p^5 {}^2P^{\circ}$	$1\frac{1}{2}$ $0\frac{1}{2}$	$0$ 9731	— 9731	$4s^2 4p^4({}^3P)5s$	$5s {}^4P$	$2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	221149 225853	— 4704
$4s 4p^6$	$4p^6 {}^2S$	$0\frac{1}{2}$	150505		$4s^2 4p^4({}^3P)5s$	$5s {}^2P$	$1\frac{1}{2}$ $0\frac{1}{2}$	232970 238203	— 5233
$4s^2 4p^4({}^3P)4d$	$4d {}^4D$	$3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	183305 186065	— 2760	$4s^2 4p^4({}^1D)5s$	$5s' {}^2D$	$1\frac{1}{2}$ $2\frac{1}{2}$	247616	
$4s^2 4p^4({}^3P)4d$	$4d {}^4P$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$	209214 209529	315	$4s^2 4p^4({}^1D)4d$	$4d' {}^2D$	$2\frac{1}{2}$ $1\frac{1}{2}$	249646	
$4s^2 4p^4({}^3P)4d$	$4d {}^2D$	$1\frac{1}{2}$ $2\frac{1}{2}$	214345		$4s^2 4p^4({}^1D)4d$	$4d' {}^2P$	$1\frac{1}{2}$ $0\frac{1}{2}$	253233	
$4s^2 4p^4({}^3P)4d$	$4d {}^2P$	$0\frac{1}{2}$ $1\frac{1}{2}$	218939		$4s^2 4p^4({}^1S)5s$	$5s'' {}^2S$	$0\frac{1}{2}$	271774	
					Sr V ( ${}^3P_2$ )	Limit	-----	460000	

February 1951.

## Sr IV OBSERVED TERMS\*

Config. $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} +$	Observed Terms	
$4s^2 4p^5$	$4p^5 {}^2P^{\circ}$	
$4s 4p^6$	$4p^6 {}^2S$	
	$ns$ ( $n \geq 5$ )	$nd$ ( $n \geq 4$ )
$4s^2 4p^4({}^3P)nx$	$\left\{ \begin{array}{l} 5s {}^4P \\ 5s {}^2P \end{array} \right.$	$\begin{array}{ll} 4d {}^4P & 4d {}^4D \\ 4d {}^2P & 4d {}^2D \end{array}$
$4s^2 4p^4({}^1D)nx'$	$5s' {}^2D$	$4d' {}^2P \quad 4d' {}^2D$
$4s^2 4p^4({}^1S)nx''$	$5s'' {}^2S$	

\*For predicted terms in the spectra of the Br I isoelectronic sequence, see Vol. II, Introduction.

## Sr XI

(Ni I sequence; 28 electrons)

 $Z=38$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} {}^1S_0$  $3d^{10} {}^1S_0$  2613800  $\text{cm}^{-1}$ 

I. P. 324 volts

Edlén has observed lines from the  $3d^{10}-3d^9 np$  ( $n=4,5$ ) and  $3d^{10}-3d^9 nf$  ( $n=4-6$ ) configurations. In figure 2 of his paper on the spectra of highly ionized atoms, some lines from each group are indicated on the photograph of vacuum spark spectra of Sr observed between 50 Å and 100 Å.

From preliminary unpublished measurements he has derived provisional absolute term values from the Rydberg  $nf$ -series. The terms in the table are from his manuscript. His unit,  $10^3 \text{ cm}^{-1}$ , has here been changed to  $\text{cm}^{-1}$ .

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## Sr XI

## Sr XI

Config.	Desig.	$J$	Level	Config.	Desig.	$J$	Level
$3d^{10}$	$3d^{10} {}^1S$	0	0	$3d^9({}^2D)5p$	$5p {}^3D^\circ$	$\frac{3}{2}$	
$3d^9({}^2D)4p$	$4p {}^1P^\circ$	1	1193900			1	1824800
$3d^9({}^2D)4p$	$4p {}^3D^\circ$	3		$3d^9({}^2D)5f$	$5f {}^1P^\circ$	1	2067000
		2		$3d^9({}^2D)5f$	$5f {}^3D^\circ$	$\frac{3}{2}$	
		1	1203500			1	2086400
$3d^9({}^2D)4f$	$4f {}^3P^\circ$	2		$3d^9({}^2D)6f$	$6f {}^1P^\circ$	1	2236600
		1	1743100	$3d^9({}^2D)6f$	$6f {}^3D^\circ$	$\frac{3}{2}$	
$3d^9({}^2D)4f$	$4f {}^1P^\circ$	1	1755900			1	2251700
$3d^9({}^2D)4f$	$4f {}^3D^\circ$	3					
		2					
		1	1781900				
$3d^9({}^2D)5p$	$5p {}^1P^\circ$	1	1814900	Sr XII ( ${}^2D_{3/2}$ )	Limit	-----	2613800

August 1950.

## Sr XII

(Co I sequence; 27 electrons)

 $Z=38$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^9 {}^2D_{3/2}$  $3d^9 {}^2D_{3/2}$   $\text{cm}^{-1}$ 

I. P. volts

Edlén has observed three lines due to the transition  $3p^6 3d^9 {}^2D-3p^5 3d^{10} {}^2P^\circ$ . From preliminary unpublished measurements he has furnished the provisional term values quoted in the table. In figure 2 of his paper on the spectra of highly ionized atoms, the lines are indicated on the photograph of the vacuum spark spectra of Sr observed between 50 Å and 100 Å. Another group of lines from  $3d^9-3d^8 4p$  is also indicated in the figure.

Edlén's unit,  $10^3 \text{ cm}^{-1}$ , has here been changed to  $\text{cm}^{-1}$ .

## REFERENCES

B. Edlén, Physica **13**, No. 9, 547 (1947).

B. Edlén, letter (July 1950). (T)



## Sr XII

Config.	Desig.	$J$	Level	Interval
$3p^6 3d^9$	$3d^9 \ ^2D$	$2\frac{1}{2}$ $1\frac{1}{2}$	0 14500	-14500
$3p^5 3d^{10}$	$3d^{10} \ ^2P^o$	$1\frac{1}{2}$ $0\frac{1}{2}$	1086400 1171800	-85400

July 1950.

## Sr XIII

(Fe I sequence; 26 electrons)

 $Z=38$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^8 \ ^3F_4$  $3d^8 \ ^3F_4$        $\text{cm}^{-1}$ 

I. P.      volts

This spectrum has not been analyzed, but Edlén has observed a group of lines due to terms from the  $3d^8-3d^7 4p$  configurations. In figure 2 of his paper on the spectra of highly ionized atoms, the lines are indicated on the photograph of vacuum spark spectra of Sr observed between 50 Å and 100 Å.

The writer has assumed the ground state indicated above, by analogy with Ni III.

## REFERENCE

B. Edlén, Physica **13**, No. 9, 547 (1947).

February 1950.

## Sr XIV

(Mn I sequence; 25 electrons)

 $Z=38$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^7 \ ^4F_{4\frac{1}{2}}$  $3d^7 \ ^4F_{4\frac{1}{2}}$        $\text{cm}^{-1}$ 

I. P.      volts

This spectrum has not been analyzed, but Edlén has observed a group of lines due to terms from the  $3d^7-3d^6 4p$  configurations. In figure 2 of his paper on the spectra of highly ionized atoms, the lines are indicated on the photograph of vacuum spark spectra of Sr observed between 50 Å and 100 Å.

The writer has assumed the ground state indicated above, by analogy with Co III.

## REFERENCE

B. Edlén, Physica **13**, No. 9, 547 (1947).

February 1950.

## YTTRIUM

## Y I

39 electrons

 $Z=39$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 5s^2 4d^2 D_{1/2}$  $4d^2 D_{1/2}$  52650  $\text{cm}^{-1}$ 

I. P. 6.5 volts

The analysis is by Meggers and Russell, who have classified 448 lines in the interval 2332.58 Å to 9494.81 Å, based chiefly on observations of wave length by Meggers and of Zeeman effect by Meggers and B. E. Moore. Observed intersystem combinations connect the doublet and quartet systems of terms. Their limit is from the  $ns^2 D(n=5,6)$ ,  $ns^4 D(n=6,7)$ ,  $ns^4 F(n=5,6)$ , and  $ns^4 P(n=5,6)$  series represented by a Rydberg formula, with a Ritz correction applied to take into account the error in limits derived from series of only two members.

The writer has changed the notation to agree with that used in the present volumes for complex spectra. The notation of Meggers and Russell is given in the first column. In their term table the  $J$ -values for  $z^2 H$  should be interchanged. This correction has been made in column one.

McNally and Harrison have observed the Zeeman Effect of Y I at the Massachusetts Institute of Technology and derived the  $g$ -values listed in the table from their own data combined with the earlier observations. In the course of this work they have adjusted the decimals of known levels to agree with their observed wave lengths, but have added no new analysis. These revisions have been adopted in the table.

## REFERENCES

- W. F. Meggers and H. N. Russell, Bur. Std. J. Research **2**, 745, RP55 (1929). (I P) (T) (C L) (Z E) (G D)  
 J. R. McNally, Jr., and G. R. Harrison, J. Opt. Soc. Am. **35**, 584 (1945). (Z E) (T) (C L)  
 J. E. Mack, Rev. Mod. Phys. **22**, No. 1, 64 (1950). (Summary hfs)

## Y I

## Y I

Au- thors	Config.	Desig.	$J$	Level	Interval	Obs. $g$	Au- thors	Config.	Desig.	$J$	Level	Interval	Obs. $g$
$a^2 D_2$ $a^2 D_3$	$4d 5s^2$	$a^2 D$	$1\frac{1}{2}$ $2\frac{1}{2}$	0. 00 530. 36	530. 36	0. 798 1. 196	$z^4 D'_1$ $z^4 D'_2$ $z^4 D'_3$ $z^4 D'_4$	$4d 5s(a^3 D)5p$	$z^4 D^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$	16435. 80 16597. 30 16816. 60 17116. 30	161. 50 219. 30 299. 70	0. 01 1. 22 1. 38 1. 42
$z^2 P_1$ $z^2 P_2$	$5s^2(a^1 S)5p$	$z^2 P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	10529. 20 11359. 70	830. 50	0. 63 1. 34	$a^2 G_5$ $a^2 G_4$	$4d^2(a^1 G)5s$	$a^2 G$	$4\frac{1}{2}$ $3\frac{1}{2}$	18499. 30 18512. 46	-13. 16	1. 12 0. 90
$a^4 F'_2$ $a^4 F'_3$ $a^4 F'_4$ $a^4 F'_5$	$4d^2(a^3 F)5s$	$a^4 F$	$1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$ $4\frac{1}{2}$	10937. 35 11078. 61 11277. 96 11532. 13	141. 26 199. 35 254. 17	0. 402 1. 033 1. 242 1. 337	$z^4 P_1$ $z^4 P_2$ $z^4 P_3$	$4d 5s(a^3 D)5p$	$z^4 P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$	18976. 30 19027. 50 19148. 00	51. 20 120. 50	1. 49
$z^4 F_2$ $z^4 F_3$ $z^4 F_4$ $z^4 F_5$	$4d 5s(a^3 D)5p$	$z^4 F^\circ$	$1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$ $4\frac{1}{2}$	14949. 00 15245. 80 15712. 40 16234. 50	296. 80 466. 60 522. 10	0. 47 1. 08 1. 26 1. 33	$a^2 P'_1$ $a^2 P'_2$	$4d^2(a^3 P)5s$	$a^2 P$	$0\frac{1}{2}$ $1\frac{1}{2}$	19237. 65 19406. 19	168. 54	1. 18? 1. 28?
$a^4 P'_1$ $a^4 P'_2$ $a^4 P'_3$	$4d^2(a^3 P)5s$	$a^4 P$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$	15221. 81 15329. 04 15476. 69	107. 23 147. 65	2. 61 1. 62 1. 27	$z^2 F_3$ $z^2 F_4$	$4d 5s(a^3 D)5p$	$z^2 F^\circ$	$2\frac{1}{2}$ $3\frac{1}{2}$	21528. 60 21915. 40	386. 80	0. 854 1. 148
$a^2 F'_3$ $a^2 F'_4$	$4d^2(a^3 F)5s$	$a^2 F$	$2\frac{1}{2}$ $3\frac{1}{2}$	15326. 83 15864. 35	537. 52	1. 15 1. 17	$y^2 D'_2$ $y^2 D'_3$	$4d 5s(a^1 D)5p$	$y^2 D^\circ$	$1\frac{1}{2}$ $2\frac{1}{2}$	24131. 20 24746. 60	615. 40	0. 823 1. 088
$b^2 D_2$ $b^2 D_3$	$4d^2(b^1 D)5s$	$b^2 D$	$1\frac{1}{2}$ $2\frac{1}{2}$	15994. 11 16158. 9	164. 8	0. 86 1. 22	$y^2 P_2$ $y^2 P_1$	$4d 5s(a^3 D)5p$	$y^2 P^\circ$	$1\frac{1}{2}$ $0\frac{1}{2}$	24480. 60 24698. 80	-218. 20	1. 302 0. 674
$z^2 D'_3$ $z^2 D'_2$	$4d 5s(a^3 D)5p$	$z^2 D^\circ$	$2\frac{1}{2}$ $1\frac{1}{2}$	16066. 00 16146. 10	-80. 10	1. 203 0. 797	$y^2 F_3$ $y^2 F_4$	$4d 5s(a^1 D)5p$	$y^2 F^\circ$	$2\frac{1}{2}$ $3\frac{1}{2}$	24518. 80 24899. 50	380. 70	0. 964 1. 147



## Y I—Continued

## Y I—Continued

Au- thors	Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>	Au- thors	Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>
<i>x</i> <sup>2</sup> P <sub>1</sub>	4 <i>d</i> 5 <i>s</i> ( <i>a</i> <sup>1</sup> D) 5 <i>p</i>	<i>x</i> <sup>2</sup> P°	0½	27824. 50	315. 10	0. 667	<i>z</i> <sup>2</sup> H <sub>5</sub>	4 <i>d</i> <sup>2</sup> ( <i>a</i> <sup>1</sup> G) 5 <i>p</i>	<i>z</i> <sup>2</sup> H°	4½	37588. 20	379. 00	0. 91
<i>x</i> <sup>2</sup> P <sub>2</sub>			1½	28139. 60		1. 324	<i>z</i> <sup>2</sup> H <sub>6</sub>			5½	37967. 20		1. 11
<i>z</i> <sup>4</sup> G <sub>3</sub>	4 <i>d</i> <sup>2</sup> ( <i>a</i> <sup>3</sup> F) 5 <i>p</i>	<i>z</i> <sup>4</sup> G°	2½	28694. 00	294. 90	0. 56	<i>b</i> <sup>4</sup> D <sub>1</sub>	4 <i>d</i> 5 <i>s</i> ( <i>a</i> <sup>3</sup> D) 5 <i>d</i>	<i>f</i> <sup>4</sup> D	0½	38469. 9	73. 8	1. 22
<i>z</i> <sup>4</sup> G <sub>4</sub>			3½	28988. 90		1. 00	<i>b</i> <sup>4</sup> D <sub>2</sub>			1½	38543. 7		
<i>z</i> <sup>4</sup> G <sub>5</sub>			4½	29364. 20		1. 18	<i>b</i> <sup>4</sup> D <sub>3</sub>			2½	38675. 4		
<i>z</i> <sup>4</sup> G <sub>6</sub>			5½	29820. 40		1. 27	<i>b</i> <sup>4</sup> D <sub>4</sub>			3½	38865. 6		
<i>b</i> <sup>4</sup> F <sub>2</sub>	4 <i>d</i> <sup>3</sup>	<i>b</i> <sup>4</sup> F	1½	29272. 0	148. 4	193. 4	<i>y</i> <sup>2</sup> G <sub>4</sub>	4 <i>d</i> <sup>2</sup> ( <i>a</i> <sup>1</sup> G) 5 <i>p</i>	<i>y</i> <sup>2</sup> G°	3½	38479. 00	117. 70	0. 89
<i>b</i> <sup>4</sup> F <sub>3</sub>			2½	29420. 4			<i>y</i> <sup>2</sup> G <sub>5</sub>			4½	38596. 70		
<i>b</i> <sup>4</sup> F <sub>4</sub>			3½	29613. 8			<i>a</i> <sup>4</sup> G <sub>3</sub>	4 <i>d</i> 5 <i>s</i> ( <i>a</i> <sup>3</sup> D) 5 <i>d</i>	<i>e</i> <sup>4</sup> G	2½	38635. 5	126. 6	0. 73
<i>b</i> <sup>4</sup> F <sub>5</sub>			4½	29842. 7			<i>a</i> <sup>4</sup> G <sub>4</sub>			3½	38762. 1		
<i>y</i> <sup>4</sup> F <sub>2</sub>	4 <i>d</i> <sup>2</sup> ( <i>a</i> <sup>3</sup> F) 5 <i>p</i>	<i>y</i> <sup>4</sup> F°	1½	31508. 40	171. 60	0. 402	<i>a</i> <sup>4</sup> G <sub>5</sub>			4½	38949. 6		
<i>y</i> <sup>4</sup> F <sub>3</sub>			2½	31680. 00			<i>a</i> <sup>4</sup> G <sub>6</sub>			5½	39223. 0		
<i>y</i> <sup>4</sup> F <sub>4</sub>			3½	31909. 20			<i>c</i> <sup>4</sup> F <sub>2</sub>	4 <i>d</i> 5 <i>s</i> ( <i>a</i> <sup>3</sup> D) 5 <i>d</i>	<i>e</i> <sup>4</sup> F	1½	39446. 3	118. 8	0. 57
<i>y</i> <sup>4</sup> F <sub>5</sub>			4½	32188. 10			<i>c</i> <sup>4</sup> F <sub>3</sub>			2½	39565. 1		
<i>a</i> <sup>2</sup> S <sub>1</sub>	5 <i>s</i> <sup>2</sup> ( <i>a</i> <sup>1</sup> S) 6 <i>s</i>	<i>e</i> <sup>2</sup> S	0½	31671. 5	113. 5	2. 03	<i>c</i> <sup>4</sup> F <sub>4</sub>			3½	39757. 8		
<i>b</i> <sup>4</sup> P <sub>1</sub>	4 <i>d</i> <sup>3</sup>	<i>b</i> <sup>4</sup> P	0½	31977. 5			<i>c</i> <sup>4</sup> F <sub>5</sub>			4½	39963. 7		
<i>b</i> <sup>4</sup> P <sub>2</sub>			1½	32091. 0			<i>d</i> <sup>4</sup> P <sub>1</sub>	4 <i>d</i> 5 <i>s</i> ( <i>a</i> <sup>3</sup> D) 5 <i>d</i>	<i>f</i> <sup>4</sup> P	0½	40455. 1	62. 0	1. 52
<i>b</i> <sup>4</sup> P <sub>3</sub>			2½	32366. 3			<i>d</i> <sup>4</sup> P <sub>2</sub>			1½	40517. 1		
<i>a</i> <sup>4</sup> D <sub>1</sub>	4 <i>d</i> 5 <i>s</i> ( <i>a</i> <sup>3</sup> D) 6 <i>s</i>	<i>e</i> <sup>4</sup> D	0½	33148. 3	89. 6	0. 01	<i>d</i> <sup>4</sup> P <sub>3</sub>			2½	40517. 1	36. 10	1. 25
<i>a</i> <sup>4</sup> D <sub>2</sub>			1½	33237. 9			<i>v</i> <sup>2</sup> D <sub>2</sub>	4 <i>d</i> <sup>2</sup> ( <i>a</i> <sup>3</sup> P) 5 <i>p</i>	<i>v</i> <sup>2</sup> D°	1½	40636. 30		
<i>a</i> <sup>4</sup> D <sub>3</sub>			2½	33411. 6			<i>v</i> <sup>2</sup> D <sub>3</sub>			2½	40672. 40		
<i>a</i> <sup>4</sup> D <sub>4</sub>			3½	33752. 8			<i>e</i> <sup>2</sup> D <sub>2</sub>	5 <i>s</i> <sup>2</sup> ( <i>a</i> <sup>1</sup> S) 5 <i>d</i>	<i>g</i> <sup>2</sup> D	1½	42655. 6	414. 4	
<i>y</i> <sup>4</sup> D <sub>1</sub>	4 <i>d</i> <sup>2</sup> ( <i>a</i> <sup>3</sup> F) 5 <i>p</i>	<i>y</i> <sup>4</sup> D°	0½	33215. 40	49. 90	-0. 04	<i>e</i> <sup>2</sup> D <sub>3</sub>			2½	43070. 0		
<i>y</i> <sup>4</sup> D <sub>2</sub>			1½	33265. 30			<i>b</i> <sup>2</sup> S <sub>1</sub>	5 <i>p</i> <sup>2</sup> ( <sup>1</sup> S) 5 <i>s</i> ?	<i>f</i> <sup>2</sup> S	0½	42685. 7	136. 90	
<i>y</i> <sup>4</sup> D <sub>3</sub>			2½	33357. 60			<i>v</i> <sup>2</sup> F <sub>3</sub>	4 <i>d</i> <sup>2</sup> ( <i>a</i> <sup>1</sup> G) 5 <i>p</i>	<i>v</i> <sup>2</sup> F°	2½	42857. 90		
<i>y</i> <sup>4</sup> D <sub>4</sub>			3½	33614. 50			<i>v</i> <sup>2</sup> F <sub>4</sub>			3½	42994. 80		
<i>z</i> <sup>2</sup> G <sub>4</sub>	4 <i>d</i> <sup>2</sup> ( <i>a</i> <sup>3</sup> F) 5 <i>p</i>	<i>z</i> <sup>2</sup> G°	3½	33432. 30	356. 50	0. 91	<i>d</i> <sup>4</sup> F <sub>2</sub>	4 <i>d</i> <sup>2</sup> ( <i>a</i> <sup>3</sup> F) 5 <i>d</i> ?	<i>f</i> <sup>4</sup> F	1½	43095. 7	241. 9	1. 26
<i>z</i> <sup>2</sup> G <sub>5</sub>			4½	33788. 80			<i>d</i> <sup>4</sup> F <sub>3</sub>			2½	43337. 6		
<i>x</i> <sup>2</sup> F <sub>3</sub>	4 <i>d</i> <sup>2</sup> ( <i>a</i> <sup>3</sup> F) 5 <i>p</i>	<i>x</i> <sup>2</sup> F°	2½	33608. 20	421. 60	0. 985	<i>d</i> <sup>4</sup> F <sub>4</sub>			3½	43704. 5		
<i>x</i> <sup>2</sup> F <sub>4</sub>			3½	34029. 80			<i>d</i> <sup>4</sup> F <sub>5</sub>			4½	44190. 3		
<i>b</i> <sup>2</sup> P <sub>1</sub>	5 <i>p</i> <sup>2</sup> ( <i>b</i> <sup>3</sup> P) 5 <i>s</i> ?	<i>e</i> <sup>2</sup> P	0½	33613. 2	229. 2	0. 93	<i>c</i> <sup>2</sup> S <sub>1</sub>	5 <i>s</i> <sup>2</sup> ( <i>a</i> <sup>1</sup> S) 7 <i>s</i>	<i>g</i> <sup>2</sup> S	0½	43643. 6	313. 3	393. 5
<i>b</i> <sup>2</sup> P <sub>2</sub>			1½	33842. 4			<i>e</i> <sup>4</sup> F <sub>2</sub>	4 <i>d</i> <sup>2</sup> ( <i>a</i> <sup>3</sup> F) 6 <i>s</i>	<i>g</i> <sup>4</sup> F	1½	44052. 8?		
<i>x</i> <sup>2</sup> D <sub>2</sub>	4 <i>d</i> <sup>2</sup> ( <i>a</i> <sup>3</sup> F) 5 <i>p</i>	<i>x</i> <sup>2</sup> D°	1½	33906. 80	340. 90	0. 826	<i>e</i> <sup>4</sup> F <sub>3</sub>			2½	44366. 1		
<i>x</i> <sup>2</sup> D <sub>3</sub>			2½	34247. 70			<i>e</i> <sup>4</sup> F <sub>4</sub>			3½	44759. 6		
<i>c</i> <sup>4</sup> P <sub>1</sub>	5 <i>p</i> <sup>2</sup> ( <i>b</i> <sup>3</sup> P) 5 <i>s</i>	<i>e</i> <sup>4</sup> P	0½	33911. 5	244. 4	2. 58	<i>e</i> <sup>4</sup> F <sub>5</sub>			4½	44759. 6	267	
<i>c</i> <sup>4</sup> P <sub>2</sub>			1½	34155. 9			<i>c</i> <sup>4</sup> D <sub>1</sub>	4 <i>d</i> 5 <i>s</i> ( <i>a</i> <sup>3</sup> D) 7 <i>s</i>	<i>g</i> <sup>4</sup> D	0½	44654. 8		
<i>c</i> <sup>4</sup> P <sub>3</sub>			2½	34521. 3			<i>c</i> <sup>4</sup> D <sub>2</sub>			1½	44922		
<i>c</i> <sup>2</sup> D <sub>2</sub>	5 <i>p</i> <sup>2</sup> ( <i>f</i> <sup>1</sup> D) 5 <i>s</i> ?	<i>e</i> <sup>2</sup> D	1½	34231. 6	25. 8	0. 94?	<i>c</i> <sup>4</sup> D <sub>3</sub>			2½	44654. 8	88. 2	260. 1
<i>c</i> <sup>2</sup> D <sub>3</sub>			2½	34257. 4			<i>c</i> <sup>4</sup> D <sub>4</sub>			3½	44922		
<i>z</i> <sup>2</sup> S <sub>1</sub>	4 <i>d</i> <sup>2</sup> ( <i>a</i> <sup>3</sup> P) 5 <i>p</i>	<i>z</i> <sup>2</sup> S°	0½	34438. 20	319. 00	0. 18	<i>d</i> <sup>4</sup> D <sub>1</sub>	5 <i>p</i> <sup>2</sup> ( <i>b</i> <sup>3</sup> P) 4 <i>d</i>	<i>h</i> <sup>4</sup> D	0½	44660. 1		
<i>x</i> <sup>4</sup> D <sub>1</sub>	4 <i>d</i> <sup>2</sup> ( <i>a</i> <sup>3</sup> P) 5 <i>p</i>	<i>x</i> <sup>4</sup> D°	0½	35816. 70			<i>d</i> <sup>4</sup> D <sub>2</sub>			1½	44748. 3		
<i>x</i> <sup>4</sup> D <sub>2</sub>			1½	36135. 70			<i>d</i> <sup>4</sup> D <sub>3</sub>			2½	45008. 4		
<i>x</i> <sup>4</sup> D <sub>3</sub>			2½	36061. 00			<i>d</i> <sup>4</sup> D <sub>4</sub>			3½	45204. 0	326. 6?	319. 2
<i>x</i> <sup>4</sup> D <sub>4</sub>			3½	36361. 30	300. 30	1. 38	<i>f</i> <sup>4</sup> F <sub>2</sub>	5 <i>p</i> <sup>2</sup> ( <i>b</i> <sup>3</sup> P) 4 <i>d</i>	<i>h</i> <sup>4</sup> F	1½	44742. 7?		
<i>d</i> <sup>2</sup> D <sub>2</sub>	4 <i>d</i> 5 <i>s</i> ( <i>a</i> <sup>3</sup> D) 6 <i>s</i>	<i>f</i> <sup>2</sup> D	1½	36420. 6			<i>f</i> <sup>4</sup> F <sub>3</sub>			2½	45069. 3		
<i>d</i> <sup>2</sup> D <sub>3</sub>			2½	36431. 1			<i>f</i> <sup>4</sup> F <sub>4</sub>			3½	45388. 5		
<i>w</i> <sup>2</sup> D <sub>2</sub>	4 <i>d</i> <sup>2</sup> ( <i>b</i> <sup>1</sup> D) 5 <i>p</i>	<i>w</i> <sup>2</sup> D°	1½	36452. 30	166. 20	0. 86	<i>f</i> <sup>4</sup> F <sub>5</sub>			4½	45796. 5	408. 0	1. 37
<i>w</i> <sup>2</sup> D <sub>3</sub>			2½	36618. 50			2		2	{0½ 1½}	44984. 1		
<i>z</i> <sup>4</sup> S <sub>2</sub>	4 <i>d</i> <sup>2</sup> ( <i>a</i> <sup>3</sup> P) 5 <i>p</i>	<i>z</i> <sup>4</sup> S°	1½	36750. 80	109. 00	2. 28	3		3	3½	45663. 5	46. 7	
<i>y</i> <sup>4</sup> P <sub>1</sub>	4 <i>d</i> <sup>2</sup> ( <i>a</i> <sup>3</sup> P) 5 <i>p</i>	<i>y</i> <sup>4</sup> P°	0½	37039. 50			<i>c</i> <sup>2</sup> P <sub>1</sub>	5 <i>p</i> <sup>2</sup> ( <i>b</i> <sup>3</sup> P) 4 <i>d</i> ?	<i>f</i> <sup>2</sup> P	0½	45947. 5		
<i>y</i> <sup>4</sup> P <sub>2</sub>			1½	37148. 50			<i>c</i> <sup>2</sup> P <sub>2</sub>			1½	45994. 2		
<i>y</i> <sup>4</sup> P <sub>3</sub>			2½	37476. 00			<i>e</i> <sup>4</sup> P <sub>1</sub>	4 <i>d</i> <sup>2</sup> ( <i>a</i> <sup>3</sup> P) 6 <i>s</i>	<i>g</i> <sup>4</sup> P	0½	50254. 0		
1		1	2½	37074. 2	-35. 41	0. 60	<i>e</i> <sup>4</sup> P <sub>2</sub>			1½			
<i>w</i> <sup>2</sup> P <sub>2</sub>	4 <i>d</i> <sup>2</sup> ( <i>b</i> <sup>1</sup> D) 5 <i>p</i>	<i>w</i> <sup>2</sup> P°	1½	37243. 89			<i>e</i> <sup>4</sup> P <sub>3</sub>			2½			
<i>w</i> <sup>2</sup> P <sub>1</sub>			0½	37279. 30	206. 90	0. 86							
<i>w</i> <sup>2</sup> F <sub>3</sub>	4 <i>d</i> <sup>2</sup> ( <i>b</i> <sup>1</sup> D) 5 <i>p</i>	<i>w</i> <sup>2</sup> F°	2½	37412. 90									
<i>w</i> <sup>2</sup> F <sub>4</sub>			3½	37619. 80		1. 14							
								Y II ( <sup>1</sup> S <sub>0</sub> )	Limit		52650		



Y I OBSERVED TERMS\*

Config. $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 +$	Observed Terms		
$4d 5s^2$	$a^2D$		
$4d^3$	$b^4P$ $b^4F$		
	$ns (n \geq 5)$	$np (n \geq 5)$	$nd (n \geq 4)$
$5s^2(a^1S)nx$	$e, g^2S$	$z^2P^o$	$g^2D$
$4d 5s(a^3D)nx$	$\{ \begin{matrix} e, g^4D \\ f^2D \end{matrix}$	$z^4P^o$ $z^4D^o$ $z^4F^o$ $y^2P^o$ $z^2D^o$ $z^2F^o$	$f^4P$ $f^4D$ $e^4F$ $e^4G$
$4d 5s(a^1D)nx$		$x^2P^o$ $y^2D^o$ $y^2F^o$	
$4d^2(a^3F)nx$		$y^4D^o$ $y^4F^o$ $z^4G^o$ $x^2D^o$ $x^2F^o$ $z^2G^o$	$f^4F?$
$4d^2(a^3P)nx$	$\{ \begin{matrix} a, g^4P \\ a^2P \end{matrix}$	$z^4S^o$ $y^4P^o$ $x^4D^o$ $z^2S^o$ $y^2D^o$ $y^2F^o$	
$4d^2(b^1D)nx$	$b^2D$	$w^2P^o$ $w^2D^o$ $w^2F^o$	
$4d^2(a^1G)nx$	$a^2G$	$y^2G^o$ $z^2H^o$	
$5p^2(b^3P)nx$	$\{ \begin{matrix} e^4P \\ e^2P? \end{matrix}$		
$5p^2(f^1D)nx$	$e^2D?$		$f^2P?$
$5p^2(1S)nx$	$f^2S?$		$h^4D$ $h^4F$

\*For predicted terms in the spectra of the Y I isoelectronic sequence, see Vol. II, Introduction.

## Y II

(Sr I sequence; 38 electrons)

 $Z=39$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 5s^2 {}^1S_0$  $a {}^1S_0$  100000  $\text{cm}^{-1}$ 

I. P. 12.4 volts

The analysis is by Meggers and Russell, who greatly extended the earlier work on Y II. They have published 223 classified lines in the interval 2243.06 Å to 8835.85 Å, based on Meggers' observations of wavelength and Zeeman effect. Observed intersystem combinations connect the systems of terms of different multiplicity.

Their limit has been determined by applying a Rydberg formula to the  $ns$ -series terms  $a, e {}^1S$  and  $a, f {}^1S$ , ( $n=5,6$ ); and an empirical correction to compensate for the error resulting in limits from series of only two members.

Subsequently McNally and Harrison observed the Zeeman effect of Y II at the Massachusetts Institute of Technology, and determined  $g$ -values for all but one of the 61 known energy levels. Their work confirms in great detail the 1929 analysis. In the course of this work they have adjusted the decimals of the known levels to agree with their observations, but have added no new levels. Their revised level values and  $g$ -values are quoted in the table.

In 1937 Miss Ho observed the Y spectra with a hollow cathode discharge, and provisionally suggested 39 miscellaneous levels of Y II based on the additional lines observed with this source. Since these levels are not fitted into the term array of Y II, they are not included in the table, pending further confirmation of the new lines as observed with higher dispersion.

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 I-djen Ho, Dissertation, unpublished; see I. Ho and R. A. Sawyer, *Phys. Rev.* **51**, 1020 (A) (1937).  
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## Y II

## Y II

Au- thors	Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>	Au- thors	Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>
<i>a</i> <sup>1</sup> S	5s <sup>2</sup>	<i>a</i> <sup>1</sup> S	0	0. 00		0/0	<i>a</i> <sup>3</sup> S	5s(2S)6s	<i>e</i> <sup>3</sup> S	1	58262. 1		1. 99
<i>a</i> <sup>3</sup> D	4d(2D)5s	<i>a</i> <sup>3</sup> D	1 2 3	840. 18 1045. 07 1449. 75	204. 89 404. 68	0. 495 1. 162 1. 332	<i>a</i> <sup>1</sup> F'	4d(2D)5d	<i>e</i> <sup>1</sup> F	3	58532. 8		1. 02
<i>a</i> <sup>1</sup> D	4d(2D)5s	<i>a</i> <sup>1</sup> D	2	3296. 20		1. 000	<i>c</i> <sup>3</sup> D	4d(2D)5d	<i>f</i> <sup>3</sup> D	1 2 3	58719. 6 58946. 6 59326. 7	227. 0 380. 1	0. 58 1. 17 1. 17
<i>a</i> <sup>3</sup> F'	4d <sup>2</sup>	<i>a</i> <sup>3</sup> F	2 3 4	8003. 12 8328. 03 8743. 33	324. 91 415. 30	0. 668 1. 087 1. 256	<i>b</i> <sup>3</sup> P'	5p <sup>2</sup>	<i>e</i> <sup>3</sup> P	0 1 2	58776. 3 59147. 4 59669. 3	371. 1 521. 9	0/0 1. 49 1. 38
<i>a</i> <sup>3</sup> P'	4d <sup>2</sup>	<i>a</i> <sup>3</sup> P	0 1 2	13883. 44 14018. 24 14098. 08	134. 86 79. 84	0/0 1. 497 1. 41	<i>a</i> <sup>3</sup> G	4d(2D)5d	<i>e</i> <sup>3</sup> G	3 4 5	59179. 4 59472. 1 59900. 5	292. 7 428. 4	0. 90 1. 06 1. 22
<i>b</i> <sup>1</sup> D	4d <sup>2</sup>	<i>b</i> <sup>1</sup> D	2	14832. 89		1. 10	<i>b</i> <sup>1</sup> S	4d(2D)5d	<i>e</i> <sup>1</sup> S	0	59616. 0?		
<i>a</i> <sup>1</sup> G	4d <sup>2</sup>	<i>a</i> <sup>1</sup> G	4	15682. 91		0. 999	<i>a</i> <sup>1</sup> P'	4d(2D)5d	<i>e</i> <sup>1</sup> P	1	59715. 8		0. 99
<i>z</i> <sup>3</sup> P	5s(2S)5p	<i>z</i> <sup>3</sup> P°	0 1 2	23445. 05 23776. 25 24647. 14	331. 20 870. 89	0/0 1. 489 1. 493	<i>d</i> <sup>1</sup> D	4d(2D)5d	<i>f</i> <sup>1</sup> D	2	60535. 1		1. 09
<i>z</i> <sup>1</sup> D'	4d(2D)5p	<i>z</i> <sup>1</sup> D°	2	26147. 27		0. 912	<i>b</i> <sup>3</sup> S	4d(2D)5d	<i>f</i> <sup>3</sup> S	1	61199. 6		1. 97
<i>z</i> <sup>3</sup> F	4d(2D)5p	<i>z</i> <sup>3</sup> F°	2 3 4	27227. 00 27532. 34 28394. 17	305. 34 861. 83	0. 764 1. 082 1. 254	<i>b</i> <sup>3</sup> F'	4d(2D)5d	<i>e</i> <sup>3</sup> F	2 3 4	61336. 6 61650. 8 61934. 5	314. 2 283. 7	0. 69 1. 09 1. 26
<i>z</i> <sup>1</sup> P	4d(2D)5p	<i>z</i> <sup>1</sup> P°	1	27516. 70		0. 910	<i>c</i> <sup>1</sup> S	5s(2S)6s	<i>f</i> <sup>1</sup> S	0	61367. 4		0/0
<i>z</i> <sup>3</sup> D'	4d(2D)5p	<i>z</i> <sup>3</sup> D°	1 2 3	28595. 27 28730. 02 29213. 95	134. 75 483. 93	0. 596 1. 165 1. 333	<i>e</i> <sup>1</sup> D	5s(2S)5d	<i>g</i> <sup>1</sup> D	2	62495. 2		0. 99
<i>y</i> <sup>3</sup> P	4d(2D)5p	<i>y</i> <sup>3</sup> P°	0 1 2	32048. 76 32124. 07 32283. 43	75. 31 159. 36	0/0 1. 496 1. 494	<i>b</i> <sup>1</sup> G	4d(2D)5d	<i>e</i> <sup>1</sup> G	4	63350. 3		1. 00
<i>z</i> <sup>1</sup> F	4d(2D)5p	<i>z</i> <sup>1</sup> F°	3	33336. 74		0. 997	<i>c</i> <sup>3</sup> P'	4d(2D)5d	<i>f</i> <sup>3</sup> P	0 1 2	64102. 8 64263. 2 64596. 9	160. 4 333. 7	0/0 1. 50 1. 48
<i>y</i> <sup>1</sup> P	5s(2S)5p	<i>y</i> <sup>1</sup> P°	1	44568. 63		0. 998	<i>d</i> <sup>3</sup> D	5s(2S)5d	<i>g</i> <sup>3</sup> D	1 2 3	65132. 0 65188. 9 65274. 9	56. 9 86. 0	0. 50 1. 16 1. 37
<i>b</i> <sup>3</sup> D	4d(2D)6s	<i>e</i> <sup>3</sup> D	1 2 3	54955. 2 55032. 2 55645. 2	77. 0 613. 0	0. 52 1. 12 1. 34	<i>f</i> <sup>1</sup> D	5p <sup>2</sup>	<i>h</i> <sup>1</sup> D	2	70223. 4		0. 99
<i>c</i> <sup>1</sup> D	4d(2D)6s	<i>e</i> <sup>1</sup> D	2	55724. 9		1. 05		Y III (2D <sub>1/2</sub> )	<i>Limit</i>	-----	100000		

May 1951.



## Y II OBSERVED TERMS\*

$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 +$	Observed Terms	
$5s^2$	$a^1S$	
$4d^2$	{ $a^3P$ $b^1D$ $a^3F$ $a^1G$ }	
$5p^2$	{ $e^3P$ $h^1D$ }	
	$ns$ ( $n \geq 5$ )	$np$ ( $n \geq 5$ )
$4d(^2D)nx$	{ $a, e^3D$ $a, e^1D$ }	$y^3P^\circ$ $z^3D^\circ$ $z^3F^\circ$ $z^1P^\circ$ $z^1D^\circ$ $z^1F^\circ$
$5s(^2S)nx$	{ $e^3S$ $f^1S$ }	$z^3P^\circ$ $y^1P^\circ$
	$nd$ ( $n \geq 4$ )	
$4d(^2D)nx$	{ $f^3S$ $f^3P$ $f^3D$ $e^3F$ $e^3G$ $e^1S$ $e^1P$ $f^1D$ $e^1F$ $e^1G$ }	
$5s(^2S)nx$	{ $g^3D$ $g^1D$ }	

\*For predicted terms in the spectrum of the Sr I isoelectronic sequence, see Vol. II, Introduction.

## Y III

(Rb I sequence; 37 electrons)

$Z=39$

Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 4d^2 D_{1/2}$

$4d^2 D_{1/2}$  165289  $\text{cm}^{-1}$

I. P. 20.5 volts

The analysis is incomplete. Twelve lines have been classified, in the interval between 989.21 Å and 2945.92 Å. The term values in the table are quoted from the paper by Meggers and Russell. They are based on the measurements by Meggers, except for the two ultraviolet lines 989.21 Å and 996.37 Å from Bowen and Millikan.

Gibbs and White published Moseley diagrams for the  $5s$  and  $5p$  electrons of this isoelectronic sequence. Bowen and Millikan extended these diagrams to include  $4d$ ,  $5d$ , and  $4f$  electrons and showed that the  $4d$  electron was the most firmly bound in Y III. By comparison with Rb I and Sr II they estimated the value of the  $4f^2 F^\circ$  term and from this derived the limit quoted here.

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## Y III

Config.	Desig.	$J$	Level	Interval	Obs. $g$
$4p^6(^1S)4d$	$4d\ ^2D$	$1\frac{1}{2}$ $2\frac{1}{2}$	0. 0 724. 8	724. 8	0. 79 1. 22
$4p^6(^1S)5s$	$5s\ ^2S$	$0\frac{1}{2}$	7466. 2		2. 00
$4p^6(^1S)5p$	$5p\ ^2P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	41401. 2 42954. 7	1553. 5	0. 66 1. 33
$4p^6(^1S)6s$	$6s\ ^2S$	$0\frac{1}{2}$	86713. 9		
$4p^6(^1S)5d$	$5d\ ^2D$	$1\frac{1}{2}$ $2\frac{1}{2}$	88378. 8 88577. 1	198. 3	
$4p^6(^1S)4f$	$4f\ ^2F^\circ$	$\left\{ \begin{array}{l} 2\frac{1}{2} \\ 3\frac{1}{2} \end{array} \right\}$	101090. 0		
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Y IV ( $^1S_0$ )	<b>Limit</b>	---	[165289]		

March 1951.

## Y V

(Br I sequence; 35 electrons)

 $Z=39$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^5\ ^2P^\circ_{1\frac{1}{2}}$  $4p^5\ ^2P^\circ_{1\frac{1}{2}}$  620000  $\text{cm}^{-1}$ 

I. P. 77 volts

The analysis is incomplete. Paul and Rense have classified 41 lines between 313 Å and 629 Å, as due to transitions from the ground term to 13 higher terms.

They have estimated the limit by extrapolation of isoelectronic sequence data.

## REFERENCE

F. W. Paul and W. A. Rense, Phys. Rev. **56**, 1110 (1939). (I P) (T) (C L)

## Y V

## Y V

Config.	Desig.	$J$	Level	Interval	Config.	Desig.	$J$	Level	Interval
$4s^2 4p^5$	$4p^5\ ^2P^\circ$	$1\frac{1}{2}$ $0\frac{1}{2}$	0 12068	—12068	$4s^2 4p^4(^1D)4d$	$4d'\ ^2D$	$2\frac{1}{2}$ $1\frac{1}{2}$	289836 297072	—7236
$4s\ 4p^6$	$4p^6\ ^2S$	$0\frac{1}{2}$	170936		$4s^2 4p^4(^1D)4d$	$4d'\ ^2F$	$3\frac{1}{2}$ $2\frac{1}{2}$	291052	
$4s^2 4p^4(^3P)4d$	$4d\ ^4D$	$3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	202902 213254 219116	—10352 —5862	$4s^2 4p^4(^3P)5s$	$5s\ ^2P$	$1\frac{1}{2}$ $0\frac{1}{2}$	296745 306349	—9604
$4s^2 4p^4(^3P)4d$	$4d\ ^4P$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$	247473 248352 250406	879 2054	$4s^2 4p^4(^1D)4d$	$4d'\ ^2P$	$0\frac{1}{2}$ $1\frac{1}{2}$	299567 300217	650
$4s^3 4p^4(^3P)4d$	$4d\ ^2D$	$1\frac{1}{2}$ $2\frac{1}{2}$	253678 263524	9846	$4s^2 4p^4(^1D)5s$	$5s'\ ^2D$	$2\frac{1}{2}$ $1\frac{1}{2}$	315430 317192	—1762
$4s^2 4p^4(^3P)4d$	$4d\ ^2P$	$0\frac{1}{2}$ $1\frac{1}{2}$	258518 258567	49	$4s^2 4p^4(^1S)4d$	$4d''\ ^2D$	$2\frac{1}{2}$ $1\frac{1}{2}$	318885	
$4s^2 4p^4(^3P)4d$	$4d\ ^2F$	$3\frac{1}{2}$ $2\frac{1}{2}$	274254		-----	-----	-----	-----	-----
$4s^2 4p^4(^3P)5s$	$5s\ ^4P$	$2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	280932 287205 290911	—6273 —3706	Y VI ( $^3P_2$ )	[Limit]	-----	[620000]	

February 1951.

## Y V OBSERVED TERMS\*

Config. $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} +$	Observed Terms	
$4s^2 4p^5$	$4p^5 \ ^2P^\circ$	
$4s 4p^6$	$4p^6 \ ^2S$	
	$ns \ (n \geq 5)$	$nd \ (n \geq 4)$
$4s^2 4p^4(^3P)nx$	$\left\{ \begin{array}{l} 5s \ ^4P \\ 5s \ ^2P \end{array} \right.$	$\begin{array}{lll} 4d \ ^4P & 4d \ ^4D & \\ 4d \ ^2P & 4d \ ^2D & 4d \ ^2F \end{array}$
$4s^2 4p^4(^1D)nx'$	$5s' \ ^2D$	$4d' \ ^2P \ 4d' \ ^2D \ 4d' \ ^2F$
$4s^2 4p^4(^1S)nx''$		$4d'' \ ^2D$

\*For predicted terms in the spectra of the Br I isoelectronic sequence, see Vol. II, Introduction.

## Y XII

(Ni I sequence; 28 electrons)

$Z=39$

Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} \ ^1S_0$

$3d^{10} \ ^1S_0$  3016800  $\text{cm}^{-1}$

I. P. 374 volts

Edlén has observed three lines from the  $3d^{10} - 3d^9 np$  and  $3d^{10} - 3d^9 nf$  ( $n=4, 5$ ) configurations. In figure 2 of his paper on the spectra of highly ionized atoms, two lines of the former group are indicated on the photograph of vacuum spark spectra of Y observed between 50 Å and 100 Å.

From preliminary unpublished measurements he has derived provisional absolute term values from the Rydberg  $nf$ -series. The terms in the table are from his manuscript. His unit,  $10^3 \text{ cm}^{-1}$ , has here been changed to  $\text{cm}^{-1}$ .

## REFERENCES

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B. Edlén, letter (July 1950). (I P (T))

## Y XII

## Y XII

Config.	Desig.	$J$	Level	Config.	Desig.	$J$	Level
$3d^{10}$	$3d^{10} \ ^1S$	0	0	$3d^9(^2D)5p$	$5p \ ^3D^\circ$	$\begin{array}{c} 3 \\ 2 \\ 1 \end{array}$	
$3d^9(^2D)4p$	$4p \ ^1P^\circ$	1	1874600			1	2099500
$3d^9(^2D)4p$	$4p \ ^3D^\circ$	$\begin{array}{c} 3 \\ 2 \\ 1 \end{array}$	1386800	$3d^9(^2D)5f$	$5f \ ^3D^\circ$	$\begin{array}{c} 3 \\ 2 \\ 1 \end{array}$	2388900
$3d^9(^2D)4f$	$4f \ ^1P^\circ$	1	1994800				
$3d^9(^2D)4f$	$4f \ ^3D^\circ$	$\begin{array}{c} 3 \\ 2 \\ 1 \end{array}$	2026800				
$3d^9(^2D)5p$	$5p \ ^1P^\circ$	1	2088600				
				Y XIII ( $^2D_{3/2}$ )	Limit		3016800

August 1950.



## Y XIII

(Co I sequence; 27 electrons)

 $Z=39$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^9 {}^2D_{3/2}$  $3d^9 {}^2D_{3/2}$   $\text{cm}^{-1}$ 

I. P. volts

Edlén has observed three lines due to the transition  $3p^6 3d^9 {}^2D - 3p^5 3d^{10} {}^2P^{\circ}$ . From preliminary unpublished measurements he has furnished the provisional term values quoted in the table. In figure 2 of his paper on the spectra of highly ionized atoms, the lines are indicated on the photograph of the vacuum spark spectra of Y observed between 50 A and 100 A. Another group of lines from  $3d^9 - 3d^8 4p$  is also indicated in the figure.

Edlén's unit,  $10^3 \text{ cm}^{-1}$ , has here been changed to  $\text{cm}^{-1}$ .

## REFERENCES

B. Edlén, *Physica* **13**, No. 9, 547 (1947).

B. Edlén, letter (July 1950). (T)

## Y XIII

Config.	Desig.	$J$	Level	Interval
$3p^6 3d^9$	$3d^9 {}^2D$	$2\frac{1}{2}$ $1\frac{1}{2}$	$0$ 17200	$-17200$
$3p^5 3d^{10}$	$3d^{10} {}^2P^{\circ}$	$1\frac{1}{2}$ $0\frac{1}{2}$	$1143600$ $1242400$	$-98800$

July 1950.

## Y XIV

(Fe I sequence; 26 electrons)

 $Z=39$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^8 {}^3F_4$  $3d^8 {}^3F_4$   $\text{cm}^{-1}$ 

I. P. volts

This spectrum has not been analyzed, but Edlén has observed a group of lines due to terms from the  $3d^8 - 3d^7 4p$  configurations. In figure 2 of his paper on the spectra of highly ionized atoms, the lines are indicated on the photograph of vacuum spark spectra of Y observed between 50 A and 100 A.

The writer has assumed the ground state indicated above, by analogy with Ni III.

## REFERENCE

B. Edlén, *Physica* **13**, No. 9, 547 (1947).

February 1950.

## Y XV

(Mn I sequence; 25 electrons)

 $Z=39$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^7 {}^4F_{3/2}$  $3d^7 {}^4F_{3/2}$   $\text{cm}^{-1}$ 

I. P. volts

This spectrum has not been analyzed, but Edlén has observed a group of lines due to terms from the  $3d^7 - 3d^6 4p$  configurations. In figure 2 of his paper on the spectra of highly ionized atoms, the lines are indicated on the photograph of vacuum spark spectra of Y observed between 50 A and 100 A.

The writer has assumed the ground state indicated above by analogy with Co III.

## REFERENCE

B. Edlén, *Physica* **13**, No. 9, 547 (1947).

February 1950.

## ZIRCONIUM

## Zr I

40 electrons

 $Z=40$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 4d^2 5s^2 {}^3F_2$  $a {}^3F_2$  56077  $\text{cm}^{-1}$ 

I. P. 6.95 volts

The analysis is by Kiess and Mrs. Kiess, who have observed nearly 1600 lines in this spectrum between 2088.89 Å and 9276.94 Å, and classified approximately 80 percent of them. Meggers and Kiess have since extended the observations to 10738.94 Å. Many of the terms are confirmed by the Zeeman patterns, for which the observations by B. E. Moore as well as those of the authors were utilized.

Their limit is from a Rydberg representation of the  $ns {}^3F$  and  $ns {}^5F$  series ( $n=5,6$ ), the former having the configuration  $4d^2 5s(a {}^4F)ns$ , and the latter  $4d^3(b {}^4F)ns$ .

The singlet, triplet, and quintet systems of terms are connected by observed intersystem combinations.

Kiess has suggested that his published configuration assignment of the  $c {}^2D$  term in Zr II be changed from  $4d^3$  to  $4d 5s^2$ , and that the term  $d {}^2D$  remain unassigned. These changes have been adopted here. Consequently, the three Zr I terms having the limit term  $d {}^2D$  in Zr II,  $q {}^3F^\circ$ ,  $o {}^3D^\circ$ , and  $t {}^3P^\circ$ , do not appear in the array of observed terms following the table.

The observed  $g$ -values are those given by Sancho except for seven pairs of levels affected by  $g$ -sharing, which are taken from Table 5 of the Kiess' paper.

The detailed analysis of this complex spectrum presents another beautiful confirmation of Hund's theory of line spectra and atomic structure.

## REFERENCES

- C. C. Kiess and H. K. Kiess, *Bur. Std. J. Research* **6**, 621, RP296 (1931). (I P) (T) (C L) (Z E) (E D)  
 W. F. Meggers and C. C. Kiess, *Bur. Std. J. Research* **9**, 324, RP473 (1932). (C L)  
 P. M. Sancho, *Anal. Soc. Esp. de Fisica y Quimica* (Madrid) **30**, 867 (1932). (Z E)  
 J. E. Mack, *Rev. Mod. Phys.* **22**, No. 1, 64 (1950). (Summary hfs)

## Zr I

## Zr I

Config.	Desig.	$J$	Level	Interval	Obs. $g$	Config.	Desig.	$J$	Level	Interval	Obs. $g$
$4d^2 5s^2$	$a {}^3F$	2	0.00		0.66	$4d^3(a {}^2G)5s$	$a {}^3G$	3	12503.44		0.78
		3	570.41	570.41	1.06			4	12760.66	257.22	1.15
		4	1240.84	670.43	1.24			5	12772.78	12.12	1.20
$4d^2 5s^2$	$a {}^3P$	2	4186.11		1.25	$4d^2 5s^2$	$a {}^1S$	0	13141.76		
		1	4376.28	-190.17	1.48						
		0	4196.85	179.43	0.00						
$4d^3(b {}^4F)5s$	$a {}^5F$	1	4870.53		0.00	$4d^3(b {}^2D)5s$	$a {}^3D$	1	14123.01		0.61
		2	5023.41	152.88	0.98			2	14348.78	225.77	1.17
		3	5249.07	225.66	1.28			3	14697.03	348.25	1.35
		4	5540.54	291.47	1.31	$4d^2 5s(a {}^4F)5p$	$z {}^6G^\circ$	2	14783.54		0.43
		5	5888.93	348.39	1.37			3	15201.26	417.72	1.09
$4d^2 5s^2$	$a {}^1D$	2	5101.68		1.25			4	15720.36	519.10	1.12
								5	16316.96	596.60	1.28
								6	16978.29	661.33	1.36
$4d^2 5s^2$	$a {}^1G$	4	8057.30		1.00	$4d^3(a {}^3H)5s$	$a {}^3H$	4	14791.28		0.77
								5	14988.51	197.23	1.03
								6	15119.66	131.15	1.15
$4d^3(b {}^4P)5s$	$a {}^5P$	1	10885.36		2.50	$4d^3(b {}^3F)5s$	$c {}^3F$	2	15146.48		
		2	11016.65	131.29	1.82			3	15457.40	310.92	
		3	11258.38	241.73	1.66			4	15699.86	242.46	
$4d^3(b {}^4F)5s$	$b {}^3F$	2	11640.72		0.75						
		3	11956.33	315.61	1.05						
		4	12342.37	386.04	1.15						



## Zr I—Continued

## Zr I—Continued

Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>	Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>
$4d^3(b^4P)5s$	$b^3P$	0 1 2	15932. 10		1. 46	$4d^3(b^4F)5p$	$y^3G^\circ$	3 4 5	25729. 96 26011. 55 26433. 72	281. 59 422. 17	0. 82 1. 05 1. 15
$4d^2 5s(a^4F)5p$	$z^3F^\circ$	2 3 4	16296. 51 16843. 93 17556. 26	547. 42 712. 33	0. 67 1. 08 1. 23	$4d^2 5s(a^2D)5p$	$x^3F^\circ$	2 3 4	26061. 70 26443. 88 26938. 42	382. 18 494. 54	0. 67 1. 06 1. 13
$4d^2 5s(a^4F)5p$	$z^5F^\circ$	1 2 3 4 5	16786. 93 17059. 61 17422. 17 17832. 73 18276. 92	272. 68 362. 56 410. 56 444. 19	0. 30 0. 95 1. 25 1. 35 1. 40	$4d^2 5s(a^2P)5p$	$x^3D^\circ$	1 2 3	26154. 13 26557. 21 27111. 16	403. 08 553. 95	0. 49 1. 15 1. 33
$4d^3(b^2P)5s$	$c^3P$	2 1 0	17142. 72 17059. 82 17321. 52	82. 90 -261. 70		$4d^3(b^4F)5p$	$w^3D^\circ$	1 2 3	26902. 45 27121. 96 27482. 26	219. 51 360. 30	0. 50 1. 14 1. 31
$4d^3(b^2D)5s$	$b^1D$	2	17228. 42			$4d^2 5s(a^2F)5p$	$z^1G^\circ$	4	26931. 35		1. 13
$4d^2 5s(a^4F)5p$	$z^3D^\circ$	1 2 3	17429. 86 17813. 64 18243. 56	383. 78 429. 92	0. 42 1. 09 1. 32	$4d^3(b^2D)5p$	$x^1D^\circ$	2	27515. 38		
$4d^2 5s(a^2D)5p$	$z^1D^\circ$	2	17511. 78		0. 96	$4d^2 5s(a^4P)5p$	$y^3P^\circ$	0 1 2	27600. 24 27572. 52 27673. 35	-27. 72 100. 83	0. 00 1. 47 1. 45
$4d^3(a^2G)5s$	$b^1G$	4	17752. 73		1. 00	$4d^2 5s(a^2F)5p$	$w^3F^\circ$	2 3 4	27876. 16 28157. 42 28528. 36	281. 26 370. 94	0. 70 1. 03 1. 15
$4d^3(a^2H)5s$	$a^1H$	5	18738. 94		1. 02	$4d^3(a^2G)5p$	$z^3H^\circ$	4 5 6	27908. 28 28211. 82 28608. 62	303. 54 396. 80	0. 78 1. 00 1. 18
$4d^2 5s(a^4F)5p$	$z^5D^\circ$	0 1 2 3 4	18976. 36 19096. 53 19323. 84 19625. 58 19833. 78	120. 17 227. 31 301. 74 208. 20	0. 00 1. 55 1. 45 1. 50 1. 49	$4d^2 5s(a^2F)5p$	$x^3G^\circ$	3 4 5	28404. 26 28749. 80 29001. 65	345. 54 251. 85	0. 79 1. 15 1. 21
$4d^2 5s(a^2P)5p$	$z^3P^\circ$	0 1 2	20233. 97 20519. 20 20466. 83	285. 23 -52. 37	0. 00 1. 51 1. 47	$4d^3(b^4F)5p$	$y^5F^\circ$	1 2 3 4 5	28446. 92 28595. 03 28818. 02 29122. 71 29535. 48	148. 11 222. 99 304. 69 412. 77	0. 00 1. 03 1. 22 1. 33 1. 37
$4d^4$	$a^5D$	0 1 2 3 4	21726. 28 21801. 21 21943. 74 22145. 31 22398. 00	74. 93 142. 53 201. 57 252. 69		$4d^2 5s(a^2D)5p$	$x^3P^\circ$	0 1 2	28632. 75 28709. 88 28909. 57	77. 13 199. 69	0. 00 1. 45 1. 50
$4d^2 5s(a^4F)5p$	$z^3G^\circ$	3 4 5	21849. 33 22144. 08 22563. 89	294. 75 419. 81	0. 75 1. 03 1. 21	$4d^2 5s(a^2D)5p$	$v^3D^\circ$	1 2 3	28800. 51 29057. 84 29274. 82	257. 33 216. 98	0. 75 1. 16 1. 31
$4d^2 5s(a^2P)5p$	$z^3S^\circ$	1	21974. 18		2. 01	$4d^2 5s(a^2D)5p$	$z^1P^\circ$	1	28999. 46		0. 75
$4d^2 5s(a^2P)5p$	$y^1D^\circ$	2	22750. 53		1. 09	$4d^3(b^4F)5p$	$x^5D^\circ$	0 1 2 3 4	29588. 07 29677. 14 29847. 49 30087. 33 30384. 50	89. 07 170. 35 239. 84 297. 17	0. 00 1. 48 1. 54 1. 48 1. 46
$4d^2 5s(a^2D)5p$	$z^1F^\circ$	3	22862. 02		0. 90	$4d^3(a^2G)5p$	$y^1G^\circ$	4	31050. 48		1. 01
$4d^2 5s(a^4P)5p$	$y^3D^\circ$	1 2 3	23018. 92 23319. 86 23660. 97	300. 94 341. 11	0. 52 1. 14 1. 23	$4d^3(b^2F)5p$	$w^3G^\circ$	3 4 5	31326. 81 31694. 52 32152. 16	367. 71 457. 64	0. 75 1. 04 1. 20
$4d^2 5s(a^4P)5p$	$z^5S^\circ$	2	23085. 06			$4d^2 5s(a^4P)5p$	$y^3S^\circ$	1	31850. 77		
$4d^2 5s(a^4P)5p$	$y^5D^\circ$	0 1 2 3 4	23122. 29 23246. 33 23489. 43 23889. 03 24376. 37	124. 04 243. 10 399. 60 487. 34	1. 45	$4d^2 5s(a^2P)5p$	$y^1P^\circ$	1	32722. 80		
$4d^3(b^4F)5p$	$y^3F^\circ$	2 3 4	23597. 47 23567. 12 24006. 30	-30. 35 439. 18	1. 08	$4d^3(b^2F)5p$	$v^3F^\circ$	2 3 4	32972. 30 33191. 86 33688. 23	219. 56 496. 37	1. 08 1. 08
$4d^2 5s(a^2F)5p$	$y^1F^\circ$	3	24387. 52		1. 01	$4d^3(b^4P)5p$	$x^3S^\circ$	1	33113. 80		1. 93
$4d^2 5s(a^4P)5p$	$z^5P^\circ$	1 2 3	25489. 87 25645. 97 25898. 16	156. 10 252. 19	1. 65 0. 34 0. 93	$4d^3(b^2D)5p$	$u^3F^\circ$	2 3 4	33163. 98 33420. 47 33559. 34	256. 49 138. 87	0. 70 1. 06 1. 24



## Zr I—Continued

## Zr I—Continued

Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>	Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>
$4d^3(b^4P)5p$	$w^5D^\circ$	0	33349.56	95.31	0.00	$4d^2 5s(b^2G)5p$	$u^3G^\circ$	3	39389.29	544.85	
		1	33444.87	187.61	1.52			4	39934.14	244.30	1.05
		2	33632.48	279.61	1.51			5	40178.44		1.13
		3	33912.09	375.40	1.49	$4d^3(b^2D)5p$	$x^1P^\circ$	1	39704.10		
		4	34287.49		1.51	$4d^3(b^2D)5p$	$r^3D^\circ$	1			
$4d^2 5s(a^2F)5p$	$u^3D^\circ$	1	33486.82	277.30	0.62			2	39766.47	579.88	1.29
		2	33764.12	475.70	1.10			3	40346.35		
		3	34239.82		1.35	$4d^3(a^2G)5p$	$v^1F^\circ$	3	39803.73		
$4d^2 5s(b^2G)5p$	$z^1H^\circ$	5	33839.20		1.03	$4d^3(a^2G)5p$	$y^1H^\circ$	5	39855.22		1.02
$4d^3(a^2H)5p$	$y^3H^\circ$	4	34450.60	255.30	0.80	$4d^2 5s(a^4F)5d$	$e^5H$	3			
		5	34705.90	429.17	1.02			4	39936.70	700.35	1.07
		6	35135.07		1.16			5	40637.05	806.48	
$4d^3(b^4P)5p$	$y^5P^\circ$	1	34617.00	144.52	2.46			6	41443.53	643.29	1.36
		2	34761.52	329.38	1.42			7	42086.82		
		3	35090.90		1.66	$4d 5s^2(c^2D)5p$	$t^3P^\circ$	0	40536.38	437.56	
$4d 5s^2(c^2D)5p$	$w^1D^\circ$	2	34850.96		1.42			1	40973.94	813.68	
$4d^2 5s(a^4F)6s$	$e^5F$	1	35046.95	163.35				2	41787.62		
		2	35210.30	265.77	1.26	$4d^3(b^2F)5p$	$v^1D^\circ$	2	40557.65		
		3	35476.07	384.76	1.23	$4d^3(b^4F)6s$	$f^5F$	1			
		4	35860.83	499.37	1.35			2			
		5	36360.20		1.40			3	40653.41	196.29	
$4d^3(b^4P)5p$	$w^3P^\circ$	0						4	40849.70	218.30	
		1	35205.52	250.73	1.45	$4d^2 5s(a^4F)5d$	$e^5G$	2	40660.65	226.96	1.09
		2	35456.25					3	40887.61	291.69	1.07
$4d^2 5s(b^2G)5p$	$t^3F^\circ$	2	35514.53	291.10	0.69			4	41179.30	358.93	
		3	35805.63	195.72	1.00			5	41538.23	402.63	1.41
		4	36001.35		1.22	$4d 5s^2(c^2D)5p$	$w^1P^\circ$	1	40931.60		
$4d^3(a^2H)5p$	$z^3I^\circ$	5	35781.67	391.36	0.82	$4d^3(a^2H)5p$	$w^1G^\circ$	4	41319.96		0.99
		6	36173.03	—20.18	1.02	$4d^3(a^2H)5p$	$t^3G^\circ$	3	42102.56	169.85	
		7	36152.85		1.13			4	42272.41	562.55	
$4d^3(b^4P)5p$	$y^5S^\circ$	2	35990.21		2.01			5	42834.96		
$4d^3(b^2D)5p$	$v^3P^\circ$	0	36034.54	454.56		$4d 5s^2(c^2D)5p$	$q^3D^\circ$	1	42296.80	136.85	
		1	36489.10	519.30				2	42433.65	365.55	1.35
		2	37008.40		1.55	$4d^3(a^2H)5p$	$x^1H^\circ$	5	42309.29		
$4d^3(b^4P)5p$	$t^3D^\circ$	1	36125.16	169.71	0.45	$4d 5s^2(d^2D)5p$	$q^3F^\circ$	2	42706.00	562.24	
		2	36294.87	—74.42	1.16			3	43268.24	7.76	
		3	36220.45		1.28	$4d^3(b^2P)5p$	$w^3S^\circ$	1	43182.96		
$4d^2 5s(b^2G)5p$	$x^1G^\circ$	4	36336.48		1.15	$4d^3(b^2P)5p$	$s^3P^\circ$	0			
$4d 5s^2(c^2D)5p$	$u^3P^\circ$	0	36538.27	432.38				1	44882.30	134.83	
		1	36970.65	479.58				2	45017.13		
		2	37450.23			$4d^3(b^2P)5p$	$p^3D^\circ$	1	45405.30	182.32	
$4d^2 5s(b^2G)5p$	$x^3H^\circ$	4	36608.41	—10.93	0.82			2	45587.62	122.67	
		5	36597.48	243.11	1.04	$4d^2 5p^2$	$f^5G$	2	45710.29		
		6	36840.59		1.13			3	45798.48	396.67	
$4d 5s^2(c^2D)5p$	$w^1F^\circ$	3	36759.90		0.87			4	46641.42	446.27	
					0.87			5	47134.50	493.08	
$4d^3(a^2G)5p$	$v^3G^\circ$	3	36941.65	287.89	1.02			6	47698.29	563.79	
		4	37229.54	192.82	1.18	$4d^3(b^2F)5p$	$u^1F^\circ$	3	46328.16		
		5	37422.36			$4d 5s^2(d^2D)5p$	$o^3D^\circ$	1	47765.56	368.08	
$4d^3(a^2G)5p$	$s^3F^\circ$	2	37123.42	345.45	0.71			2	48133.64	579.80	
		3	37468.87	452.09	1.11			3	48713.44		
		4	37920.96		1.26	$4d^2 5s(a^2S)5p$	$v^1P^\circ$	1	51899.40		
$4d^2 5s(a^4F)6s$	$e^3F$	2	37459.60	241.48	1.02						
		3	37701.08	400.01	1.25						
		4	38101.09								
$4d^3(b^2F)5p$	$s^3D^\circ$	1	38270.81								
		2	38326.72	55.91	1.41						
		3	38435.83	109.16	1.00						
$4d^3(a^2H)5p$	$z^1I^\circ$	6	38475.82								
$4d 5s^2(c^2D)5p$	$r^3F^\circ$	2	38566.00	315.80							
		3	38881.80	292.64	1.26						
		4	39174.44								
						Zr II ( $^4F_{1/2}$ )	Limit		56077		

## Zr I OBSERVED TERMS \*

Config. 1s <sup>2</sup> 2s <sup>2</sup> 2p <sup>6</sup> 3s <sup>2</sup> 3p <sup>6</sup> 3d <sup>10</sup> 4s <sup>2</sup> 4p <sup>6</sup> +	Observed Terms		
4d <sup>2</sup> 5s <sup>2</sup>	$\{ a^1S$	$a^3P$	$a^3F$
4d <sup>4</sup>		$a^1D$	$a^1G$
4d <sup>2</sup> 5p <sup>2</sup>		$a^5D$	
			$f^5G$
	$ns (n \geq 5)$		$np (n \geq 5)$
4d <sup>2</sup> 5s(a <sup>4</sup> F) <sub>nx</sub>	$\{$	$e^5F$ $e^3F$	$z^1D^\circ$ $z^3D^\circ$ $z^5F^\circ$ $z^3F^\circ$ $z^5G^\circ$ $z^3G^\circ$
4d <sup>3</sup> (b <sup>4</sup> F) <sub>nx</sub>	$\{$	$a, f^5F$ $b^3F$	$x^3D^\circ$ $w^3D^\circ$ $y^5F^\circ$ $y^3F^\circ$ $y^5G^\circ$ $y^3G^\circ$
4d <sup>2</sup> 5s(a <sup>2</sup> D) <sub>nx</sub>	$\{$		$x^3P^\circ$ $z^1P^\circ$ $x^3F^\circ$ $z^1F^\circ$
4d <sup>2</sup> 5s(a <sup>2</sup> P) <sub>nx</sub>	$\{$		$z^3S^\circ$ $z^3P^\circ$ $y^1P^\circ$ $x^3D^\circ$ $y^1D^\circ$ $x^3F^\circ$ $y^1F^\circ$
4d <sup>2</sup> 5s(a <sup>2</sup> F) <sub>nx</sub>	$\{$		$u^3D^\circ$ $x^3G^\circ$ $z^1G^\circ$
4d <sup>2</sup> 5s(a <sup>4</sup> P) <sub>nx</sub>	$\{$		$z^5S^\circ$ $y^3S^\circ$ $z^3P^\circ$ $y^1D^\circ$ $y^5D^\circ$ $y^3D^\circ$
4d <sup>3</sup> (a <sup>2</sup> G) <sub>nx</sub>	$\{$	$a^3G$ $b^1G$	$s^3F^\circ$ $v^1F^\circ$ $v^3G^\circ$ $y^1G^\circ$ $z^3H^\circ$ $y^1H^\circ$
4d <sup>3</sup> (b <sup>4</sup> P) <sub>nx</sub>	$\{$	$a^5P$ $b^3P$	$y^5S^\circ$ $x^3S^\circ$ $y^3P^\circ$ $w^3P^\circ$ $l^3D^\circ$ $t^3D^\circ$
4d <sup>3</sup> (a <sup>2</sup> H) <sub>nx</sub>	$\{$	$a^3H$ $a^1H$	$l^3G^\circ$ $w^1G^\circ$ $y^3H^\circ$ $x^1H^\circ$ $z^3I^\circ$ $z^1I^\circ$
4d <sup>3</sup> (b <sup>2</sup> D) <sub>nx</sub>	$\{$	$a^3D$ $b^1D$	$v^3P^\circ$ $x^1P^\circ$ $r^3D^\circ$ $x^1D^\circ$ $u^3F^\circ$ $x^1F^\circ$
4d <sup>2</sup> 5s(b <sup>2</sup> G) <sub>nx</sub>	$\{$		$l^3F^\circ$ $u^3G^\circ$ $x^1G^\circ$ $x^3H^\circ$ $z^1H^\circ$
4d 5s <sup>2</sup> (c <sup>2</sup> D) <sub>nx</sub>	$\{$		$u^3P^\circ$ $w^1P^\circ$ $q^3D^\circ$ $w^1D^\circ$ $r^3F^\circ$ $w^1F^\circ$
4d <sup>3</sup> (b <sup>2</sup> F) <sub>nx</sub>	$\{$	$c^3F$	$s^3D^\circ$ $v^1D^\circ$ $w^3G^\circ$ $u^3F^\circ$ $u^1F^\circ$
4d <sup>3</sup> (b <sup>2</sup> P) <sub>nx</sub>	$\{$	$c^3P$	$w^3S^\circ$ $s^3P^\circ$ $p^3D^\circ$
4d <sup>2</sup> 5s(a <sup>2</sup> S) <sub>nx</sub>			$v^1P^\circ$

\* For predicted terms in the spectra of the Zr I isoelectronic sequence, see Vol. II, Introduction.

## Zr II

(Y I sequence; 39 electrons)

 $Z=40$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 4d^2 5s^4 F_{1\frac{1}{2}}$  $a^4 F_{1\frac{1}{2}}$  113175  $\text{cm}^{-1}$ 

I. P. 14.03 volts

The analysis is by Kiess and Mrs. Kiess, whose line list extends from 1743.53 to 6787.15 Å, includes 735 classified lines, and gives observed and theoretical Zeeman patterns. The terms of different multiplicities are connected by observed intersystem combinations.

Their value of the limit is based on the four pairs of series terms involving 5s and 6s electrons, and is derived by using a Rydberg formula.

C. C. Kiess has recently revised the configuration assignments of  $b^2D$ ,  $c^2D$ , and  $d^2D$  as given in the table. On theoretical grounds, Ufford suggests that these configurations be interchanged as follows:

Term	C. C. Kiess	Ufford
$b^2D$	$4d^3$	$4d 5s^2$
$c^2D$	$4d 5s^2$	$4d^3$
$d^2D$	Unassigned	Unassigned

The observed  $g$ -values are from three sources: those for  $z^4F_{1\frac{1}{2}}$  and  $y^2F_{2\frac{1}{2}}$  are from the Kiess paper. All other three-place entries are from unpublished material by Miss Weeks furnished especially for inclusion here. These are from films of spectrograms taken with the Bitter magnet at the Massachusetts Institute of Technology. The rest are quoted from the paper by Sancho.

## REFERENCES

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 C. W. Ufford, Phys. Rev. **44**, 732 (1933).  
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## Zr II

## Zr II

Config.	Desig.	$J$	Level	Interval	Obs. $g$	Config.	Desig.	$J$	Level	Interval	Obs. $g$
$4d^2(a^3F)5s$	$a^4F$	$1\frac{1}{2}$	0. 00		0. 398	$4d^3$	$a^2G$	$3\frac{1}{2}$	7837. 74		0. 887
		$2\frac{1}{2}$	314. 67	314. 67	1. 023			$4\frac{1}{2}$	8152. 80	315. 06	1. 107
		$3\frac{1}{2}$	763. 44	448. 77	1. 235	$4d^3$	$b^4P$	$0\frac{1}{2}$	9553. 10		2. 649
		$4\frac{1}{2}$	1322. 91	559. 47	1. 324			$1\frac{1}{2}$	9742. 80	189. 70	1. 721
$4d^3$	$b^4F$	$1\frac{1}{2}$	2572. 21	322. 84	0. 413	$4d^3$	$a^2H$	$2\frac{1}{2}$	9968. 65	225. 85	1. 593
		$2\frac{1}{2}$	2895. 05	404. 59	1. 025			$4\frac{1}{2}$	11984. 46		0. 910
		$3\frac{1}{2}$	3299. 64	458. 02	1. 227			$5\frac{1}{2}$	12359. 66	375. 20	1. 091
		$4\frac{1}{2}$	3757. 66		1. 326						
$4d^2(a^1D)5s$	$a^2D$	$1\frac{1}{2}$	4248. 30		0. 812	$4d^3$	$b^2D$	$1\frac{1}{2}$	13428. 50		0. 800
		$2\frac{1}{2}$	4505. 50	257. 20	1. 172			$2\frac{1}{2}$	14162. 90	734. 40	1. 209
$4d^2(a^3P)5s$	$a^2P$	$0\frac{1}{2}$	5724. 38		0. 690	$4d^2(^1G)5s$	$b^2G$	$3\frac{1}{2}$	14059. 76		0. 890
		$1\frac{1}{2}$	6111. 70	387. 32	1. 304			$4\frac{1}{2}$	14190. 45	130. 69	1. 103
$4d^2(a^3F)5s$	$a^2F$	$2\frac{1}{2}$	5752. 92		0. 883	$4d 5s^2$	$c^2D$	$1\frac{1}{2}$	14298. 64		0. 807
		$3\frac{1}{2}$	6467. 61	714. 69	1. 144			$2\frac{1}{2}$	14733. 37	434. 73	1. 188
$4d^2(a^3P)5s$	$a^4P$	$0\frac{1}{2}$	7512. 67		2. 656	$4d^2$	$d^2D$	$1\frac{1}{2}$	17614. 00		
		$1\frac{1}{2}$	7736. 02	223. 35	1. 720			$2\frac{1}{2}$	18396. 54	782. 54	
		$2\frac{1}{2}$	8058. 16	322. 14	1. 585						



## Zr II—Continued

Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>
$4d^3$	$b\ ^2F$	$3\frac{1}{2}$ $2\frac{1}{2}$	19433. 24 19514. 84	81. 60	1. 153 0. 855
$4d^3$	$b\ ^2P$	$0\frac{1}{2}$ $1\frac{1}{2}$	19613. 54 20080. 30	466. 76	0. 514 1. 326
$4d^2(^1S)5s$	$a\ ^2S$	$0\frac{1}{2}$	25201. 57		1. 990
$4d^2(a\ ^3F)5p$	$z\ ^4G^\circ$	$2\frac{1}{2}$ $3\frac{1}{2}$ $4\frac{1}{2}$ $5\frac{1}{2}$	27983. 83 28909. 04 29839. 87 30795. 74	925. 21 930. 83 955. 87	0. 664 0. 998 1. 164 1. 275
$4d^2(a\ ^3F)5p$	$z\ ^2F^\circ$	$2\frac{1}{2}$ $3\frac{1}{2}$	29504. 97 30561. 75	1056. 78	0. 841 1. 132
$4d^2(a\ ^3F)5p$	$z\ ^4F^\circ$	$1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$ $4\frac{1}{2}$	29777. 60 30551. 48 31249. 28 31866. 49	773. 88 697. 80 617. 21	0. 700 1. 046 1. 238 1. 321
$4d^2(a\ ^3F)5p$	$z\ ^2D^\circ$	$1\frac{1}{2}$ $2\frac{1}{2}$	30435. 38 31160. 04	724. 66	0. 589 1. 117
$4d^2(a\ ^3F)5p$	$z\ ^4D^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$	31981. 25 32256. 71 32614. 71 32899. 46	275. 46 358. 00 284. 75	0. 016 1. 166 1. 342 1. 408
$4d^2(a\ ^3P)5p$	$y\ ^2D^\circ$	$1\frac{1}{2}$ $2\frac{1}{2}$	32983. 73 33419. 45	435. 72	0. 810 1. 195
$4d^2(a\ ^3F)5p$	$z\ ^2G^\circ$	$3\frac{1}{2}$ $4\frac{1}{2}$	34485. 42 35185. 64	700. 22	0. 889 1. 109
$4d^2(a\ ^3P)5p$	$z\ ^2S^\circ$	$0\frac{1}{2}$	34810. 03		1. 956
$4d^2(a\ ^1D)5p$	$z\ ^2P^\circ$	$1\frac{1}{2}$ $0\frac{1}{2}$	35914. 81 36196. 57	-281. 76	1. 340 0. 610
$4d^2(a\ ^3P)5p$	$y\ ^4D^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$	36237. 04 36638. 50 37171. 22 38041. 49	401. 46 532. 72 870. 27	0. 144 1. 038 1. 140 1. 306
$4d\ 5s(a\ ^3D)5p$	$y\ ^4F^\circ$	$1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$ $4\frac{1}{2}$	36451. 79 36869. 00 37429. 76 38644. 12	417. 21 560. 76 1214. 36	0. 579 1. 091 1. 266 1. 321
$4d^2(^1G)5p$	$y\ ^2F^\circ$	$2\frac{1}{2}$ $3\frac{1}{2}$	37346. 31 37787. 59	441. 28	0. 975 1. 212
$4d^2(a\ ^3P)5p$	$z\ ^4S^\circ$	$1\frac{1}{2}$	37681. 75		1. 908
$4d\ 5s(a\ ^3D)5p$	$z\ ^4P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$	38063. 40 38133. 50 38482. 64	70. 10 349. 14	2. 448 1. 734 1. 606
$4d\ 5s(a\ ^3D)5p$	$x\ ^4D^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$	38934. 37 39192. 35 39640. 08 40238. 55	257. 98 447. 73 598. 47	0. 055 1. 209 1. 370 1. 408
$4d^2(a\ ^3P)5p$	$y\ ^2P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	40727. 26 41337. 36	610. 10	0. 677 1. 326
$4d^2(^1G)5p$	$y\ ^2G^\circ$	$3\frac{1}{2}$ $4\frac{1}{2}$	40852. 74 40878. 25	25. 51	0. 915 1. 083
$4d^2(a\ ^1D)5p$	$x\ ^2D^\circ$	$1\frac{1}{2}$ $2\frac{1}{2}$	41467. 72 41676. 82	209. 10	0. 821 1. 184
$4d^2(^1G)5p$	$z\ ^2H^\circ$	$4\frac{1}{2}$ $5\frac{1}{2}$	41738. 21 42409. 93	671. 72	0. 954 1. 080

## Zr II—Continued

Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>
$4d^2(a\ ^1D)5p$	$x\ ^2F^\circ$	$3\frac{1}{2}$ $2\frac{1}{2}$	42504. 11 42860. 72	-356. 61	1. 134 0. 887
$4d^2(a\ ^3P)5p$	$y\ ^4P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$	42789. 24 42893. 54 43202. 45	104. 30 308. 91	2. 632 1. 710 1. 561
$4d\ 5s(a\ ^1D)5p$	$w\ ^2D^\circ$	$1\frac{1}{2}$ $2\frac{1}{2}$	45054. 87 45186. 05	131. 18	0. 870 1. 226
$4d^2(^1S)5p$	$x\ ^2P^\circ$	$1\frac{1}{2}$ $0\frac{1}{2}$	45568. 21 45944. 00	-375. 79	1. 14 0. 724
$4d\ 5s(a\ ^1D)5p$	$w\ ^2F^\circ$	$2\frac{1}{2}$ $3\frac{1}{2}$	47881. 88 48344. 91	463. 03	0. 871 1. 142
$4d\ 5s(a\ ^1D)5p$	$w\ ^2P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	52585. 80 52876. 80	291. 00	0. 659 1. 318
$4d\ 5s(a\ ^3D)5p$	$v\ ^2D^\circ$	$1\frac{1}{2}$ $2\frac{1}{2}$	55835. 53 56569. 44	733. 91	1. 16
$4d\ 5s(a\ ^3D)5p$	$v\ ^2F^\circ$	$2\frac{1}{2}$ $3\frac{1}{2}$	57062. 00 57741. 16	679. 16	1. 24
$4d\ 5s(a\ ^3D)5p$	$v\ ^2P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	60814. 50 61861. 90	1047. 40	
$4d^2(a\ ^3F)6s$	$e\ ^4F$	$1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$ $4\frac{1}{2}$	63602. 64 63868. 45 64368. 28 64901. 71	265. 81 499. 83 533. 43	1. 11 1. 205 1. 274
$4d^2(a\ ^3F)6s$	$e\ ^2F$	$2\frac{1}{2}$ $3\frac{1}{2}$	65872. 41 66192. 68	320. 27	1. 18
$4d^2(a\ ^1D)6s$	$e\ ^2D$	$1\frac{1}{2}$ $2\frac{1}{2}$	66686. 25 66868. 35	182. 10	1. 14
$4d^2(^1G)6s$	$e\ ^2G$	$3\frac{1}{2}$ $4\frac{1}{2}$	69116. 70 69283. 38	166. 68	
$4d^2(a\ ^3F)5d$	$f\ ^2F$	$2\frac{1}{2}$ $3\frac{1}{2}$	73852. 95 74496. 80	643. 85	
$4d^2(a\ ^3F)5d$	$f\ ^4F$	$1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$ $4\frac{1}{2}$	74611. 28 75343. 57 76009. 05 76593. 58	732. 29 665. 48 584. 53	
$4d^2(^1G)5d$	$e\ ^2I$	$5\frac{1}{2}$ $6\frac{1}{2}$	76395. 50 76838. 70	443. 20	0. 999 1. 081
$4d^2(^1G)5d$	$e\ ^2H$	$4\frac{1}{2}$ $5\frac{1}{2}$	77743. 00 78280. 90	537. 90	1. 073
$4d^2(a\ ^3F)5d$	$e\ ^4H$	$3\frac{1}{2}$ $4\frac{1}{2}$ $5\frac{1}{2}$ $6\frac{1}{2}$	78577. 85 78847. 67 79198. 35 79280. 30	269. 82 350. 68 81. 95	
$4d^2(^1G)5d$	$f\ ^2G$	$3\frac{1}{2}$ $4\frac{1}{2}$	79624. 60 80311. 54	686. 94	
$4d^2(a\ ^3F)5d$	$g\ ^2G$	$3\frac{1}{2}$ $4\frac{1}{2}$	83221. 45 83547. 45	326. 00	
$4d^2(a\ ^3F)5d$	$f\ ^2H$	$4\frac{1}{2}$ $5\frac{1}{2}$	90986. 50 91737. 40	750. 90	
Zr III ( $^3F_2$ )	Limit	-----	113175		

Zr II OBSERVED TERMS\*

Config. 1s <sup>2</sup> 2s <sup>2</sup> 2p <sup>6</sup> 3s <sup>2</sup> 3p <sup>6</sup> 3d <sup>10</sup> 4s <sup>2</sup> 4p <sup>6</sup> +	Observed Terms			
4d 5s <sup>2</sup>	c <sup>2</sup> D			
4d <sup>3</sup>	{ b <sup>4</sup> P b <sup>2</sup> P	b <sup>4</sup> F b <sup>2</sup> F	a <sup>2</sup> G a <sup>2</sup> H	
	ns (n ≥ 5)		np (n ≥ 5)	nd (n ≥ 4)
4d <sup>2</sup> (a <sup>3</sup> F)nx	{    a <sup>2</sup> S  {	a, e <sup>4</sup> F a, e <sup>2</sup> F	z <sup>4</sup> D° z <sup>2</sup> D°	f <sup>4</sup> F f <sup>2</sup> F
4d <sup>2</sup> (a <sup>1</sup> D)nx		a, e <sup>2</sup> D	z <sup>2</sup> P°	z <sup>2</sup> G° z <sup>2</sup> Q°
4d <sup>2</sup> (a <sup>3</sup> P)nx		a <sup>4</sup> P a <sup>2</sup> P	z <sup>2</sup> P° y <sup>4</sup> P° y <sup>2</sup> P°	z <sup>2</sup> F° x <sup>2</sup> F°
4d <sup>2</sup> ( <sup>1</sup> G)nx		b, e <sup>2</sup> G	z <sup>4</sup> S° z <sup>2</sup> S°	z <sup>4</sup> D° y <sup>4</sup> D° y <sup>2</sup> D°
4d <sup>2</sup> ( <sup>1</sup> S)nx			x <sup>2</sup> P°	y <sup>2</sup> F°
4d 5s(a <sup>3</sup> D)nx	{		z <sup>4</sup> P° v <sup>2</sup> P°	y <sup>2</sup> G° z <sup>2</sup> H°
4d 5s(a <sup>1</sup> D)nx			w <sup>2</sup> P°	f <sup>2</sup> G e <sup>2</sup> H e <sup>2</sup> I

\*For predicted terms of the Y I isoelectronic sequence, see Vol. II, Introduction.

(Sr I sequence; 38 electrons)

Z=40

Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 4d^2 {}^3F_2$  $a {}^3F_2$  200000  $\pm$  cm<sup>-1</sup>

I. P. 24.8 volts

Kiess has revised the earlier work by himself and Lang, especially for inclusion here, and he has further analysis in progress. The observations extend from 732 Å to 3497 Å, and the total number of classified lines is about 200. Observed intersystem combinations connect the singlet and triplet series of terms.

His value of the limit quoted here is provisional, since it has been derived by the application of a Rydberg formula to the  $nd {}^3F$  and  $nd {}^1D$  series ( $n=4,5$ ).

The observed  $g$ -values are from plates and films furnished by Harrison at the Massachusetts Institute of Technology. Kiess has examined the plates and Miss Weeks the films; both have contributed to the values quoted here.

## REFERENCES

C. C. Kiess and R. J. Lang, Bur. Std. J. Research **5**, 309, RP 202 (1930). (I P) (T) (C L) (G D)

D. W. Weeks, unpublished material (March 1951). (Z E)

C. C. Kiess, unpublished material (1951). (I P) (T) (C L) (Z E)

## Zr III

## Zr III

Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>	Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>		
$4d^2$	$a\ ^3F$	2	0. 00	681. 0 805. 4		$4d(^2D)5d$	$e\ ^3D$	1	105006. 9	314. 0 979. 9			
		3	681. 0					2	105320. 9				
		4	1486. 4					3	106300. 8				
$4d^2$	$a\ ^1D$	2	5741. 55	263. 58 512. 56		$4d(^2D)5d$	$e\ ^1P$	1	105550. 2	567. 6 493. 8			
$4d^2$	$a\ ^3P$	0	8062. 07			$4d(^2D)5d$	$e\ ^1D$	2	106499. 6				
		1	8325. 65					2	107253. 0				
		2	8838. 21					3	107820. 6				
$4d^2$	$a\ ^1G$	4	11048. 70	403. 92 730. 56		$4d(^2D)5d$	$e\ ^3F$	2	107253. 0	567. 6 493. 8			
$4d^2$	$a\ ^1S$	0	13832. 0?			$4d(^2D)5d$	$e\ ^1G$	3	107820. 6				
								4	108314. 4				
								4	107456. 2				
$4d(^2D)5s$	$a\ ^3D$	1	18398. 87	403. 92 730. 56		$4d(^2D)5d$	$e\ ^1S$	4	107650. 5	—329. 9			
		2	18802. 79			$4d(^2D)5d$	$e\ ^3S$	0	109073. 3				
		3	19533. 35					1	109268. 7				
$4d(^2D)5s$	$b\ ^1D$	2	25066. 25	1. 000		$4d(^2D)5d$	$e\ ^3P$	2	109598. 6	—329. 9			
$5s^2$	$b\ ^1S$	0	36257. 8??									1	109598. 6
												0	
$4d(^2D)5p$	$z\ ^1D^\circ$	2	53647. 21	519. 70 1606. 07	0. 927	$4d(^2D)4f$	$y\ ^3F^\circ$	4	117813	—1713 —1892			
$4d(^2D)5p$	$z\ ^3F^\circ$	3	55555. 63			0. 789 1. 112 1. 233	$4d(^2D)4f$	$z\ ^3G^\circ$	3			119526	
		2	56075. 33						2			121418	
		4	57681. 40	4	121923								
$4d(^2D)5p$	$z\ ^3D^\circ$	1	55614. 42	821. 23 911. 18	0. 519 1. 119 1. 337	$4d(^2D)4f$	$x\ ^3P^\circ$	4	122600	677 900			
		2	56435. 65			$4d(^2D)4f$	$x\ ^3P^\circ$	5	123500				
		3	57346. 83					0	123390				
$4d(^2D)5p$	$z\ ^3P^\circ$	0	59944. 79	—247. 97 659. 16		$4d(^2D)4f$	$y\ ^1F^\circ$	1	123593	203 362			
		1	59696. 82			$4d(^2D)4f$	$y\ ^1F^\circ$	2	123955				
		2	60355. 98					3	127378				
$4d(^2D)5p$	$z\ ^1P^\circ$	1	62115. 66	1. 044		$4d(^2D)4f$	$y\ ^1D^\circ$	3	128877				
$4d(^2D)5p$	$z\ ^1F^\circ$	3	62589. 13			1. 000	$4d(^2D)4f$	$y\ ^3D^\circ$	2			131010	
									1			131509	
$5s(^2S)5p$	$y\ ^3P^\circ$	0	79436. 7	666. 3 1450. 6		$4d(^2D)4f$	$x\ ^1P^\circ$	2	132187	499 678			
		1	80103. 0			$4d(^2D)4f$	$x\ ^1P^\circ$	3	134614				
		2	81553. 6					4	134975?				
$5s(^2S)5p$	$y\ ^1P^\circ$	1	86512. 3??	556. 2 530. 5?		$4d(^2D)4f$	$z\ ^1G^\circ$	1	138517?				
$4d(^2D)5d$	$e\ ^1F$	3	103581. 5			$4d(^2D)4f$	$z\ ^1H^\circ$	4					
								4					
								5					
$4d(^2D)5d$	$e\ ^3G$	3	104633. 4	556. 2 530. 5?		$Zr\ VI\ (^2D_{1/2})$	<i>Limit</i>	-----	200000				
		4	105189. 6										
		5	105720. 1?										



Zr III OBSERVED TERMS\*

Config. 1s <sup>2</sup> 2s <sup>2</sup> 2p <sup>6</sup> 3s <sup>2</sup> 3p <sup>6</sup> 3d <sup>10</sup> 4s <sup>2</sup> 4p <sup>6</sup> +	Observed Terms	
4d <sup>2</sup>	{ a <sup>1</sup> S   a <sup>3</sup> P   a <sup>1</sup> D   a <sup>3</sup> F   a <sup>1</sup> G	
5s <sup>2</sup>	b <sup>1</sup> S?	
	ns (n ≥ 5)	np (n ≥ 5)
4d( <sup>2</sup> D)nx	{ a <sup>3</sup> D b <sup>1</sup> D	z <sup>3</sup> P°   z <sup>3</sup> D°   z <sup>3</sup> F° z <sup>1</sup> P°   z <sup>1</sup> D°   z <sup>1</sup> F°
5s( <sup>2</sup> S)nx	{	y <sup>3</sup> P° y <sup>1</sup> P°?
	nd (n ≥ 5)	nf (n ≥ 4)
4d( <sup>2</sup> D)nx	{ e <sup>3</sup> S   e <sup>3</sup> P   e <sup>3</sup> D   e <sup>3</sup> F   e <sup>3</sup> G e <sup>1</sup> S   e <sup>1</sup> P   e <sup>1</sup> D   e <sup>1</sup> F   e <sup>1</sup> G	x <sup>3</sup> P°   y <sup>3</sup> D°   y <sup>3</sup> F°   z <sup>3</sup> G° x <sup>1</sup> P°   y <sup>1</sup> D°   y <sup>1</sup> F°   z <sup>1</sup> G°   z <sup>1</sup> H°

\*For predicted terms in the spectra of the Sr I isoelectronic sequence, see Vol. II, Introduction.

Zr IV

(Rb I sequence; 37 electrons)

Z=40

Ground state 1s<sup>2</sup> 2s<sup>2</sup> 2p<sup>6</sup> 3s<sup>2</sup> 3p<sup>6</sup> 3d<sup>10</sup> 4s<sup>2</sup> 4p<sup>6</sup> 4d <sup>2</sup>D<sub>1/2</sub>

4d <sup>2</sup>D<sub>1/2</sub> **274067** cm<sup>-1</sup>

I. P. 33.97 volts

Fourteen lines have been classified as transitions among seven terms. The analysis is from the paper by Kiess and Lang who reobserved the spectrum from 628.66 Å to 2286.66 Å, and extended the earlier work of Bowen and Millikan and of Gibbs and White.

From a Ritz formula applied to the ns <sup>2</sup>S series (n=5 to 7) Kiess and Lang have determined the limit quoted here.

REFERENCE

C. C. Kiess and R. J. Lang, Bur. Std. J. Research **5**, 307, RP202 (1930). (I P) (T) (C L) (G D)

Zr IV

Config.	Desig.	J	Level	Interval
4p <sup>6</sup> ( <sup>1</sup> S)4d	4d <sup>2</sup> D	1½ 2½	0 1250	1250
4p <sup>6</sup> ( <sup>1</sup> S)5s	5s <sup>2</sup> S	0½	38258	
4p <sup>6</sup> ( <sup>1</sup> S)5p	5p <sup>2</sup> P°	0½ 1½	81976 84462	2486
4p <sup>6</sup> ( <sup>1</sup> S)5d	5d <sup>2</sup> D	1½ 2½	146650 147001	351
4p <sup>6</sup> ( <sup>1</sup> S)6s	6s <sup>2</sup> S	0½	152509	
4p <sup>6</sup> ( <sup>1</sup> S)4f	4f <sup>2</sup> F°	2½ 3½	159068 159088	20
4p <sup>6</sup> ( <sup>1</sup> S)7s	7s <sup>2</sup> S	0½	198840	
-----	-----	---	-----	-----
Zr V ( <sup>1</sup> S <sub>0</sub> )	Limit	---	<b>274067</b>	

March 1951.

Zr VI

(Br I sequence; 35 electrons)

Z=40

Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^5 \ ^2P_{1/2}^\circ$

$4p^5 \ ^2P_{1/2}^\circ$  798000  $\text{cm}^{-1}$

I. P. 99 volts

The analysis is incomplete. Paul and Rense have classified 46 lines between 236 Å and 568 Å as due to transitions from the ground term to 15 higher terms.

They have estimated the limit by extrapolation of isoelectronic sequence data.

REFERENCE

F. W. Paul and W. A. Rense, Phys. Rev. **56**, 1110 (1939). (I P) (T) (C L)

Zr VI

Zr VI

Config.	Desig.	J	Level	Interval	Config.	Desig.	J	Level	Interval
$4s^2 4p^5$	$4p^5 \ ^2P^\circ$	$1\frac{1}{2}$ $0\frac{1}{2}$	$0$ 15600	—15600	$4s^2 4p^4(^3P)4d$	$4d \ ^2F$	$3\frac{1}{2}$ $2\frac{1}{2}$	319496	
$4s 4p^6$	$4p^6 \ ^2S$	$0\frac{1}{2}$	191570		$4s^2 4p^4(^1D)4d$	$4d' \ ^2D$	$2\frac{1}{2}$ $1\frac{1}{2}$	335527 346344	—10817
$4s^2 4p^4(^3P)4d$	$4d \ ^4D$	$3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	241099 246007 248938	—4908 —2931	$4s^2 4p^4(^1D)4d$	$4d' \ ^2F$	$3\frac{1}{2}$ $2\frac{1}{2}$	336345	
$4s^2 4p^4(^3P)4d$	$4d \ ^4F$	$4\frac{1}{2}$ $3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$	288606 288680	—74	$4s^2 4p^4(^1D)4d$	$4d' \ ^2P$	$0\frac{1}{2}$ $1\frac{1}{2}$	355280 355604	324
$4s^2 4p^4(^3P)4d$	$4d \ ^4P$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$	289323 291660 295919	2337 4259	$4s^2 4p^4(^3P)5s$	$5s \ ^2P$	$1\frac{1}{2}$ $0\frac{1}{2}$	369716 379780	—10064
$4s^2 4p^4(^3P)4d$	$4d \ ^2D$	$1\frac{1}{2}$ $2\frac{1}{2}$	296155 306483	10328	$4s^2 4p^4(^1D)5s$	$5s' \ ^2D$	$2\frac{1}{2}$ $1\frac{1}{2}$	380383 384790	—4407
$4s^2 4p^4(^3P)4d$	$4d \ ^2P$	$0\frac{1}{2}$ $1\frac{1}{2}$	298923 299453	530	$4s^2 4p^4(^1S)5s$	$5s'' \ ^2S$	$0\frac{1}{2}$	423215	
$4s^2 4p^4(^3P)5s$	$5s \ ^4P$	$2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	314483 334692 346616	—20209 —11924	Zr VII ( $^3P_2$ )	Limit	-----	798000	

## Zr VI OBSERVED TERMS\*

Config. $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} +$	Observed Terms	
$4s^2 4p^5$	$4p^5 \ ^2P^\circ$	
$4s \ 4p^6$	$4p^6 \ ^2S$	
	$ns \ (n \geq 5)$	$nd \ (n \geq 4)$
$4s^2 4p^4(^3P)nx$	$\left\{ \begin{array}{l} 5s \ ^4P \\ 5s \ ^2P \end{array} \right.$	$\begin{array}{lll} 4d \ ^4P & 4d \ ^4D & 4d \ ^4F \\ 4d \ ^2P & 4d \ ^2D & 4d \ ^2F \end{array}$
$4s^2 4p^4(^1D)nx'$	$5s' \ ^2D$	$4d' \ ^2P \ 4d' \ ^2D \ 4d' \ ^2F$
$4s^2 4p^4(^1S)nx''$	$5s'' \ ^2S$	$4d'' \ ^2D$

\*For predicted terms in the spectra of the Br I isoelectronic sequence, see Vol. II, Introduction.

## Zr XIV

(Co I sequence; 27 electrons)

$Z=40$

Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^9 \ ^2D_{3/2}$

$3d^9 \ ^2D_{3/2} \quad \text{cm}^{-1}$

I. P. volts

Edlén has observed three lines due to the transition  $3p^6 3d^9 \ ^2D - 3p^5 3d^{10} \ ^2P^\circ$ . From preliminary unpublished measurements he has furnished the provisional term values quoted in the table. In figure 4 of his paper on the spectra of highly ionized atoms, the observed wave numbers are plotted against atomic numbers for this combination in the Co I-like spectra Rb XI to Mo XVI, and compared with the closely related X-ray transition of the same elements.

Edlén's unit,  $10^3 \text{ cm}^{-1}$ , has here been changed to  $\text{cm}^{-1}$ .

## REFERENCES

- B. Edlén, Physica **13**, No. 9, 550 (1947).  
B. Edlén, letter (July 1950). (T)

## Zr XIV

Config.	Desig.	$J$	Level	Interval
$3p^6 3d^9$	$3d^9 \ ^2D$	$2\frac{1}{2}$ $1\frac{1}{2}$	$0$ $20300$	$-20300$
$3p^5 3d^{10}$	$3d^{10} \ ^2P^\circ$	$1\frac{1}{2}$ $0\frac{1}{2}$	$1201800$ $1314500$	$-112700$

July 1950.



## NIOBIUM

## Nb I

41 electrons

 $Z=41$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 4d^4 5s \ ^6D_{0\frac{1}{2}}$  $a \ ^6D_{0\frac{1}{2}} \ 54600 \text{ cm}^{-1}$ 

I. P. 6.77 volts

Humphreys and Meggers have observed the Nb I spectrum from 2161.54 Å to 10920.7 Å. Of the 3313 lines recorded in this range, they have classified 2836 as combinations among 364 atomic energy levels "representing 58 doublet, 55 quartet, and 13 sextet spectral terms." The systems of terms of different multiplicity are connected by observed intersystem combinations. Zeeman patterns measured for 911 Nb I lines have been utilized in this analysis.

The limit is derived from four two-member series, namely:  $4d^4 ns \ (^6D)$  and  $4d^3 5s np \ (^6D^\circ \ ^6F^\circ \ ^6G^\circ)$  ( $n=5,6$ ), by means of a Rydberg formula.

This element is familiarly known as Columbium (Cb). The International Union of Chemistry has recently adopted Niobium as the official name of element 41. In compliance with this agreement, the revised name and symbol are adopted here.

## REFERENCES

- C. J. Humphreys and W. F. Meggers, J. Research Nat. Bur. Std. **34**, 515, RP1656 (1945).  
J. E. Mack, Rev. Mod. Phys. **22**, No. 1, 64 (1950). (Summary hfs)

## Nb I

## Nb I

Config.	Desig.	$J$	Level	Interval	Obs. $g$	Config.	Desig.	$J$	Level	Interval	Obs. $g$
$4d^4(a \ ^5D)5s$	$a \ ^6D$	$0\frac{1}{2}$	0. 00		3. 323	$4d^5$	$a \ ^6S$	$2\frac{1}{2}$	11344. 70		1. 99
		$1\frac{1}{2}$	154. 19	154. 19	1. 863	$4d^4(a \ ^3G)5s$	$a \ ^4G$	$2\frac{1}{2}$	12018. 25		0. 742
		$2\frac{1}{2}$	391. 99	237. 80	1. 652			$3\frac{1}{2}$	12136. 86	118. 61	1. 081
		$3\frac{1}{2}$	695. 25	303. 26	1. 582			$4\frac{1}{2}$	12357. 70	220. 84	1. 23
		$4\frac{1}{2}$	1050. 26	355. 01	1. 549			$5\frac{1}{2}$	13012. 20	654. 50	1. 26
$4d^3 5s^2$	$a \ ^4F$	$1\frac{1}{2}$	1142. 79		0. 402	$4d^3 5s^2$	$a \ ^2H$	$4\frac{1}{2}$	12102. 12		0. 93
		$2\frac{1}{2}$	1586. 90	444. 11	1. 029			$5\frac{1}{2}$	12502. 97	400. 85	1. 10
		$3\frac{1}{2}$	2154. 11	567. 21	1. 235	$4d^4(b \ ^3F)5s$	$b \ ^4F$	$1\frac{1}{2}$	12288. 25		0. 402
		$4\frac{1}{2}$	2805. 36	651. 25	1. 330			$2\frac{1}{2}$	12692. 12	403. 87	0. 852
$4d^3 5s^2$	$a \ ^4P$	$0\frac{1}{2}$	4998. 17		2. 650			$3\frac{1}{2}$	12982. 38	290. 26	1. 120
		$1\frac{1}{2}$	5297. 92	299. 75	1. 721			$4\frac{1}{2}$	13145. 71	163. 33	1. 224
		$2\frac{1}{2}$	5965. 45	667. 53	1. 596	$4d^3 5s^2$	$a \ ^2F$	$2\frac{1}{2}$	13404. 77		0. 860
$4d^4(a \ ^5D)5s$	$a \ ^4D$	$1\frac{1}{2}$	8410. 90		0. 06			$3\frac{1}{2}$	13515. 20	110. 43	1. 130
		$1\frac{1}{2}$	8705. 32	294. 42	1. 197	$4d^4(a \ ^3P)5s$	$b \ ^4P$	$0\frac{1}{2}$	13629. 15		2. 64
		$2\frac{1}{2}$	9043. 14	337. 82	1. 360			$1\frac{1}{2}$	14211. 30	592. 15	1. 71
		$3\frac{1}{2}$	9497. 52	454. 38	1. 420			$2\frac{1}{2}$	14899. 26	687. 96	1. 54
$4d^3 5s^2$	$a \ ^2G$	$3\frac{1}{2}$	8827. 00		0. 885	$4d^4(a \ ^3D)5s$	$b \ ^4D$	$3\frac{1}{2}$	15282. 35		1. 43
		$4\frac{1}{2}$	9328. 88	501. 88	1. 103			$2\frac{1}{2}$	15467. 08	—184. 73	1. 42
$4d^3 5s^2$	$a \ ^2D$	$1\frac{1}{2}$	9439. 08		0. 953			$1\frac{1}{2}$	15439. 25	27. 83	1. 21
		$2\frac{1}{2}$	10237. 51	798. 43	1. 206			$0\frac{1}{2}$	15460. 77	—21. 52	0. 04
$4d^3 5s^2$	$a \ ^2P$	$0\frac{1}{2}$	10126. 06		0. 66	$4d^3 5s(a \ ^5F)5p$	$z \ ^6G^\circ$	$1\frac{1}{2}$	16672. 00		0. 00
		$1\frac{1}{2}$	11318. 09	1192. 03	1. 175			$2\frac{1}{2}$	16981. 01	309. 01	
$4d^4(a \ ^3H)5s$	$a \ ^4H$	$3\frac{1}{2}$	10922. 74		0. 690			$3\frac{1}{2}$	17303. 96	322. 95	
		$4\frac{1}{2}$	11044. 08	121. 34	0. 984			$4\frac{1}{2}$	17937. 26	633. 30	
		$5\frac{1}{2}$	11247. 88	203. 80	1. 12			$5\frac{1}{2}$	18435. 14	497. 88	
		$6\frac{1}{2}$	11524. 65	276. 77	1. 22			$6\frac{1}{2}$	18876. 46	441. 32	

## Nb I—Continued

## Nb I—Continued

Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>	Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>
$4d^4(a^3H)5s$	$b^2H$	$4\frac{1}{2}$ $5\frac{1}{2}$	16828. 52 17476. 22	647. 70	1. 04 1. 01	$4d^4(a^5D)5p$	$y^4D^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$	26717. 73 26936. 86 27359. 70 27596. 74	219. 13 422. 84 237. 04	1. 141 1. 292 1. 32 1. 422
$4d^4(a^3G)5s$	$b^2G$	$3\frac{1}{2}$ $4\frac{1}{2}$	16918. 78 18035. 97	1117. 19	0. 88 0. 97	$4d^4(a^3H)5p$	$z^2G^\circ$	$3\frac{1}{2}$ $4\frac{1}{2}$	26896. 68 27331. 80	435. 12	1. 013 1. 078
	183	$5\frac{1}{2}$	18332. 04			$4d^3 5s(c^3P)5p$	$y^4P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$	27498. 94 27782. 57 28445. 33	283. 63 662. 76	2. 467 1. 660 1. 606
$4d^3 5s(a^5F)5p$	$z^6F^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$ $4\frac{1}{2}$ $5\frac{1}{2}$	18791. 09 19036. 55 19427. 90 19916. 69 20432. 11	245. 46 391. 35 488. 79 515. 42	−0. 373 1. 145 1. 35 1. 39 1. 44		276°	$2\frac{1}{2}$	27614. 10		1. 370
$4d^3 5s(a^5F)5p$	$z^6D^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$ $4\frac{1}{2}$	19623. 96 19765. 18 19993. 78 20315. 74 20733. 38	141. 22 228. 60 321. 96 418. 14	3. 01 1. 72 1. 56 1. 55 1. 54	$4d^3 5s(c^3P)5p$	$x^4D^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$	27666. 46 28079. 09 28549. 42 29209. 42	412. 63 470. 33 660. 00	0. 222 1. 443 1. 472 1. 241
$4d^3 5s(a^3F)5p$	$z^4D^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$	20107. 86 20383. 62 20837. 98 21512. 18	276. 26 454. 36 674. 20	−0. 02 1. 26 1. 39 1. 44	$4d^3 5s(a^3F)5p$	$z^2F^\circ$	$2\frac{1}{2}$ $3\frac{1}{2}$	27797. 44 28535. 36	737. 92	1. 16 1. 12
$4d^4(a^5D)5p$	$z^4P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$	22006. 74 23006. 86 23684. 44	1000. 12 677. 58	2. 47 1. 61 1. 477	$4d^3 5s(a^3F)5p$	$y^2G^\circ$	$3\frac{1}{2}$ $4\frac{1}{2}$	27855. 13 28433. 74	578. 61	0. 92 1. 12
$4d^3 5s(a^3F)5p$	$z^4G^\circ$	$2\frac{1}{2}$ $3\frac{1}{2}$ $4\frac{1}{2}$ $5\frac{1}{2}$	22647. 03 23022. 56 23536. 77 24203. 05	375. 53 514. 21 666. 28	0. 578 0. 98 1. 15 1. 25		$z^2P^\circ$	$1\frac{1}{2}$ $0\frac{1}{2}$	27918. 85 28442. 16	−523. 31	1. 450 0. 772
$4d^3 5s(a^3F)5p$	$z^4F^\circ$	$1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$ $4\frac{1}{2}$	23243. 87 23574. 14 24015. 11 24506. 53	330. 27 440. 97 491. 42	0. 416 1. 061 1. 243 1. 336	$4d^4(a^3P)5p$	$z^4S^\circ$	$1\frac{1}{2}$	28208. 48		1. 794
$4d^4(a^3P)5p$	$z^2D^\circ$	$1\frac{1}{2}$ $2\frac{1}{2}$	23525. 80 24773. 03	1247. 23	0. 898 1. 30	$4d^3 5s(a^5P)5p$	$y^6P^\circ$	$1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$	28278. 25 28652. 66 28973. 12	374. 41 320. 46	1. 981 1. 768 1. 701
$4d^4(a^3P)5p$	$z^2S^\circ$	$0\frac{1}{2}$	23910. 90		2. 123	$4d^3 5s(b^3G)5p$	$z^4H^\circ$	$3\frac{1}{2}$ $4\frac{1}{2}$ $5\frac{1}{2}$ $6\frac{1}{2}$	29271. 99 29519. 05 29846. 50 30191. 25	247. 06 327. 45 344. 75	0. 890 1. 01 1. 15 1. 23
$4d^4(a^5D)5p$	$y^6F^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$ $4\frac{1}{2}$ $5\frac{1}{2}$	23984. 87 24164. 79 24396. 80 24769. 91 25199. 81 25680. 36	179. 92 232. 01 373. 11 429. 90 480. 55	−0. 601 1. 060 1. 306 1. 380 1. 427 1. 450	$4d^4(a^3H)5p$	$y^4G^\circ$	$2\frac{1}{2}$ $3\frac{1}{2}$ $4\frac{1}{2}$ $5\frac{1}{2}$	29359. 58 29762. 70 30117. 32 30657. 60	403. 12 354. 62 540. 28	0. 693 0. 999 1. 276 1. 25
$4d^4(a^5D)5p$	$z^6P^\circ$	$1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$	24283. 34 24543. 13 24904. 86	259. 79 361. 73	2. 382 1. 874 1. 703	$4d^3 5s(a^3F)5p$	$y^2D^\circ$	$1\frac{1}{2}$ $2\frac{1}{2}$	29622. 73 29775. 80	153. 07	0. 81 1. 348
$4d^3 5s(a^5P)5p$	$y^6D^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$ $4\frac{1}{2}$	25379. 81 26067. 06 26386. 36 26832. 43 27419. 62	187. 25 319. 30 446. 07 587. 19	3. 22 1. 820 1. 610 1. 248 1. 422	$4d^4(b^3F)5p$	$x^4F^\circ$	$1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$ $4\frac{1}{2}$	29779. 44 29987. 45 30161. 56 30279. 23	208. 01 174. 11 117. 67	0. 42 1. 006 1. 18 1. 20
$4d^4(a^5D)5p$	$z^6P^\circ$	$1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$	24283. 34 24543. 13 24904. 86	259. 79 361. 73	2. 382 1. 874 1. 703	$4^3 5s(a^5P)5p$	$z^6S^\circ$	$2\frac{1}{2}$	30059. 60		
$4d^3 5s(a^5P)5p$	$y^6D^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$ $4\frac{1}{2}$	25379. 81 26067. 06 26386. 36 26832. 43 27419. 62	187. 25 319. 30 446. 07 587. 19	3. 22 1. 820 1. 610 1. 248 1. 422	$4d^4(a^1D)5p$	$y^2F^\circ$	$2\frac{1}{2}$ $3\frac{1}{2}$	30716. 50 31025. 52	309. 02	0. 891 1. 139
$4d^4(a^5D)5p$	$y^4F^\circ$	$1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$ $4\frac{1}{2}$	25930. 01 26060. 65 26165. 79 26440. 33	130. 64 105. 14 274. 54	0. 467 1. 085 1. 245 1. 334	$4d^3 5s(a^5F)5p$	$x^4G^\circ$	$2\frac{1}{2}$ $3\frac{1}{2}$ $4\frac{1}{2}$ $5\frac{1}{2}$	31056. 60 31485. 20 32004. 63 32572. 72	428. 60 519. 43 568. 09	0. 630 1. 012 1. 160 1. 24
$4d^4(a^5D)5p$	$x^6D^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$ $4\frac{1}{2}$	26552. 40 26713. 32 26983. 34 27427. 07 27974. 87	160. 92 270. 02 443. 73 547. 80	2. 441 1. 45 1. 618 1. 567 1. 542	$4d^3 5s(c^3P)5p$	$y^4S^\circ$	$1\frac{1}{2}$	31174. 65		1. 957
						$4d^3 5s(a^5F)5p$	$w^4F^\circ$	$1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$ $4\frac{1}{2}$	31551. 46 32013. 40 32333. 18 32923. 87	461. 94 319. 78 590. 69	0. 501 1. 01 1. 199 1. 24
						$4d^3 5s(b^1G)5p$	$x^2F^\circ$	$2\frac{1}{2}$ $3\frac{1}{2}$	31687. 53		1. 20



## Nb I—Continued

Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>
$4d^4(a^3D)5p$	$v^4F^\circ$	$1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$ $4\frac{1}{2}$	31707. 94 31807. 55 31973. 24 32605. 39	99. 61 165. 69 632. 15	0. 80 1. 048 1. 343 1. 216
$4d^3 5s(b^1G)5p$	$x^2G^\circ$	$3\frac{1}{2}$ $4\frac{1}{2}$	31800. 74 32213. 94	413. 20	0. 906 1. 092
$4d^4(a^3G)5p$	$u^4F^\circ$	$1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$ $4\frac{1}{2}$	31907. 74 32139. 78 32451. 99 33136. 30	232. 04 312. 21 684. 31	0. 791 1. 035 1. 115 1. 240
$4d^4(a^1G)5p$	$w^2F^\circ$	$2\frac{1}{2}$ $3\frac{1}{2}$	31933. 68 32087. 58	153. 90	0. 982 1. 074
$4d^4(a^3P)5p$	$w^4D^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$	32066. 06 32248. 69 32545. 52 33003. 89	182. 63 296. 83 458. 37	0. 046 1. 184 1. 320 1. 341
$4d^4(a^3H)5p$	$z^4I^\circ$	$4\frac{1}{2}$ $5\frac{1}{2}$ $6\frac{1}{2}$ $7\frac{1}{2}$	32156. 00 32382. 24 32672. 39 33116. 36	226. 24 290. 15 443. 97	0. 835 0. 993 1. 08 1. 19
$4d^4(b^3F)5p$	$w^4G^\circ$	$2\frac{1}{2}$ $3\frac{1}{2}$ $4\frac{1}{2}$ $5\frac{1}{2}$	32501. 33 32802. 44 33428. 20	301. 11 625. 76	1. 06 1. 21 1. 27
$4d^3 5s(a^1P)5p$	$x^2D^\circ$	$1\frac{1}{2}$ $2\frac{1}{2}$	32623. 02		1. 00
$4d^4(a^3G)5p$	$v^2F^\circ$	$2\frac{1}{2}$ $3\frac{1}{2}$	32654. 48 32899. 08	244. 60	0. 830 1. 17
$4d^3 5s(a^5F)5p$	$v^4D^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$	33011. 45 33717. 01 33872. 18 34168. 94	705. 56 155. 17 296. 76	0. 46 1. 230 1. 350 1. 390
$4d^3 5s(b^1D)5p$	$w^2D^\circ$	$1\frac{1}{2}$ $2\frac{1}{2}$	33086. 98 33389. 87	302. 89	1. 058 1. 212
$4d^3 5s(c^3P)5p$	$y^2P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	33902. 24 34252. 96	350. 72	0. 442
$4d^3 5s(a^1H)5p$	$z^2I^\circ$	$5\frac{1}{2}$ $6\frac{1}{2}$	34004. 08 34323. 20	319. 12	0. 946 1. 08
$4d^3 5s(a^1H)5p$	$w^2G^\circ$	$4\frac{1}{2}$ $3\frac{1}{2}$	34235. 04 34319. 09	—84. 05	1. 10 0. 87
$4d^4(a^3H)5p$	$z^2H^\circ$	$4\frac{1}{2}$ $5\frac{1}{2}$	34415. 52 34838. 33	422. 81	0. 819 1. 01
$4d^3 5s(a^5P)5p$	$x^4P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$	34644. 22 34867. 68 34703. 70	223. 46 —163. 98	2. 05 1. 587 1. 55
$4d^4(a^3G)5p$	$v^4G^\circ$	$2\frac{1}{2}$ $3\frac{1}{2}$ $4\frac{1}{2}$ $5\frac{1}{2}$	34654. 79 34853. 50 35156. 94 35630. 62	198. 71 303. 44 473. 68	0. 627 1. 000 1. 073 1. 160
$4d^3 5s(b^3P)5p$	$v^2D^\circ$	$1\frac{1}{2}$ $2\frac{1}{2}$	34752. 70 35497. 48	744. 78	0. 948 1. 160
$4d^3 5s(c^3P)5p$	$y^2S^\circ$	$0\frac{1}{2}$	34807. 57		2. 080
$4d^3 5s(b^1D)5p$	$u^2F^\circ$	$2\frac{1}{2}$ $3\frac{1}{2}$	35099. 86 35178. 82	78. 96	0. 868 1. 117
$4d^3 5s(b^3P)5p$	$x^4S^\circ$	$1\frac{1}{2}$	35119. 65		1. 806
$4d^4(a^3G)5p$	$y^2H^\circ$	$5\frac{1}{2}$ $4\frac{1}{2}$	35344. 86 35496. 39	—151. 53	1. 125 0. 954
$4d^4(b^3F)5p$	$u^2D^\circ$	$1\frac{1}{2}$ $2\frac{1}{2}$	35829. 46 35928. 35	98. 89	0. 834 1. 17

## Nb I—Continued

Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>
$4d^4(b^3F)5p$	$u^4D^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$	35920. 45 36016. 26 36180. 13 36334. 21	95. 81 163. 87 154. 08	0. 019 1. 195 1. 316 1. 378
$4d^3 5s(b^3G)5p$	$v^2G^\circ$	$3\frac{1}{2}$ $4\frac{1}{2}$	36048. 10 36333. 70	285. 60	0. 925 1. 086
$4d^4(a^1G)5p$	$x^2H^\circ$	$4\frac{1}{2}$ $5\frac{1}{2}$	35275. 77		1. 14
$4d^3 5s(a^5P)5p$	$w^4S^\circ$	$1\frac{1}{2}$	36371. 05		1. 948
$4d^4(a^3H)5p$	$y^4H^\circ$	$3\frac{1}{2}$ $4\frac{1}{2}$ $5\frac{1}{2}$ $6\frac{1}{2}$	36460. 34 36717. 11 36976. 10 37254. 41	256. 77 258. 99 278. 31	0. 691 0. 970 1. 15 1. 23
$4d^3 5s(b^3G)5p$	$t^2F^\circ$	$2\frac{1}{2}$ $3\frac{1}{2}$	36511. 49		
$4d^4(a^3D)5p$	$s^2F^\circ$	$2\frac{1}{2}$ $3\frac{1}{2}$	36866. 60 36979. 20	112. 60	0. 846 1. 14
$4d^4(c^3F)5p$	$t^4F^\circ$	$1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$ $4\frac{1}{2}$	37111. 67 37286. 62 37539. 67 37831. 58	174. 95 253. 05 291. 91	0. 526 0. 964 1. 172 1. 260
$4d^4(c^3F)5p$	$u^4G^\circ$	$2\frac{1}{2}$ $3\frac{1}{2}$ $4\frac{1}{2}$ $5\frac{1}{2}$	37188. 28 37348. 50 37523. 53 37760. 60	155. 22 180. 03 237. 07	0. 840 1. 058 1. 190 1. 25
$4d^4(a^5D)6s$	$e^6D$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$ $4\frac{1}{2}$	37410. 17 37578. 72 37842. 36 38177. 65 38567. 85	168. 55 263. 64 335. 29 390. 20	
$4d^4(a^3D)5p$	$t^4D^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$	37536. 56 37954. 99 38393. 49 38854. 14	418. 43 438. 50 460. 65	0. 10 1. 051 1. 371 1. 305
$4d^4(a^3G)5p$	$x^4H^\circ$	$3\frac{1}{2}$ $4\frac{1}{2}$ $5\frac{1}{2}$ $6\frac{1}{2}$	37624. 53 37866. 06 38143. 76 38513. 85	241. 53 277. 70 370. 09	0. 706 0. 992 1. 089 1. 21
$4d^4(b^3F)5p$	$r^2F^\circ$	$2\frac{1}{2}$ $3\frac{1}{2}$	37814. 64 38231. 85	417. 21	0. 876 1. 111
$4d^3 5s(b^3D)5p$	$t^2D^\circ$	$1\frac{1}{2}$ $2\frac{1}{2}$	37865. 42 38180. 32	314. 90	0. 90 1. 077
$4d^3 5s(a^5F)6s$	$e^6F$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$ $4\frac{1}{2}$ $5\frac{1}{2}$	37871. 30 38021. 41 38276. 59 38638. 47 39100. 73 39408. 88	150. 11 255. 18 361. 88 462. 26 308. 15	
$4d^4(a^3D)5p$	$x^2P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	38182. 96 38446. 78	263. 82	0. 564 1. 29
$4d^4(a^3H)5p$	$y^2I^\circ$	$5\frac{1}{2}$ $6\frac{1}{2}$	38251. 28 38583. 04	331. 76	0. 97 1. 09
$4d^3 5s(b^1G)5p$	$w^2H^\circ$	$4\frac{1}{2}$ $5\frac{1}{2}$	38448. 77 39020. 81	572. 04	0. 936 1. 084
$4d^4(a^3D)5p$	$w^4P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$	38730. 16 38709. 66 38763. 34	—20. 50 53. 68	2. 55 1. 660 1. 588
$4d^3 5s(b^3G)5p$	$s^4F^\circ$	$1\frac{1}{2}$ $2\frac{1}{2}$ $3\frac{1}{2}$ $4\frac{1}{2}$	38903. 00 39248. 30 39620. 13 40008. 52	345. 30 371. 83 388. 39	0. 448 0. 973 1. 094 1. 108



## Nb I—Continued

## Nb I—Continued

Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>	Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>
4d <sup>3</sup> 5s(b <sup>3</sup> H) 5p	<i>u</i> <sup>2</sup> G°	3½ 4½	38982. 20 39380. 77	398. 57	1. 010 1. 10	4d <sup>3</sup> 5s(b <sup>3</sup> D) 5p	<i>p</i> <sup>4</sup> D°	0½ 1½ 2½ 3½	42801. 67 42900. 07 43187. 00 43414. 44	98. 40 286. 93 227. 44	
4d <sup>3</sup> 5s(d <sup>3</sup> F) 5p	<i>t</i> <sup>2</sup> G°	3½ 4½	39426. 84 39637. 83	210. 99	0. 91 1. 04	4d <sup>3</sup> 5s(b <sup>3</sup> D) 5p	<i>o</i> <sup>2</sup> F°	2½ 3½	42888. 84		
4d <sup>3</sup> 5s(b <sup>3</sup> G) 5p	<i>t</i> <sup>4</sup> G°	2½ 3½ 4½ 5½	39530. 46 39885. 66 40421. 93 40481. 96	355. 20 536. 27 60. 03	0. 61 1. 085 1. 228 1. 18	4d <sup>3</sup> 5s(d <sup>3</sup> F) 5p	<i>p</i> <sup>4</sup> F°	1½ 2½ 3½ 4½	42894. 24 43022. 60 43173. 00 43395. 80	128. 36 150. 40 222. 80	1. 22 1. 28
4d <sup>4</sup> (a <sup>1</sup> I) 5p	<i>v</i> <sup>2</sup> H°	4½ 5½	39845. 51 40003. 00	157. 49	1. 152	4d <sup>3</sup> 5s(d <sup>3</sup> F) 5p	<i>n</i> <sup>2</sup> F°	2½ 3½	43342. 88 43553. 17	210. 29	
4d <sup>3</sup> 5s(b <sup>3</sup> D) 5p	<i>r</i> <sup>4</sup> F°	1½ 2½ 3½ 4½	39981. 20 40209. 72 40362. 00 40853. 89	228. 52 152. 28 491. 89	0. 45 0. 886 1. 129 1. 250	4d <sup>3</sup> 5s(b <sup>3</sup> D) 5p	<i>q</i> <sup>2</sup> G°	3½ 4½	43880. 22		
4d <sup>3</sup> 5s(b <sup>3</sup> H) 5p	400° <i>s</i> <sup>4</sup> G°	2½ 3½ 4½ 5½	40009. 84 40079. 30 40555. 28 40921. 15 41371. 17	475. 98 365. 87 450. 02	0. 929 1. 089 1. 243 1. 25	4d <sup>3</sup> 5s(b <sup>3</sup> D) 5p	<i>v</i> <sup>2</sup> P°	1½ 0½	44063. 49 46004. 29	—1940. 80	1. 27
4d <sup>3</sup> 5s(b <sup>1</sup> F) 5p	<i>q</i> <sup>2</sup> F°	3½ 2½	40469. 71 40735. 18	—265. 47	1. 17 0. 91	4d <sup>3</sup> 5s(b <sup>3</sup> G) 5p	<i>o</i> <sup>4</sup> D°	0½ 1½ 2½ 3½	44939. 08 44905. 54 45170. 90	—33. 54 265. 36	
4d <sup>4</sup> (c <sup>3</sup> F) 5p	<i>s</i> <sup>4</sup> D°	0½ 1½ 2½ 3½	40473. 90 40953. 36	479. 46	1. 29 1. 367	4d <sup>4</sup> (c <sup>3</sup> F) 5p	<i>u</i> <sup>2</sup> H°	4½ 5½	45110. 13 45259. 03	148. 90	1. 09
4d <sup>3</sup> 5s(b <sup>1</sup> D) 5p	<i>w</i> <sup>2</sup> P°	0½ 1½	41082. 24		1. 38	4d <sup>4</sup> (c <sup>3</sup> F) 5p	<i>m</i> <sup>2</sup> F°	2½ 3½	45297. 30		0. 94
4d <sup>3</sup> 5s(b <sup>3</sup> P) 5p	411° 414° <i>q</i> <sup>4</sup> F°	3½ 1½ 1½ 2½ 2½ 3½ 4½	41139. 95 41460. 97 41554. 86 41746. 34 41930. 87 41873. 91	191. 48 184. 53 —56. 96	0. 556 1. 25 1. 186	4d <sup>3</sup> 5s(a <sup>3</sup> F) 6p	<i>p</i> <sup>2</sup> G°	3½ 4½	45719. 07 45982. 56	263. 49	0. 84
4d <sup>4</sup> (a <sup>3</sup> G) 5p	<i>s</i> <sup>2</sup> G°	3½ 4½	41571. 61 41895. 67	324. 06		4d <sup>3</sup> 5s(a <sup>3</sup> F) 6p	<i>n</i> <sup>4</sup> D°	0½ 1½ 2½ 3½	45978. 84 46364. 79 46812. 58 47275. 64	385. 95 447. 79 463. 06	
4d <sup>3</sup> 5s(b <sup>3</sup> P) 5p	<i>r</i> <sup>4</sup> D°	0½ 1½ 3½ 2½	41676. 81 42339. 56 42551. 56 42719. 18	662. 75 212. 00 167. 62	1. 45 1. 39	4d <sup>3</sup> 5s(a <sup>3</sup> F) 6p	<i>r</i> <sup>4</sup> G°	2½ 3½ 4½ 5½	46011. 48 46470. 71 46724. 20 47080. 83	459. 23 253. 49 356. 63	
4d <sup>4</sup> (a <sup>1</sup> F) 5p	<i>p</i> <sup>2</sup> F°	2½ 3½	41829. 11 41987. 35	158. 24	0. 86 1. 135	4d <sup>3</sup> 5s(b <sup>3</sup> H) 5p	<i>o</i> <sup>4</sup> F°	1½ 2½ 3½ 4½	46170. 04 46543. 56 47022. 78 47680. 59	373. 52 479. 22 657. 81	
4d <sup>4</sup> (b <sup>3</sup> F) 5p	<i>r</i> <sup>2</sup> G°	3½ 4½	42193. 70		1. 15	4d <sup>3</sup> 5s(b <sup>3</sup> H) 5p	<i>n</i> <sup>4</sup> F°	1½ 2½ 3½ 4½	46509. 80 46932. 06 47146. 06	422. 26 214. 00	
4d <sup>4</sup> (c <sup>3</sup> F) 5p	<i>s</i> <sup>2</sup> D°	1½ 2½	42316. 90		1. 21	4d <sup>3</sup> 5s(b <sup>3</sup> H) 5p	469° <i>t</i> <sup>2</sup> H°	2½ 4½ 5½	46919. 48 46954. 40 47155. 22	200. 82	1. 00
4d <sup>3</sup> 5s(a <sup>5</sup> P) 5p	<i>q</i> <sup>4</sup> D°	0½ 1½ 2½ 3½	42324. 31 42473. 21 42642. 90 43332. 66	148. 90 169. 69 689. 76		4d <sup>3</sup> 5s(b <sup>3</sup> H) 5p	<i>o</i> <sup>2</sup> G°	3½ 4½	47528. 49 48242. 44	713. 95	0. 92 1. 10
							475° <i>n</i> <sup>2</sup> G°	1½ 3½ 4½	47537. 67 51788. 30		
						Nb II ( <sup>5</sup> D <sub>0</sub> )	Limit	-----	54600		

May 1951.

## Nb I OBSERVED TERMS\*

Config. 1s <sup>2</sup> 2s <sup>2</sup> 2p <sup>6</sup> 3s <sup>2</sup> 3p <sup>6</sup> 3d <sup>10</sup> 4s <sup>2</sup> 4p <sup>6</sup> +	Observed Terms	
4d <sup>5</sup>	<i>a</i> <sup>6</sup> S	
4d <sup>3</sup> 5s <sup>2</sup>	{ <i>a</i> <sup>4</sup> P <i>a</i> <sup>2</sup> P <i>a</i> <sup>2</sup> D <i>a</i> <sup>4</sup> F <i>a</i> <sup>2</sup> F <i>a</i> <sup>2</sup> G <i>a</i> <sup>2</sup> H	
	<i>ns</i> ( <i>n</i> ≥ 5)	<i>np</i> ( <i>n</i> ≥ 5)
4d <sup>4</sup> ( <i>a</i> <sup>5</sup> D) <i>nx</i>	{ <i>a, c</i> <sup>6</sup> D <i>a</i> <sup>4</sup> D	<i>z</i> <sup>6</sup> P° <i>x</i> <sup>6</sup> D° <i>y</i> <sup>6</sup> F° <i>z</i> <sup>4</sup> P° <i>y</i> <sup>4</sup> D° <i>y</i> <sup>4</sup> F°
4d <sup>3</sup> 5s( <i>a</i> <sup>5</sup> F) <i>nx</i>	{ <i>e</i> <sup>6</sup> F	<i>z</i> <sup>6</sup> D° <i>z</i> <sup>6</sup> F° <i>z</i> <sup>6</sup> G° <i>v</i> <sup>4</sup> D° <i>w</i> <sup>4</sup> F° <i>x</i> <sup>4</sup> G°
4d <sup>4</sup> ( <i>a</i> <sup>3</sup> P) <i>nx</i>	{ <i>b</i> <sup>4</sup> P	<i>z</i> <sup>4</sup> S° <i>w</i> <sup>4</sup> D° <i>z</i> <sup>2</sup> S° <i>z</i> <sup>2</sup> D°
4d <sup>3</sup> 5s( <i>a</i> <sup>3</sup> F) <i>nx</i>	{	<i>z, n</i> <sup>4</sup> D° <i>z, o</i> <sup>4</sup> F° <i>z, r</i> <sup>4</sup> G° <i>y</i> <sup>2</sup> D° <i>z</i> <sup>2</sup> F° <i>y</i> <sup>2</sup> G°
4d <sup>4</sup> ( <i>a</i> <sup>3</sup> H) <i>nx</i>	{ <i>a</i> <sup>4</sup> H <i>b</i> <sup>2</sup> H	<i>y</i> <sup>4</sup> G° <i>y</i> <sup>4</sup> H° <i>z</i> <sup>4</sup> I° <i>z</i> <sup>2</sup> G° <i>z</i> <sup>2</sup> H° <i>y</i> <sup>2</sup> I°
4d <sup>4</sup> ( <i>a</i> <sup>3</sup> G) <i>nx</i>	{ <i>a</i> <sup>4</sup> G <i>b</i> <sup>2</sup> G	<i>u</i> <sup>4</sup> F° <i>v</i> <sup>4</sup> G° <i>x</i> <sup>4</sup> H° <i>v</i> <sup>2</sup> F° <i>s</i> <sup>2</sup> G° <i>y</i> <sup>2</sup> H°
4d <sup>3</sup> 5s( <i>a</i> <sup>5</sup> P) <i>nx</i>	{	<i>z</i> <sup>6</sup> S° <i>y</i> <sup>6</sup> P° <i>y</i> <sup>6</sup> D° <i>w</i> <sup>4</sup> S° <i>x</i> <sup>4</sup> P° <i>q</i> <sup>4</sup> D°
4d <sup>4</sup> ( <i>a</i> <sup>1</sup> D) <i>nx</i>	{	<i>y</i> <sup>2</sup> F°
4d <sup>4</sup> ( <i>b</i> <sup>3</sup> F) <i>nx</i>	{ <i>b</i> <sup>4</sup> F	<i>u</i> <sup>4</sup> D° <i>x</i> <sup>4</sup> F° <i>w</i> <sup>4</sup> G° <i>u</i> <sup>2</sup> D° <i>r</i> <sup>2</sup> F° <i>r</i> <sup>2</sup> G°
4d <sup>4</sup> ( <i>a</i> <sup>3</sup> D) <i>nx</i>	{ <i>b</i> <sup>4</sup> D	<i>w</i> <sup>4</sup> P° <i>t</i> <sup>4</sup> D° <i>v</i> <sup>4</sup> F° <i>x</i> <sup>2</sup> P° <i>s</i> <sup>2</sup> F°
4d <sup>3</sup> 5s( <i>b</i> <sup>3</sup> P) <i>nx</i>	{	<i>x</i> <sup>4</sup> S° <i>r</i> <sup>4</sup> D° <i>v</i> <sup>2</sup> D°
4d <sup>4</sup> ( <i>a</i> <sup>1</sup> G) <i>nx</i>	{	<i>w</i> <sup>2</sup> F° <i>x</i> <sup>2</sup> H°
4d <sup>4</sup> ( <i>a</i> <sup>1</sup> I) <i>nx</i>	{	<i>v</i> <sup>2</sup> H°
4d <sup>3</sup> 5s( <i>b</i> <sup>3</sup> G) <i>nx</i>	{	<i>s</i> <sup>4</sup> F° <i>t</i> <sup>4</sup> G° <i>z</i> <sup>4</sup> H° <i>t</i> <sup>2</sup> F° <i>v</i> <sup>2</sup> G° <i>u</i> <sup>2</sup> H°
4d <sup>3</sup> 5s( <i>b</i> <sup>1</sup> G) <i>nx</i>	{	<i>x</i> <sup>2</sup> F° <i>x</i> <sup>2</sup> G° <i>w</i> <sup>2</sup> H°
4d <sup>3</sup> 5s( <i>b</i> <sup>3</sup> H) <i>nx</i>	{	<i>s</i> <sup>4</sup> G° <i>t</i> <sup>2</sup> H° <i>u</i> <sup>2</sup> G°
4d <sup>4</sup> ( <i>a</i> <sup>1</sup> F) <i>nx</i>	{	<i>p</i> <sup>2</sup> F°
4d <sup>3</sup> 5s( <i>b</i> <sup>3</sup> D) <i>nx</i>	{	<i>v</i> <sup>2</sup> P° <i>p</i> <sup>4</sup> D° <i>r</i> <sup>4</sup> F° <i>t</i> <sup>2</sup> D° <i>o</i> <sup>2</sup> F°
4d <sup>3</sup> 5s( <i>c</i> <sup>3</sup> P) <i>nx</i>	{	<i>y</i> <sup>4</sup> S° <i>y</i> <sup>4</sup> P° <i>x</i> <sup>4</sup> D° <i>y</i> <sup>2</sup> S° <i>y</i> <sup>2</sup> P°
4d <sup>3</sup> 5s( <i>a</i> <sup>1</sup> P) <i>nx</i>	{	<i>x</i> <sup>2</sup> D°
4d <sup>4</sup> ( <i>c</i> <sup>3</sup> F) <i>nx</i>	{	<i>s</i> <sup>4</sup> D° <i>t</i> <sup>4</sup> F° <i>u</i> <sup>4</sup> G° <i>s</i> <sup>2</sup> D° <i>m</i> <sup>2</sup> F° <i>p</i> <sup>2</sup> G°
4d <sup>3</sup> 5s( <i>a</i> <sup>1</sup> H) <i>nx</i>	{	<i>w</i> <sup>2</sup> G° <i>z</i> <sup>2</sup> I°
4d <sup>3</sup> 5s( <i>b</i> <sup>1</sup> D) <i>nx</i>	{	<i>w</i> <sup>2</sup> P° <i>w</i> <sup>2</sup> D° <i>u</i> <sup>2</sup> F°
4d <sup>3</sup> 5s( <i>d</i> <sup>3</sup> F) <i>nx</i>	{	<i>p</i> <sup>4</sup> F° <i>t</i> <sup>2</sup> G° <i>n</i> <sup>2</sup> F°
4d <sup>3</sup> 5s( <i>b</i> <sup>1</sup> F) <i>nx</i>	{	<i>q</i> <sup>2</sup> F°

\*For predicted terms in the spectra of the Nb I isoelectronic sequence, see Vol. II, Introduction.

## Nb II

(Zr I sequence; 40 electrons)

Z=41

Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 4d^4 {}^5D_0$  $a {}^5D_0$  113000  $\pm$  cm<sup>-1</sup>I. P. 14  $\pm$  volts

The analysis is by Humphreys and Meggers, who have observed the spectrum from 2002.41 Å to 7026.15 Å. Of the 1723 lines recorded by them, 1494 are classified. The singlet, triplet, and quintet systems of terms are connected by observed intersystem combinations. The analysis is confirmed in great detail by the Zeeman patterns observed for 646 Nb II lines.

No series have been found. "The evidence from other spectra indicates that the principal ionization potential . . . will be about 14 volts." The approximate value of the limit corresponding to this ionization potential is quoted above and entered in brackets in the table.

## REFERENCE

C. J. Humphreys and W. F. Meggers, J. Research Nat. Bur. Std. **34**, 481 RP 1656 (1945). (I P) (T) (C L) (Z E)

## Nb II

## Nb II

Config.	Desig.	J	Level	Interval	Obs. g	Config.	Desig.	J	Level	Interval	Obs. g
4d <sup>4</sup>	a <sup>5</sup> D	0	0.00		0/0	4d <sup>3</sup> ( <sup>2</sup> G)5s	b <sup>3</sup> G	3	15551.30		0.767
		1	158.99	158.99	1.500			4	15949.40	398.10	1.027
		2	438.38	279.39	1.490			5	16052.72	103.32	1.190
		3	801.38	363.00	1.486						
		4	1224.87	423.49	1.495						
4d <sup>3</sup> (a <sup>4</sup> F)5s	a <sup>5</sup> F	1	2356.76		0.000	4d <sup>3</sup> ( <sup>2</sup> G)5s	b <sup>1</sup> G	4	16219.04		0.950
		2	2629.07	272.31	0.996						
		3	3029.57	400.50	1.248						
		4	3542.50	512.93	1.350						
		5	4146.00	603.50	1.390						
4d <sup>4</sup>	a <sup>3</sup> P	0	5562.26		0/0	4d <sup>3</sup> ( <sup>2</sup> H)5s	a <sup>1</sup> S	0	17202.72		0/0
		1	6192.33		1.495						
		2	7261.33	630.07	1.450						
4d <sup>3</sup> (a <sup>4</sup> F)5s	a <sup>3</sup> F	2	7505.78		0.712	4d <sup>3</sup> ( <sup>2</sup> D)5s	b <sup>3</sup> H	6	17424.88		1.154
		3	7900.65	394.87	1.070			5	17292.49	132.39	1.052
		4	8320.40	419.75	1.230			4	17469.77	-177.28	0.880
4d <sup>4</sup>	a <sup>3</sup> H	4	9509.67		0.825	4d <sup>3</sup> ( <sup>4</sup> P)5s	c <sup>3</sup> P	0	20347.55		0/0
		5	9812.56	302.89	1.050			1	21039.56	692.01	1.218
		6	10186.41	373.85	1.157			2	21511.46	471.90	1.468
4d <sup>4</sup>	a <sup>3</sup> G	3	10247.04		0.765	4d <sup>3</sup> ( <sup>2</sup> P)5s	a <sup>1</sup> P	1	20437.58		1.115
		4	10604.28	357.24	1.052						
		5	10918.52	314.24	1.180						
4d <sup>3</sup> ( <sup>4</sup> P)5s	a <sup>5</sup> P	1	10653.40		2.477	4d <sup>4</sup>	c <sup>3</sup> F	2	20657.82		0.670
		2	10835.85	182.45	1.815			3	21117.47	459.65	1.080
		3	11339.56	503.71	1.663			4	21472.52	355.05	1.240
4d <sup>4</sup>	a <sup>1</sup> D	2	12263.26		1.003	4d <sup>3</sup> ( <sup>2</sup> H)5s	a <sup>1</sup> H	5	21073.05		0.992
4d <sup>4</sup>	b <sup>3</sup> F	2	12805.98		0.849	4d <sup>3</sup> ( <sup>2</sup> D)5s	b <sup>1</sup> D	2	24332.87		0.98
		3	13690.20	884.22	1.150						
		4	13665.68	-24.52	1.152						
4d <sup>4</sup>	a <sup>3</sup> D	3	13054.69		1.246	4d <sup>3</sup> ( <sup>2</sup> F)5s	d <sup>3</sup> F	4	25357.50		0.93
		2	13479.50	-424.81	1.002			3	25353.66	3.84	0.71
		1	13118.62	360.88	0.512			2	25414.24	-60.58	
4d <sup>3</sup> ( <sup>2</sup> P)5s	b <sup>3</sup> P	2	14660.77		1.483	4d <sup>4</sup>	d <sup>3</sup> P	2	27282.18		1.49
		1	14626.26	34.51	1.504			1	27794.15	-511.97	1.49
		0	14678.40	-52.14	0/0			0	28001.37	-207.22	0/0
4d <sup>4</sup>	a <sup>1</sup> G	4	14790.79		1.083	4d <sup>3</sup> ( <sup>2</sup> F)5s	c <sup>1</sup> G	4	29634.24		1.087
4d <sup>4</sup>	a <sup>1</sup> I	6	15396.10		1.000	4d <sup>3</sup> ( <sup>2</sup> F)5s	b <sup>1</sup> F	3	31762.31		1.01
4d <sup>4</sup>						4d <sup>3</sup> (a <sup>4</sup> F)5p	z <sup>5</sup> G <sup>o</sup>	2	33351.00		0.345
								3	33919.20	568.20	0.913
								4	34632.00	712.80	1.152
								5	35474.17	842.17	1.250
								6	36455.47	981.30	1.31



## Nb II—Continued

## Nb II—Continued

Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>	Config.	Desig.	<i>J</i>	Level	Interval	Obs. <i>g</i>
4d <sup>3</sup> (a <sup>4</sup> F)5 <i>p</i>	<i>z</i> <sup>3</sup> D°	1 2 3	34886. 33 35520. 83 36553. 27	634. 50 1032. 44	0. 420 1. 138 1. 311	4d <sup>3</sup> ( <sup>2</sup> H)5 <i>p</i>	<i>z</i> <sup>3</sup> I°	5 6 7	48130. 50 48617. 49 49389. 73	486. 99 772. 24	0. 870 1. 051 1. 15
4d <sup>3</sup> (a <sup>4</sup> F)5 <i>p</i>	<i>z</i> <sup>5</sup> F°	1 2 3 4 5	36731. 79 36962. 76 37376. 91 37528. 39 38024. 32	230. 97 414. 15 151. 48 495. 93	0. 122 1. 023 1. 266 1. 325 1. 357	4d <sup>3</sup> ( <sup>2</sup> G)5 <i>p</i>	<i>z</i> <sup>1</sup> G°	4	48253. 44		1. 083
4d <sup>3</sup> (a <sup>4</sup> F)5 <i>p</i>	<i>z</i> <sup>5</sup> D°	0 1 2 3 4	37298. 20 37480. 03 37797. 29 38216. 37 38291. 25	181. 83 317. 26 419. 08 74. 88	0/0 1. 460 1. 469 1. 466 1. 473	4d <sup>3</sup> ( <sup>2</sup> P)5 <i>p</i>	<i>z</i> <sup>1</sup> P°	1	48520. 41		0. 936
4d <sup>3</sup> (a <sup>4</sup> F)5 <i>p</i>	<i>z</i> <sup>3</sup> G°	3 4 5	38684. 96 39335. 30 40103. 61	650. 34 768. 31	0. 764 1. 072 1. 234	4d <sup>3</sup> ( <sup>2</sup> H)5 <i>p</i>	<i>y</i> <sup>1</sup> G°	4	49158. 16		0. 950
4d <sup>3</sup> (a <sup>4</sup> F)5 <i>p</i>	<i>z</i> <sup>3</sup> F°	2 3 4	38984. 40 39779. 95 40561. 00	795. 55 781. 05	0. 691 1. 088 1. 260	4d <sup>3</sup> ( <sup>2</sup> P)5 <i>p</i>	<i>x</i> <sup>3</sup> D°	1 2 3	49687. 72 49245. 55 49759. 19	—442. 17 513. 64	0. 820 1. 257 1. 288
4d <sup>3</sup> ( <sup>2</sup> P)5 <i>p</i>	<i>z</i> <sup>1</sup> S°	0	39791. 90		0/0	4d <sup>2</sup> 5s( ) 5 <i>p</i>	495°	2	49536. 62		
4d <sup>3</sup> ( <sup>2</sup> P)5 <i>p</i>	<i>z</i> <sup>1</sup> D°	2	41710. 15		1. 312	4d <sup>3</sup> ( <sup>2</sup> D)5 <i>p</i>	<i>w</i> <sup>3</sup> D°	1 2 3	49733. 45 49772. 30 49864. 25	38. 85 91. 95	0. 616 1. 167 1. 308
4d <sup>3</sup> ( <sup>4</sup> P)5 <i>p</i>	<i>y</i> <sup>5</sup> D°	0 1 2 3 4	42596. 58 42132. 70 43618. 35 43887. 00 44970. 73	—463. 88 1485. 65 268. 65 1083. 73	0/0 1. 385 1. 347 1. 447 1. 480	4d <sup>2</sup> 5s( ) 5 <i>p</i>	500°	3	50068. 70		1. 245
4d <sup>3</sup> ( <sup>2</sup> G)5 <i>p</i>	<i>z</i> <sup>3</sup> H°	4 5 6	42868. 97 43567. 93 44532. 40	698. 96 964. 47	0. 810 1. 040 1. 167	4d <sup>3</sup> ( <sup>2</sup> D)5 <i>p</i>	<i>x</i> <sup>3</sup> P°	0 1 2	50295. 20 50474. 92 50447. 36	179. 72 —27. 56	0/0 1. 202 1. 360
4d <sup>3</sup> ( <sup>4</sup> P)5 <i>p</i>	<i>y</i> <sup>3</sup> D°	1 2 3	43649. 19 43290. 34 44638. 77	—358. 85 1348. 43	0. 980 1. 227 1. 035	4d <sup>3</sup> ( <sup>2</sup> H)5 <i>p</i>	<i>x</i> <sup>3</sup> G°	5 4 3	50497. 90 50851. 70 50585. 31	—353. 80 266. 39	1. 188 1. 171 0. 811
4d <sup>3</sup> ( <sup>4</sup> P)5 <i>p</i>	<i>z</i> <sup>5</sup> P°	1 2 3	43450. 00 44226. 81 44771. 47	776. 81 544. 66	2. 255 1. 745 1. 562	4d <sup>3</sup> ( <sup>2</sup> D)5 <i>p</i>	<i>y</i> <sup>1</sup> D°	2	51182. 16		0. 965
4d <sup>3</sup> ( <sup>4</sup> P)5 <i>p</i>	<i>z</i> <sup>3</sup> P°	0 1 2	44286. 00 44066. 65 44924. 59	—219. 35 857. 94	0/0 1. 230 1. 253	4d <sup>3</sup> ( <sup>2</sup> H)5 <i>p</i>	<i>z</i> <sup>1</sup> I°	6	51707. 49		1. 010
4d <sup>3</sup> ( <sup>2</sup> P)5 <i>p</i>	<i>y</i> <sup>3</sup> P°	0 1 2	45206. 59 45374. 96 46545. 28	168. 37 1170. 32	0/0 1. 765 1. 506	4d <sup>3</sup> ( <sup>2</sup> D)5 <i>p</i>	<i>y</i> <sup>1</sup> P°	1	51787. 87		1. 13
4d <sup>3</sup> ( <sup>2</sup> G)5 <i>p</i>	<i>z</i> <sup>1</sup> H°	5	45342. 25		1. 018	4d <sup>3</sup> ( <sup>2</sup> F)5 <i>p</i>	<i>v</i> <sup>3</sup> F°	2 3 4	51927. 28 51936. 39 52279. 64	9. 11 343. 25	0. 80 1. 085 1. 261
4d <sup>3</sup> ( <sup>2</sup> G)5 <i>p</i>	<i>y</i> <sup>3</sup> G°	3 4 5	45919. 08 45621. 97 46499. 62	—297. 11 877. 65	1. 014 1. 126 1. 171	4d <sup>2</sup> 5s( ) 5 <i>p</i> ?	<i>w</i> <sup>3</sup> P°	0 1 2	52129. 80 52214. 85 52388. 59	85. 05 173. 74	0/0 1. 43 1. 44
4d <sup>3</sup> ( <sup>2</sup> G)5 <i>p</i>	<i>y</i> <sup>3</sup> F°	2 3 4	45655. 84 46428. 63 46295. 61	772. 79 —133. 02	0. 740 1. 123 1. 111	4d <sup>3</sup> ( <sup>4</sup> P)5 <i>p</i>	<i>y</i> <sup>3</sup> S°	1	52553. 90		1. 820
4d <sup>3</sup> ( <sup>2</sup> G)5 <i>p</i>	<i>z</i> <sup>1</sup> F°	3	45802. 49		1. 085	4d <sup>2</sup> 5s( ) 5 <i>p</i>	527°	3	52714. 88		1. 415
4d <sup>3</sup> ( <sup>2</sup> D)5 <i>p</i>	<i>x</i> <sup>3</sup> F°	2 3 4	46343. 10 46949. 47 50552. 26	606. 37 3602. 79	0. 43 1. 00 1. 22	4d <sup>3</sup> ( <sup>2</sup> H)5 <i>p</i>	<i>y</i> <sup>1</sup> H°	5	52788. 10		1. 006
4d <sup>3</sup> ( <sup>2</sup> P)5 <i>p</i>	<i>z</i> <sup>3</sup> S°	1	46358. 94		1. 821	4d <sup>3</sup> ( <sup>2</sup> D)5 <i>p</i>	<i>y</i> <sup>1</sup> F°	3	53035. 95		1. 036
4d <sup>3</sup> ( <sup>4</sup> P)5 <i>p</i>	<i>z</i> <sup>5</sup> S°	2	47072. 92		1. 940	4d <sup>3</sup> ( <sup>2</sup> F)5 <i>p</i>	<i>w</i> <sup>3</sup> G°	3 4 5	53702. 02 54428. 57 55021. 20	726. 55 592. 63	0. 88 1. 062 1. 180
4d <sup>3</sup> ( <sup>2</sup> H)5 <i>p</i>	<i>y</i> <sup>3</sup> H°	4 5 6	47345. 18 48500. 80 48770. 90	1155. 62 270. 10	0. 963 1. 038 1. 132	4d <sup>3</sup> ( <sup>2</sup> F)5 <i>p</i>	<i>v</i> <sup>3</sup> D°	3 2 1	54009. 50 54124. 80 54172. 60	—115. 30 —47. 80	1. 200 1. 164 0. 527
4d <sup>3</sup> ( <sup>2</sup> D)5 <i>p</i> ?	<i>w</i> <sup>3</sup> F°	2 3 4	47755. 76 48077. 67 48627. 20	321. 91 549. 53	0. 63 1. 065 1. 100	4d <sup>3</sup> ( <sup>2</sup> F)5 <i>p</i>	<i>x</i> <sup>1</sup> F°	3	55460. 54		1. 06
						4d <sup>3</sup> ( <sup>2</sup> F)5 <i>p</i>	<i>x</i> <sup>1</sup> D°	2	55721. 74		1. 000
						4d <sup>3</sup> ( <sup>2</sup> F)5 <i>p</i>	<i>x</i> <sup>1</sup> G°	4	57145. 25		1. 000
						4d <sup>2</sup> 5s(b <sup>4</sup> F)5 <i>p</i>	<i>u</i> <sup>3</sup> F°	2 3 4	57808. 35 58502. 43 59399. 80	694. 08 897. 37	0. 98 1. 25 1. 34
						4d <sup>2</sup> 5s(b <sup>4</sup> F)5 <i>p</i>	<i>u</i> <sup>3</sup> D°	1 2 3	59622. 26 59497. 02 59705. 50	—125. 24 208. 48	0. 64 1. 19 1. 33
						4d <sup>2</sup> 5s(b <sup>4</sup> F)5 <i>p</i>	<i>v</i> <sup>3</sup> G°	3 4 5	59509. 23 60094. 50 60439. 75	585. 27 345. 25	1. 19
						Nb III ( <sup>4</sup> F <sub>1/2</sub> )	Limit	-----	113000		

## Nb II OBSERVED TERMS\*

Config. 1s <sup>2</sup> 2s <sup>2</sup> 2p <sup>6</sup> 3s <sup>2</sup> 3p <sup>6</sup> 3d <sup>10</sup> 4s <sup>2</sup> 4p <sup>6</sup> +	Observed Terms	
4d <sup>4</sup>	$\left\{ \begin{array}{lllll} a^3P & a^5D & b^3F & a^3G & a^3H \\ d^3P & a^3D & c^3F & & \\ a^1S & a^1D & a^1F & a^1G & \\ & c^1D & & c^1G & a^1I \end{array} \right.$	
	<i>ns</i> ( <i>n</i> ≥ 5)	<i>np</i> ( <i>n</i> ≥ 5)
4d <sup>3</sup> (a <sup>4</sup> F) <i>nx</i>	$\left\{ \begin{array}{l} a^5F \\ a^3F \end{array} \right.$	$\begin{array}{lll} z^5D^\circ & z^5F^\circ & z^5G^\circ \\ z^3D^\circ & z^3F^\circ & z^3G^\circ \end{array}$
4d <sup>3</sup> ( <sup>4</sup> P) <i>nx</i>	$\left\{ \begin{array}{l} a^5P \\ c^3P \end{array} \right.$	$\begin{array}{lll} z^5S^\circ & z^5P^\circ & y^5D^\circ \\ y^3S^\circ & z^3P^\circ & y^3D^\circ \end{array}$
4d <sup>3</sup> ( <sup>2</sup> P) <i>nx</i>	$\left\{ \begin{array}{l} b^3P \\ a^1P \end{array} \right.$	$\begin{array}{lll} z^3S^\circ & y^3P^\circ & x^3D^\circ \\ z^1S^\circ & z^1P^\circ & z^1D^\circ \end{array}$
4d <sup>3</sup> ( <sup>2</sup> G) <i>nx</i>	$\left\{ \begin{array}{l} b^3G \\ b^1G \end{array} \right.$	$\begin{array}{lll} y^3F^\circ & y^3G^\circ & z^3H^\circ \\ z^1F^\circ & z^1G^\circ & z^1H^\circ \end{array}$
4d <sup>3</sup> ( <sup>2</sup> H) <i>nx</i>	$\left\{ \begin{array}{l} b^3H \\ a^1H \end{array} \right.$	$\begin{array}{lll} x^3G^\circ & y^3H^\circ & z^3I^\circ \\ y^1G^\circ & y^1H^\circ & z^1I^\circ \end{array}$
4d <sup>3</sup> ( <sup>2</sup> D) <i>nx</i>	$\left\{ \begin{array}{l} b^3D \\ b^1D \end{array} \right.$	$\begin{array}{lll} x^3P^\circ & w^3D^\circ & x^3F^\circ \\ y^1P^\circ & y^1D^\circ & y^1F^\circ \end{array}$
4d <sup>3</sup> ( <sup>2</sup> F) <i>nx</i>	$\left\{ \begin{array}{l} d^3F \\ b^1F \end{array} \right.$	$\begin{array}{lll} v^3D^\circ & v^3F^\circ & w^3G^\circ \\ x^1D^\circ & x^1F^\circ & x^1G^\circ \end{array}$
4d <sup>3</sup> ( <sup>2</sup> D) <i>nx</i> §		$\begin{array}{l} w^3F^\circ \end{array}$
4d <sup>2</sup> 5s(b <sup>4</sup> F) <i>nx</i>		$\begin{array}{lll} u^3D^\circ & u^3F^\circ & v^3G^\circ \end{array}$

\*For predicted terms in the spectra of the Zr I isoelectronic sequence, see Vol. II, Introduction.

§ This entry denotes the higher of the two <sup>2</sup>D limit terms for this configuration.

## Nb III

(Y I sequence; 39 electrons)

Z=41

Ground state 1s<sup>2</sup> 2s<sup>2</sup> 2p<sup>6</sup> 3s<sup>2</sup> 3p<sup>6</sup> 3d<sup>10</sup> 4s<sup>2</sup> 4p<sup>6</sup> 4d<sup>3</sup> <sup>4</sup>F<sub>1½</sub>4d<sup>3</sup> <sup>4</sup>F<sub>1½</sub> 227005 cm<sup>-1</sup>

I. P. 28.1 volts

In 1928 Gibbs and White classified 27 lines between 2218.61 Å and 2685.75 Å as combinations between 5s <sup>4</sup>F and 5p <sup>4</sup>(DFG)<sup>o</sup>. Subsequently Eliason classified 26 additional lines, in the range from 1422.87 Å to 1599.72 Å, as combinations between the ground term, 4d<sup>3</sup> <sup>4</sup>F, and the same triad of odd terms. He confirmed the earlier work in detail, except for the level 5p <sup>4</sup>F<sub>1½</sub> at 66499.5, which he rejected.

Eliason derived an improved value of the limit by a linear extrapolation of isoelectronic sequence data. His value in round figures is entered in brackets in the table.

## REFERENCES

- R. C. Gibbs and H. E. White, Phys. Rev. **31**, 520 (1928). (T) (C L)  
 A. Y. Eliason, Phys. Rev. **43**, 745 (1933). (I P) (T) (C L)

Nb III

Nb III

Config.	Desig.	<i>J</i>	Level	Interval	Config.	Desig.	<i>J</i>	Level	Interval
$4d^3$	$4d^3\ ^4F$	$1\frac{1}{2}$	0. 0	516. 9 659. 7 762. 7	$4d^2(^3F)5p$	$5p\ ^4F^\circ$	$1\frac{1}{2}$	67095. 1 67868. 7 68787. 8	773. 6 919. 1
		$2\frac{1}{2}$	516. 9				$2\frac{1}{2}$		
		$3\frac{1}{2}$	1176. 6				$3\frac{1}{2}$		
		$4\frac{1}{2}$	1939. 3				$4\frac{1}{2}$		
$4d^2(^3F)5s$	$5s\ ^4F$	$1\frac{1}{2}$	25221. 2	515. 3 728. 4 909. 8	$4d^2(^3F)5p$	$5p\ ^4D^\circ$	$0\frac{1}{2}$	69184. 2 69674. 3 70280. 7 70588. 0	490. 1 606. 4 307. 3
		$2\frac{1}{2}$	25736. 5				$1\frac{1}{2}$		
		$3\frac{1}{2}$	26464. 9				$2\frac{1}{2}$		
		$4\frac{1}{2}$	27374. 7				$3\frac{1}{2}$		
$4d^2(^3F)5p$	$5p\ ^4G^\circ$	$2\frac{1}{2}$	63687. 4	1319. 7 1449. 4 1605. 2	----- Nb IV ( $^3F_2$ )	Limit	-----	[227005]	
		$3\frac{1}{2}$	65007. 1				-----		
		$4\frac{1}{2}$	66456. 5				-----		
		$5\frac{1}{2}$	68061. 7				-----		

April 1951.

Nb III OBSERVED TERMS\*

Config. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6 +$	Observed Terms			
$4d^3$	$4d^3\ ^4F$			
	$ns\ (n \geq 5)$	$np\ (n \geq 5)$		
$4d^2(^3F)nx$	$5s\ ^4F$	$5p\ ^4D^\circ$	$5p\ ^4F^\circ$	$5p\ ^4G^\circ$

\*For predicted terms in the spectra of the Y I isoelectronic sequence, see Vol. II, Introduction.

Nb IV

(Sr I sequence; 38 electrons)

$Z=41$

Ground state  $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^2\ ^3F_2$

$4d^2\ ^3F_2\ 308600\ \text{cm}^{-1}$

I. P. 38.3 volts

The analysis is from Lang, who has extended the earlier work on this spectrum. He lists 113 classified lines in the interval from 542.38 Å to 2249.98 Å. His limit is derived by a Rydberg formula from the 5, 6s  $^1\text{D}$  series.

The values of the  $4d\ ^1G$  and  $5p\ ^1F^\circ$  terms are tentative. "These values must be nearly correct but . . . lack confirmation which can only be supplied by the discovery of the 4f singlets."

Observed intersystem combinations connect the singlet and triplet terms.

REFERENCE

R. J. Lang, *Zeeman Verhandelingen* p. 44 (Martinus Nijhoff, The Hague, 1935). (I P) (T) (C L)



## Nb IV

## Nb IV

Config.	Desig.	<i>J</i>	Level	Interval	Config.	Desig.	<i>J</i>	Level	Interval
4d <sup>2</sup>	4d <sup>2</sup> <sup>3</sup> F	2 3 4	0. 0 1086. 4 2344. 6	1086. 4 1258. 2	4d(2D)5d	5d <sup>3</sup> P	0 1 2	165272. 1 165989. 8 166963. 7	717. 7 973. 9
4d <sup>2</sup>	4d <sup>2</sup> <sup>1</sup> G	4	3054. 6?		4d(2D)5d	5d <sup>3</sup> F	2 3 4	169199 169557 170863	358 1306
4d <sup>2</sup>	4d <sup>2</sup> <sup>1</sup> D	2	7163. 3		4d(2D)5d	5d <sup>1</sup> D	2	172552. 0	
4d <sup>2</sup>	4d <sup>2</sup> <sup>3</sup> P	0 1 2	9692. 1 10123. 5 11121. 5	431. 4 998. 0	4d(2D)6s	6s <sup>1</sup> D	2	172867. 3	
4d(2D)5s	5s <sup>1</sup> D	2	46509. 3		4d(2D)5d	5d <sup>1</sup> P	1	172993. 9	
4d(2D)5s	5s <sup>3</sup> D	1 2 3	52062. 8 52628. 7 53809. 1	565. 9 1180. 4	4d(2D)6s	6s <sup>3</sup> D	1 2 3	174484. 1 174783. 9 176319. 8	299. 8 1535. 9
4d(2D)5p	5p <sup>1</sup> F°	3	92338. 7?		4d(2D)4f	4f <sup>3</sup> F°	2 3 4	174870 177696 180927	2826 3231
4d(2D)5p	5p <sup>1</sup> D°	2	95814. 3		4d(2D)4f	4f <sup>3</sup> G°	3 4 5	184372 185218 185760	846 542
4d(2D)5p	5p <sup>1</sup> P°	1	97059. 8			<sup>1</sup> D	2	183861. 7	
4d(2D)5p	5p <sup>3</sup> D°	1 2 3	98991. 5 100388. 7 101776. 7	1397. 2 1388. 0					
4d(2D)5p	5p <sup>3</sup> F°	2 3 4	99723. 8 100384. 8 102993. 3	661. 0 2608. 5					
4d(2D)5p	5p <sup>3</sup> P°	0 1 2	105273. 5 104965. 5 105827. 5	-308. 0 862. 0					
					Nb v (2D <sub>1/2</sub> )	Limit	-----	308600	

April 1951.

## Nb IV OBSERVED TERMS\*

Config. 1s <sup>2</sup> 2s <sup>2</sup> 2p <sup>6</sup> 3s <sup>2</sup> 3p <sup>6</sup> 3d <sup>10</sup> 4s <sup>2</sup> 4p <sup>6</sup> +	Observed Terms			
4d <sup>2</sup>	{ 4d <sup>2</sup> <sup>3</sup> P      4d <sup>2</sup> <sup>1</sup> D      4d <sup>2</sup> <sup>3</sup> F      4d <sup>2</sup> <sup>1</sup> G?			
	<i>ns</i> ( <i>n</i> ≥ 5)		<i>np</i> ( <i>n</i> ≥ 5)	<i>nd</i> ( <i>n</i> ≥ 5) <i>nf</i> ( <i>n</i> ≥ 4)
4d(2D) <i>nx</i>	{ 5, 6s <sup>3</sup> D 5, 6s <sup>1</sup> D		5p <sup>3</sup> P°   5p <sup>3</sup> D°   5p <sup>3</sup> F° 5p <sup>1</sup> P°   5p <sup>1</sup> D°   5p <sup>1</sup> F°?	5d <sup>3</sup> P   5d <sup>1</sup> P   5d <sup>3</sup> F      4f <sup>3</sup> F°   4f <sup>3</sup> G°

\*For predicted terms in the spectra of the Sr I isoelectronic sequence, see Vol. II, Introduction.

## Nb v

(Rb I sequence; 37 electrons)

*Z*=41Ground state 1s<sup>2</sup> 2s<sup>2</sup> 2p<sup>6</sup> 3s<sup>2</sup> 3p<sup>6</sup> 3d<sup>10</sup> 4s<sup>2</sup> 4p<sup>6</sup> 4d <sup>2</sup>D<sub>1/2</sub>4d <sup>2</sup>D<sub>1/2</sub> 400000 cm<sup>-1</sup>

I. P. 50 volts

Thirteen lines have been classified between 464 Å and 1877 Å as combinations among six terms. The analysis is by Trawick, who has extrapolated the limit (entered in brackets in the table) from isoelectronic sequence data. Charles has recently observed six lines between 464 Å and 774 Å, which agree well with the earlier measurements. He has resolved the 4d <sup>2</sup>D—4f <sup>2</sup>F° group. Of the three terms common to the two lists, an average value is used in the table for 4d <sup>2</sup>D; 5p <sup>2</sup>P° is the same in both; and Charles' value is entered for 4f <sup>2</sup>F°; but the differences are insignificant.

## Nb v—Continued

## REFERENCES

M. W. Trawick, Phys. Rev. **46**, 63 (1934). (I P) (T) (C L)G. W. Charles, Phys. Rev. **77**, 120 (1950). (T) (C L)

## Nb v

## Nb v

Config.	Desig.	<i>J</i>	Level	Interval	Config.	Desig.	<i>J</i>	Level	Interval
$4p^6(^1S)4d$	$4d\ ^2D$	$1\frac{1}{2}$ $2\frac{1}{2}$	0 1870	1870	$4p^6(^1S)4f$	$4f\ ^2F^\circ$	$2\frac{1}{2}$ $3\frac{1}{2}$	215260 215394	134
$4p^6(^1S)5s$	$5s\ ^2S$	$0\frac{1}{2}$	75929		$4p^6(^1S)6s$	$6s\ ^2S$	$0\frac{1}{2}$	228500	
$4p^6(^1S)5p$	$5p\ ^2P^\circ$	$0\frac{1}{2}$ $1\frac{1}{2}$	129196 132800	3604					
$4p^6(^1S)5d$	$5d\ ^2D$	$1\frac{1}{2}$ $2\frac{1}{2}$	211690 212237	547	Nb vi ( $^1S_0$ )	Limit		[400000]	

March 1951.

## Nb vi

(Kr I sequence; 36 electrons)

 $Z=41$ Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6\ ^1S_0$  $4p^6\ ^1S_0$  829750  $\text{cm}^{-1}$ 

I. P. 103 volts

The analysis is far from complete. Charles has classified seven lines between 164 Å and 325 Å as due to transitions from the ground term to levels produced by  $4d$ ,  $5d$ ,  $5s$ , and  $6s$  electrons. The level values in the table are the rounded off wave numbers of the observed lines. He has estimated the limit quoted above by applying a Rydberg formula to the  $ns\ s_{\frac{1}{2}}$  levels ( $n=5,6$ ). The higher limit in the table has been determined by the writer by adding the interval of the ground term of Nb vii to the lower limit.

As for Kr I the writer has introduced the  $jl$ -coupling notation in the general form suggested by Racah. Charles has noted that the  $4d$  and  $5d$  assignments are open to some question. Consequently, the pair-coupling notation for these levels may need revision.

## REFERENCES

G. Racah, Phys. Rev. **61**, 537 (L) (1942).G. W. Charles, Phys. Rev. **77**, 120 (1950). (I P) (T) (C L)

## Nb vi

## Nb vi

Author	Config.	Desig.	<i>J</i>	Level	Author	Config.	Desig.	<i>J</i>	Level
$4p^6\ p_0$	$4p^6$	$4p^6\ ^1S$	0	0	$5d\ d_{\frac{3}{2}}?$	$4p^5(^2P_{\frac{1}{2}})5d$	$5d\ [1\frac{1}{2}]^\circ$	2 1	563220
$4d\ d_{\frac{3}{2}}$	$4p^5(^2P_{\frac{1}{2}})4d$	$4d\ [1\frac{1}{2}]^\circ$	2 1	306940	$6s\ s_{\frac{1}{2}}$	$4p^5(^2P_{\frac{1}{2}})6s$	$6s\ [1\frac{1}{2}]^\circ$	2 1	587610
$5s\ s_{\frac{1}{2}}$	$4p^5(^2P_{\frac{1}{2}})5s$	$5s\ [1\frac{1}{2}]^\circ$	2 1	402050	$6s\ s_{\frac{3}{2}}$	$4p^5(^2P_{\frac{3}{2}})6s$	$6s' [0\frac{1}{2}]^\circ$	0 1	606140
$5s\ s_{\frac{3}{2}}$	$4p^5(^2P_{\frac{3}{2}})5s$	$5s' [0\frac{1}{2}]^\circ$	0 1	419860					
$5d\ d_{\frac{5}{2}}?$	$4p^5(^2P_{\frac{1}{2}})5d$	$5d\ [0\frac{1}{2}]^\circ$	0 1	553870		Nb vii ( $^2P_{\frac{1}{2}}$ )	Limit		829750
						Nb vii ( $^2P_{\frac{3}{2}}$ )	Limit		848930

February 1951.

Nb VII

(Br I sequence; 35 electrons)

Z=41

Ground state  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^5 {}^2P^{\circ}_{1\frac{1}{2}}$

$4p^5 {}^2P^{\circ}_{1\frac{1}{2}}$  1005000  $\text{cm}^{-1}$

I. P. 125 volts

The analysis is incomplete. Charles has classified 41 lines between 197 Å and 517 Å as due to transitions from the ground term to 13 higher terms.  
He has extrapolated the value of the limit from isoelectronic sequence data.

REFERENCE

G. W. Charles, Phys. Rev. **77**, 120 (1950). (I P) (T) (C L)

Nb VII

Nb VII

Config.	Desig.	<i>J</i>	Level	Interval	Config.	Desig.	<i>J</i>	Level	Interval
$4s^2 4p^5$	$4p^5 {}^2P^{\circ}$	$1\frac{1}{2}$ $0\frac{1}{2}$	$0$ 19185	— 19185	$4s^2 4p^4(^1D)4d$	$4d' {}^2P$	$1\frac{1}{2}$ $0\frac{1}{2}?$	398817 401699	— 2882
$4s 4p^6$	$4p^6 {}^2S$	$0\frac{1}{2}$	212501		$4s^2 4p^4(^1S)4d$	$4d'' {}^2D$	$2\frac{1}{2}?$ $1\frac{1}{2}?$	403260 407544	— 4284
$4s^2 4p^4(^3P)4d$	$4d {}^4D$	$3\frac{1}{2}$ $2\frac{1}{2}$ $1\frac{1}{2}$ $0\frac{1}{2}$	270858 277702 283097	— 6844 — 5395	$4s^2 4p^4(^3P)5s$	$5s {}^4P$	$2\frac{1}{2}$ $1\frac{1}{2}?$ $0\frac{1}{2}$	416055 426310	— 10255
$4s^2 4p^4(^3P)4d$	$4d {}^4P$	$0\frac{1}{2}$ $1\frac{1}{2}$ $2\frac{1}{2}$	326509 331170 336071	4661 4901	$4s^2 4p^4(^3P)5s$	$5s {}^2P$	$1\frac{1}{2}$ $0\frac{1}{2}$	446064 458824	— 12760
$4s^2 4p^4(^3P)4d$	$4d {}^2D$	$1\frac{1}{2}$ $2\frac{1}{2}$	335593 349314	13721	$4s^2 4p^4(^1D)5s$	$5s' {}^2D$	$2\frac{1}{2}$ $1\frac{1}{2}$	455071 464153	— 9082
$4s^2 4p^4(^3P)4d$	$4d {}^2P$	$0\frac{1}{2}$ $1\frac{1}{2}?$	339687		$4s^2 4p^4(^1S)5s$	$5s'' {}^2S$	$0\frac{1}{2}$	506552	
$4s^2 4p^4(^3P)4d$	$4d {}^2F$	$3\frac{1}{2}$ $2\frac{1}{2}$	364672		Nb VIII ( ${}^3P_2$ )		Limit	-----	[1005000]
$4s^2 4p^4(^1D)4d$	$4d' {}^2D$	$2\frac{1}{2}$ $1\frac{1}{2}$	381021 396124	— 15103					

February 1951.

Nb VII OBSERVED TERMS\*

$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} +$	Observed Terms	
$4s^2 4p^5$	$4p^5 {}^2P^{\circ}$	
$4s 4p^6$	$4p^6 {}^2S$	
	$ns (n \geq 5)$	$nd (n \geq 4)$
$4s^2 4p^4(^3P)nx$	{ $5s {}^4P$ $5s {}^2P$	$4d {}^4P$ $4d {}^4D$ $4d {}^2F$
$4s^2 4p^4(^1D)nx'$		$4d {}^2P$ $4d {}^2D$
$4s^2 4p^4(^1S)nx''$	$5s' {}^2D$	$4d' {}^2P$ $4d' {}^2D$
	$5s'' {}^2S$	$4d'' {}^2D$

\*For predicted terms in the spectra of the Br I isoelectronic sequence, see Vol. II, Introduction.





## Additions and Corrections to Volume I

Since the publication of Volume I, in June 1949, some investigations have been carried out that indicate important revisions and additions to data on atomic energy levels included in that work. One survey of all the material has been made quite incidentally, because W. E. Forsythe has requested a revision of the tables of binding energies of electrons for inclusion in the forthcoming revised edition of the Smithsonian Physical Tables. H. N. Russell and the writer<sup>1</sup> have, accordingly, prepared these revised tables of binding energies for the first and second spectra of the elements H to Nb. These calculations are based on the material contained in Volumes I and II of AEL.

In the course of this work Russell<sup>2</sup> has also revised the ionization potentials of the second spectra of the elements of the iron group to take into account the Ritz correction to limits derived from series of only two members. The idea is not a new one, but the excellent series recently observed in some of these spectra now make the revisions fairly definitive. Catalán<sup>3</sup> has similarly corrected the third spectra of the elements Sc through Ga,

but from more meager data. These revised limits and ionization potentials are listed below for Sc II, Sc III; Ti II, Ti III; and V II, V III.

The tables of binding energies indicate three other corrections that should be mentioned. (1) The ionization potential of P I estimated by Finkelnburg and Stern<sup>4</sup> from a study of the regularities in the run of screening constants, appears to be preferable to the value published in Volume I. (2) The P I term  $5s^4P$  at 75064, etc., should be rejected. (3) The run of the binding energies indicates that in Si I the two  $^3D^o$  terms 45276, etc. and 48399, etc. should possibly have their configurations interchanged, but further observations are needed to settle this question.

Humphreys'<sup>5</sup> recent work on infrared atomic spectra has led to the discovery of the long awaited  $3d^2\ ^3F$  term of Ca I. In addition, he has observed and classified new infrared lines in Si I and V I; and has provisionally located the new  $3d^5\ ^4D$  term in V I.

The leading revisions for spectra in Volume I are listed below.

<sup>1</sup> C. E. Moore and H. N. Russell, J. Research Nat. Bur. Std. 48, 61, RP2285 (1952).

<sup>2</sup> H. N. Russell, J. Opt. Soc. Am. 40, 618 (1950).

<sup>3</sup> M. A. Catalán, unpublished material (April 1952).

<sup>4</sup> W. Finkelnburg and F. Stern, Phys. Rev. 77, 303 (1950).

<sup>5</sup> C. J. Humphreys, J. Research Nat. Bur. Std. 47, 262, RP2252 (1951).

Page	Spectrum	Remarks
4	He I	Observations on He I sequence, see B. Edlén, Ark. f Fys. (Stockholm) 4, No. 28, 441 (1952).
6	He II	Line 2 of text, p. e. of $\Lambda$ should read $\pm 0.0009$ .
9	Li I	$10d\ ^2D$ should read 42389 instead of 41489, and should be inserted after $10p\ ^2P^o$ .
60	F I	Add reference: K. Lidén, Ark. för Fys. 1, No. 9, 229 (Stockholm) (1949). (I P) (T) (C L) (hfs); and revise terms accordingly. Revised limit should read 140524.5 I. P. 17.418.
76	Ne I	Add reference: K. Burns, K. B. Adams, and J. Longwell, J. Opt. Soc. Am. 40, 339 (1950). (T) (C L) (revised level values). See also; C. J. Humphreys and H. J. Kostkowski, J. Research Nat. Bur. Std. 49, RP2345 (1952).
124	Al I	Add reference: W. R. S. Garton, Nature 165, 322 (1950). (T) (C L) (confirm $3p^2\ ^2S$ term).
154	Si VII	Level $2p^5\ ^3P_2^o$ should read 363170.
163	P I	See discussion above. Revised limit should read 85115, I. P. 10.55 Reject $5s\ ^4P$ term, 75064.6, etc.
174	P IX	Add reference: W. Finkelnburg and F. Stern, Phys. Rev. 77, 303 (1950). (I P) H. A. Robinson (April 1951) in private conversation has stated that the terms having the configuration $2s\ 2p^4$ need revision.
176	P X	H. A. Robinson (April 1951) in private conversation has stated that the terms having the configuration $2s\ 2p^3$ need revision.
211	A I	Line 8 of the text should read "between 781 A and 786 A." Last reference should read: W. R. Sittner and E. R. Peck, J. Opt. Soc. Am. 39, 474 (1949). (C L)

Page	Spectrum	Remarks																
243 245	Ca I	<p>Add Humphreys new term discussed above:</p> <table><tr><th>Config.</th><th>Desig.</th><th><i>J</i></th><th>Level</th><th>Interval</th></tr><tr><td rowspan="3">3d<sup>2</sup></td><td rowspan="3">3d<sup>2</sup> <sup>3</sup>F</td><td>2</td><td>43474. 87</td><td rowspan="3">14. 32 18. 91</td></tr><tr><td>3</td><td>43489. 19</td></tr><tr><td>4</td><td>43508. 10</td></tr></table>	Config.	Desig.	<i>J</i>	Level	Interval	3d <sup>2</sup>	3d <sup>2</sup> <sup>3</sup> F	2	43474. 87	14. 32 18. 91	3	43489. 19	4	43508. 10		
Config.	Desig.	<i>J</i>	Level	Interval														
3d <sup>2</sup>	3d <sup>2</sup> <sup>3</sup> F	2	43474. 87	14. 32 18. 91														
		3	43489. 19															
		4	43508. 10															
260 261 262	Sc I Sc II	<p>Reference: C. J. Humphreys, J. Research Nat. Bur. Std. <b>47</b>, 262, RP2252 (1951). (T) (C L) Racah (1951) in private conversation has suggested that the configuration of the term <math>x^2P^o</math> should read <math>4s^2(a^1S)4p</math> instead of <math>3d^2(a^1S)4p</math>.</p> <p>See discussion above. Revised limit should read <b>103240</b>, I. P. 12.80.</p>																
263	Sc III	<p>Add reference: H. N. Russell, J. Opt. Soc. Am. <b>40</b>, 618 (1950). (I P). See discussion above. Revised limit should read <b>199700</b>, I. P. 24.75.</p>																
279 280	Ti II	<p>Add references: J. E. Mack, Rev. Mod. Phys. <b>22</b>, No. 1, 64 (1950). (Summary hfs.) M. A. Catalán, unpublished material (April 1952). (I P). See discussion above. Revised limit should read <b>109506</b>, I. P. 13.57.</p>																
281 282	Ti III	<p>Add reference: H. N. Russell, J. Opt. Soc. Am. <b>40</b>, 618 (1950). (I P). See discussion above. Revised limit should read <b>221600</b>, I. P. 27.47.</p>																
291 293 297	V I	<p>Add reference: M. A. Catalán, unpublished material (April 1952). (I P). Add provisional new term by Humphreys and Kostkowski discussed above:</p> <table><tr><th>Config.</th><th>Desig.</th><th><i>J</i></th><th>Level</th><th>Inverval</th></tr><tr><td rowspan="4">3d<sup>5</sup></td><td rowspan="4"><i>c</i> <sup>4</sup>D</td><td>0½</td><td>34329. 05</td><td rowspan="4">14. 17 16. 04 7. 58</td></tr><tr><td>1½</td><td>34343. 22</td></tr><tr><td>2½</td><td>34359. 26</td></tr><tr><td>3½</td><td>34366. 84</td></tr></table>	Config.	Desig.	<i>J</i>	Level	Inverval	3d <sup>5</sup>	<i>c</i> <sup>4</sup> D	0½	34329. 05	14. 17 16. 04 7. 58	1½	34343. 22	2½	34359. 26	3½	34366. 84
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		1½	34343. 22															
		2½	34359. 26															
		3½	34366. 84															
298 300	V II	<p>Racah (1951 in private conversation) has suggested that the configuration of the term <math>e^4F</math> should read <math>3d^4(c^3F)4s</math> instead of <math>3d^5</math>. Add reference: C. J. Humphreys and H. J. Kostkowski. J. Opt. Soc. Am. <b>40</b>, 801 (A) (1950) and unpublished material (May 1951) (T) (C L) See discussion above. Revised limit should read <b>[118200]</b> I. P. 14.65.</p>																
301 302	V III	<p>Add reference: H. N. Russell, J. Opt. Soc. Am. <b>40</b>, 618 (1950). (I P). See discussion above. Revised limit should read <b>[236500]</b> I. P. 29.31. Add reference: M. A. Catalán, unpublished material (April 1952). (I P).</p>																

The writer hopes that the users of these Volumes will report further additions and corrections that come to their attention. The present list is included here in order that readers may have the benefit of these corrections while this program is still in progress.



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