LONG-WAVE ARC SPECTRA OF ALKALIS AND ALKALINE EARTHS

By William F. Meggers

ABSTRACT

New types of photographic plates sensitive to red and infrared radiation are employed to record the emission spectra of electric arcs containing alkalis or alkaline earths. Several lines characteristic of sodium, potassium, rubidium, and cesium are observed in the interval 8,500 to 11,800 A. A larger number of lines are measured in calcium, strontium, and barium spectra between the limits 6,500 and 11,300 A. Practically all of the observed lines are accounted for as combinations of identified spectral terms. A new system of band heads, presumably due to CaO, was found in the infrared.

CONTENTS

I. INTRODUCTION

Seventeen years ago I had the good fortune to be among the first to photograph infrared emission spectra with the aid of dicyanin which was at that time the best photosensitizing dye for the longer waves. The arc spectra of the alkalis, alkaline earths, and various other elements were photographed with a large concave grating, and the stronger infrared lines were recorded[1] to about 9,600 A. Now an opportunity to improve and extend these results has been created by the discovery, in the research laboratory of the Eastman Kodak Co., of vastly superior photosensitizing dyes.

Two new dyes are especially important; they have been named mesocyanine and xenocyanine. The former imparts a maximum sensitizing action at wave length 8,600 A, while the latter exhibits a very broad sensitizing band with a maximum at 9,700 A, and still appreciable beyond 12,000 A. With these materials a considerable range

[1] W. F. Meggers, B.S.Sci. Papers, vol. 14 (no. 312), p. 371, 1918.

of infrared spectra either unknown or explored heretofore only with radiometric devices become accessible to spectrography with all the advantages of high resolution and precision accompanying the photographic method. As an example of the application of improved photographic plates, new data on the red and infrared arc spectra of the alkalis and of the alkaline earths are reported in this paper.

The spectra of these elements have played an important part in the development of a theoretical interpretation of atomic spectra. Since alkali atoms possess a single valence electron and the alkaline earths only two, their spectra are of relatively simple types. Indeed, this is the reason that law and order was found in them nearly half a century ago, or shortly after the first significant connection between spectral lines was discovered for the visible lines of atomic hydrogen.

Analysis of the alkali spectra first suggested the general law that any spectral lines can be represented as the difference of two terms, any term being expressed in the form $T=R/(m+\mu)^2$, in which R has since been called the Rydberg constant, m is an integer subsequently recognized as the total-quantum number, and μ is a correction factor.

Furthermore, the discovery of series in the alkali spectra first disclosed the fact that several different types of series were present. Certain properties of these different types suggested their names ("principal", "sharp", "diffuse", "fundamental"), and the initial letters of these names have been retained in the modern notation for spectral terms. According to modern theory such series types are distinguished by the quantum number l, which in the planetary model of an atom represents the moment of momentum (in units of $h/2\pi$) of the valence electron coursing in its orbit; the l values are 0, 1, 2, 3, for S, P, D, F terms, respectively.

The pioneer studies of series in these spectra also brought out the fact that most spectral terms are complex or multiple. Spectral terms characteristic of alkalis are double, whereas those of the alkaline earths are either single or triple, but ionized atoms of the alkaline earths are again represented by doublets like the alkalis. Extension of these term multiplicities to other spectra later suggested the alternation and displacement laws of spectroscopy which now appear to be generally valid. In order to distinguish the various sublevels of a multiple term the so-called inner-quantum number "j" was empirically introduced almost 10 years ago, but it was several years later that its interpretation as the vector sum J of electron orbital momentum l and electron spin momentum s was first suggested by the doublet character of alkali spectra. Every electron is assumed to possess the same spin, which gives it an angular momentum of $sh/2\pi$ and since s always has a value of one half it follows that J values of spectral levels are always integers for odd multiplicities and half integers for even multiplicities.

Finally, analysis of the alkaline earth spectra, in the production of which two valence electrons are involved, indicated that when two (or more) electrons simultaneously play a part in radiation the quantum numbers L associated with various types of terms are to be considered as the vector sum of the l's of the individual electrons. This important discovery was the key to a complete theory of spectral terms correlated with electron configurations, now a guiding principle in the structural analysis of any atomic spectrum.

The alkali and alkaline earth spectra also have played a prominent role in the development of the theory of spectral line intensities and of

Zeeman effects, but it is unnecessary to cite any further examples to demonstrate the importance of complete and accurate descriptions of their spectra. However, despite numerous investigations during 70 years or more, it must be admitted today that improvement in the spectral data for all of these elements in still desirable. It can safely be said that scarcely any of the wave lengths are known to the third decimal in angstrom units, many of them are uncertain in the first decimal place and some are surely in error by one or more units. The results reported below represent preliminary observations of lines which either have not been recorded photographically heretofore or only with much smaller intensity and dispersion. The accuracy of the wave-length measurements may be increased only by employing sources giving sharper lines, and the estimated relative intensities should eventually be replaced by quantitative measurements.

II. WAVE-LENGTH MEASUREMENTS

The spectra here dealt with were derived from electric arcs at atmospheric pressure, the light being dispersed by large concave diffraction gratings and photographed with special types of sensitized emulsions. Chloride salts of the elements were used on graphite or on copper electrodes with an applied potential of 220 volts and direct current of 8 to 10 amperes in the arc. Bands due to carbon or its compounds which are very prominent and troublesome when graphite electrodes are used, are almost completely suppressed when an abundance of salt is present, but the difficulty with such bands was entirely eliminated by making duplicate exposures with copper electrodes. In the latter case the bands which appear are most likely due to oxides of the elements inserted in the arc.

Two concave diffraction gratings of 21.7 feet radius of curvature were employed as stigmatic spectrographs, the slit being at the principal focus of a stainless-steel mirror which then illuminates the grating with parallel light. One grating has 20,000 lines per inch and gives a scale of 3.5 A/mm, while the other has 7,500 per inch and a scale of 10.2 A/mm. The former was used in the interval 6,500 to 9,000 A, and the latter in the longer wave region from 8,500 to 12,000 A. The second is the identical grating and type of mounting employed in our earlier campaign on infrared spectra and has been described in detail elsewhere.[2]

Exposures of 30 to 60 minutes were made in the first-order spectra; the longer time designed to record faint or farther infrared lines always resulted in tremendous over-exposure of the spectrograms in the region of their maximum sensitiveness.

Eastman plates for spectroscopy have been described by C. E. K. Mees.[3] The N, P, and Q types of sensitizing were chosen for the exploration of alkaline earth spectra, but only Q plates were used on the alkalis. In other words, the arc spectra of Ca, Sr, and Ba have been photographed from the red at 6,500 A to the infrared beyond 11,000 A, but the alkali spectra were examined only in the region beyond 8,500 A. Each plate was hypersensitized in a dilute ammonia bath before use and developed in Eastman's X-ray developer after exposure. The red and infrared radiation was always recorded in

[2] W. F. Meggers and Keivin Burns, B.S. Sci. Papers, vol. 18 (no. 441), p. 191, 1922.
[3] C. E. K. Mees, J. Opt. Soc. Am., vol. 21, p. 753; 1931; vol. 22, p. 204; 1932. Addendum dated February 1932.

the first-order spectrum of the grating, the overlapping higher orders being removed by a deep-red glass filter. Adjacent to the first-order spectra on each spectrogram the arc spectrum of iron was recorded to supply standards for wave-length measurements. For the red to 8,000 A first-order comparison spectra were used, but the longer waves were measured against second- or third-order iron lines, the wave lengths being doubled or trebled to serve as first-order standards in accordance with the fundamental law of diffraction gratings. Most of the lines reported here were recorded on two or more spectrograms, and each spectrogram was measured in both directions, so that the wave length values for sharp lines in the range of larger dispersion (6,500 to 9,000 A) are expected to be correct within ± 0.01 A, while the probable errors of the remainder are several times larger on the average. Many of the lines are hazy, wide, and shaded either to longer or shorter waves; these characteristics are indicated in the tables by the letters *h*, *w*, *l*, and *v*, respectively.

III. RESULTS

1. ALKALIS

It is well known that the arc spectra of the alkali metals consist of doublets, in which the separations become larger with increasing atomic number. In general, also, the corresponding spectral series in the different elements are displaced toward longer waves as the atomic number increases. In each case the various series begin with their most intense lines in the red and infrared (detected by means of bolometers or thermopiles) and converge to limits in the ultraviolet or visible regions.[4] The first members of the principal, sharp, and diffuse series for each of the alkalis had already been recorded photographically with the following exceptions: sharp series of Na, K, Rb, Cs, and diffuse series of K, Rb, and Cs. Now with xenocyanine plates it has become possible to complete the photographic record for the sharp series of Na and for the diffuse series of K. The first members of the fundamental series still remain beyond photographic reach except for Cs, which is now easily recorded, while only the first lines are out of range for Rb and K, and all but the first two in Li and Na are now accessible to photography.

It seemed at first that observations of the fundamental series in alkali spectra might constitute the major portion of this contribution to infrared spectroscopy, but the expectations have been curtailed by the nature of the spectral lines. Fundamental series lines in general have a tendency toward excessive and unsymmetrical diffuseness, and this is especially true in alkali spectra when the source is an electric arc at atmospheric pressure. Diffuseness of the fundamental series lines is most marked in the lighter elements; the lines gradually become sharper with increasing atomic number, until in Cs they do not differ much in appearance from the so-called "diffuse-series" lines. This increasing homogeneity is no doubt due in part to the reduced Döppler-Fizeau width, but perhaps more to a smaller Stark effect as the limit

[4] Summaries of the spectral series for alkali metals were published by Paschen and Götze and by Fowler in 1922, several years before the quantum theory and the notation for spectral structures had been developed. The same data with revised notation are contained in handbooks by Grotrian and by Bacher and Goudsmit:
F. Paschen and R. Götze, Seriengesetze der Linienspektren, Julius Springer, Berlin, 1922.
A. Fowler, Report on Series in Line Spectra, Fleetway Press, London, 1922.
W. Grotrian, Handbuch der Astrophysik, III, pp. 475–602, Julius Springer, Berlin, 1930.
R. F. Bacher and S. Goudsmit, Atomic Energy States, McGraw-Hill Co., New York, 1933.

of the fundamental series sinks in the energy diagram and approaches that of the diffuse series.

(*a*) LITHIUM (Li, Z=3)

Only two lines of the fundamental series of Li have been detected radiometrically in the infrared; their approximate wave lengths are 18,697 and 12,782 A. The next succeeding lines are expected to have wave lengths of about 10,906, 10,017, 9,513 A, etc., all within the range of a xenocyanine plate. My Li spectrogram shows hazy patches at about these positions, but the lines are too diffuse to measure. In order to obtain useful wave lengths it will be necessary to use a vacuum arc or other source in which the fundamental series lines are more homogeneous.

(*b*) SODIUM (Na, Z=11)

As for Li, only two lines of the fundamental series of Na are known; their wave lengths are 18,460, 12,678 A. The succeeding lines are expected near 10,830, 9,894, 9,455 A, etc.; indications of them appear on my spectrograms, but they are too diffuse to permit of accurate measurement. The first member of the sharp series occurs near 11,400 A and is easily photographed, while a new combination is found near 10,746 A. The measured wave lengths' estimated intensities, vacuum wave numbers, and term combinations of these lines are presented in table 1.

TABLE 1.—*Arc spectrum of sodium*

Intensity	λ_{air} I.A.	ν_{vac} cm^{-1}	Term combination
10	11, 403. 96	8, 766. 49	$3^2P_{1/2}$–$4^2S_{1/2}$
6	11, 381. 62	8, 783. 69	$3^2P^\circ_{1/2}$–$4^2S_{1/2}$
2	10, 748. 7	9, 300. 9	$4^2S_{1/2}$–$5^2P^\circ_{1/2}$
4	10, 745. 9	9, 303. 3	$4^2S_{1/2}$–$5^2P^\circ_{1/2}$

(*c*) POTASSIUM (K, Z=19)

With xenocyanine plates no difficulty was experienced in recording in full detail the first lines of the diffuse series of K with wave lengths approaching 1.2 μ. This is an excellent example of two doublet terms combining to produce a multiplet of three lines, the levels of the ^2P term being separated 57.6 cm^{-1}, while an interval of 2.6 cm^{-1} occurs between the ^2D levels. These lines are reasonably sharp in the ordinary arc, because they involve relatively low energy states, but the remaining lines observed in the K arc involve higher levels and are consequently too diffuse and wide to permit definitive wave-length determinations. New data acquired with xenocyanine photography are given in table 2. Most of the lines are so very hazy and wide that capital initial letters are required to represent these characteristics.

TABLE 2.—*Arc spectrum of potassium*

Intensity	λ_{air} I.A.	ν_{vac} cm^{-}	Term combination
15r	11, 773. 05	8, 491. 65	$4^2P^o_{1½}$–$3^2D_{2½}$
3	11, 769. 41	8, 494. 28	$4^2P^o_{1½}$–$3^2D_{1½}$
10	11, 690. 17	8, 551. 85	$4^2P^o_{½}$–$3^2D_{1½}$
10HW	11, 022. 3	9, 070. 0	$3^2D_{1½}$–5^2F^o
			$3^2D_{2½}$–5^2F^o
1H	10, 487. 7	9, 532. 3	$3^2D_{1½}$–$7^2P_{½}$
3H	10, 480. 3	9, 539. 0	$3^2D_{2½}$–$7^2P^o_{1½}$
10H	9, 955. 2	10, 042. 2	$5^2S_{½}$–$7^2P^o_{½}$
20H	9, 950. 5	10, 047. 0	$5^2S_{½}$–$7^2P^o_{1½}$
20HlW	9, 597. 1	10, 417. 0	$3^2D_{1½}$–6^2F^o
50HlW	9, 591. 8	10, 422. 7	$3^2D_{2½}$–6^2F^o

(*d*) RUBIDIUM (Rb, Z=37)

Although the principal series of Rb begins with a widely separated term (237.6 cm^{-1}) no ^2P terms beyond the sixth and no ^2D or ^2F terms have been resolved. The second and third members of the fundamental series and two other doublet combinations in the infrared have now been photographed with xenocyanine plates. All of these lines are too hazy and unsymmetrical for precision measurements, but two of the pairs show separations of 19.3 cm^{-1} and, therefore, involve the 6^2P term. The fundamental series members are observed also as pairs (with separations of 20.6 and 10.5 cm^{-1}), but with very anomalous intensity ratios which suggest that the two main lines are fused. Furthermore, the satellites which ordinarily have the largest wave length here appear with shorter wave length and while all of these lines are usually shaded to longer waves, the satellite at 10,053 A is unexpectedly shaded toward the violet. These peculiarities are illustrated in figure 1 and in table 3.

TABLE 3.—*Arc spectrum of rubidium*

Intensity	λ_{air} IA.	ν_{vac} cm^{-1}	Term combination
2Hl	10, 305. 3	9, 701. 1	$6^2S_{½}$ –$8^2P^o_{½}$
4Hl	10, 284. 8	9, 720. 4	$6^2S_{½}$ –$8^2P^o_{1½}$
500 Hl	10, 076. 1	9, 921. 8	4^2D –5^2F^o
30Hv	10, 055. 2	9, 942. 4	4^2D –5^2F^o
5Hl	9, 540. 8	10, 478. 4	$4^2D_{1½}$–$8^2P^o_{½}$
10Hl	9, 523. 4	10, 497. 6	$4^2D_{2½}$–$8^2P^o_{1½}$
100 Hl	8, 869. 7	11, 271. 2	4^2D –6^2F^o
20 Hl	8, 861. 5	11, 281. 7	4^2D –6^2F^o

(e) CESIUM (Cs, Z=55)

In the arc spectrum of Cs Fowler lists the separations of nine successive ^2P terms and of five terms in the ^2D sequence. The ^2F terms were not resolved until Meissner [5] examined the vacuum arc spectrum of Cs with a Fabry-Perot interferometer and found satellites close to

[5] K. W. Meissner, Ann. d. Phys., vol. 65, p. 378, 1921.

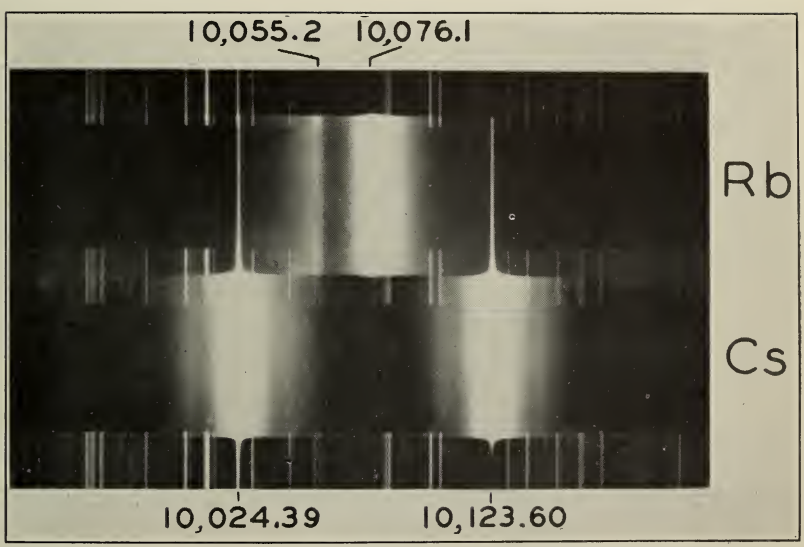

FIGURE 1.—*Fundamental series lines in arc spectra of rubidium and cesium.*

the stronger lines of longer wave length, but on the violet side. Data for the second member of the fundamental series are as follows:

Combination	Intensity	Wave length A	Separation cm^{-1}	
$^2D_{2½}$–$^2F^3_{3½}$	10	8, 079. 021		
$^2D_{2½}$–$^2F^3_{3½}$	2	8, 078. 923	97. 59	97. 74
$^2D_{1½}$–$^2F^3_{2½}$	10	8, 015. 710		

This shows that the F terms for Cs are very narrow doublets, and furthermore that they are inverted so that the lower energy level has the larger j value.

The arc spectrum of cesium is the only one in which the first lines of the fundamental series are within easy reach of the xenocyanine plate. It is also the first alkali spectrum in which lines of this type become sharp enough to observe reasonably well in the ordinary arc. A reproduction of the lines beyond 10,000 A is shown in figure 1. The two Cs lines appear to be about equal in intensity, but if allowance is made for the gradual decline in photographic sensitivity, the line of greater wave length must be judged the more intense. The theoretical intensity ratio is 21 to 14 if the intensity of the satellite (1) is added to that of the stronger component (20). Data for infrared lines of Cs photographed with xenocyanine are presented in table 4. The observed separation of the fundamental series doublet (97.73 cm^{-1}) is in excellent agreement with the value (97.74 cm^{-1}) found by Meissner between the main lines of the second member.

TABLE 4.—*Arc spectrum of cesium*

Intensity	λ_{air} I.A.	ν_{vac} cm^{-1}	Term combination
1,200	10, 123. 60	9, 875. 20	$5^2D_{2½}$–$4^2F^3_{3½}$
1,000	10, 024. 39	9, 972. 93	$5^2D_{1½}$–$4^2F^3_{2½}$
200	9, 208. 46	10, 856. 60	$6^2P^0_{1½}$–$6^2D_{1½}$
1,000	9, 172. 24	10, 899. 48	$6^2P^0_{1½}$–$6^2D_{2½}$
2,000 R	8, 943. 50	11, 178. 24	$6^2S_{½}$–$6^2P^0_{½}$
500	8, 761. 38	11, 410. 60	$6^2P^0_{½}$–$6^2D_{1½}$
4,000 R	8, 521. 10	11, 732. 35	$6^2S_{½}$–$6^2P^0_{1½}$

2. ALKALINE EARTHS

Compared with the simple doublet spectra of alkali atoms the presence of two valence electrons in alkaline earth (or earth) atoms produces very similar types of spectral series except that the multiplicities are odd, and two complete sets of terms appear, one set belonging to the singlet and the other to the triplet system. When alkaline earth atoms are singly ionized, so that only one valence electron remains, the atoms again exhibit doublet spectra like the neutral alkalis, but the corresponding lines are displaced toward higher frequencies. The published information on the structural analyses of alkaline earth spectra will be found in the treatises referred to above.[6] New terms reported by Russell and Saunders [7] accounted for practi-

[6] See footnote 5, p. 672.
[7] H. N. Russell and F. A. Saunders, Astrophys. J. vol. 61, p. 38, 1925.

cally all of the stronger lines of Ca, Sr, and Ba, and contained a clue to the interpretation of complex spectra characteristic of atoms with two or more valence electrons. Professor Russell has still farther extended the analysis of these spectra and has kindly communicated new or revised term values with permission to use them in the interpretation of the data in this paper.

It is unfortunate that almost nothing is known of the arc spectrum of the heaviest alkaline earth—radium. Cooperation of a radium chemist and a spectroscopist could remedy this defect with little or no loss of precious material.

(a) CALCIUM (Ca, Z=20)

Exploration of the infrared arc spectrum of Ca with xenocyanine plates has yielded some new results, including a $^3P^o$–^3P multiplet (10,833 to 10,880 A) and a new system of band heads. The band spectrum of CaO in the red and adjacent infrared has been studied recently by Brodersen [8] who measured 20 band heads, arranged them all in a single system, in which both electron terms are $^1\Sigma$, and analyzed the rotation structure of three of them (7,308, 7,318, and 8,652 A). Most of these bands were also recognized on my spectrograms, although many of them are faint and lack the characteristic aspect of band heads. The vibrational analysis of these bands (system I) is displayed in table 5. Several new sequences of band heads were recorded farther in the infrared; the intervals between their vibration levels are not identifiable with those of system I, so they are arranged and presented as system II in table 5.

All the data obtained from my Ca spectrograms are collected in table 6, and the Ca I spectral terms involved in the production of red and infrared lines are shown in table 7. In this, and in succeeding tables, the letters *n*, *p*, symbolize band head and part of band, respectively.

TABLE 5.—*CaO bands*

SYSTEM I

v' \ v''	0	1	2	3	4	5
0	7, 308. 31(2) 13, 679. 29 *692. 46*		8, 152. 96(40) 12, 262. 12 *694. 8* *695. 09*	8, 642. 7(2) 11, 567. 3 *694. 8*		
1	6, 956. 18(20) 14, 371. 75 *711. 3* *686. 1*	7, 318. 4(3) 13, 660. 4 *703. 2*	7, 715. 59(5) 12, 957. 21 *695. 1* *686, 1*	8, 152. 96(40) 12, 262. 12 *707. 5* *685. 9*	8, 652. 16(20) 11, 554. 64 *686. 1*	
2		6, 968. 4(2) 14, 346. 5 *703. 2* *673. 5*	7, 327. 6(2) 13, 643. 3 *695. 3*	7, 721. 1(4) 12, 948. 0 *707. 3*	8, 167. 2(5) 12, 240. 7 *656. 1*	8, 629. 8(1) 11, 584. 6
3			6, 982. 9(3) 14, 316. 8			

[8] P. H. Brodersen, Zeitschr. f. Phys. vol. 79, p. 613, 1932.

TABLE 5.—*CaO bands*—Continued

SYSTEM II

v' \ v''	0	1	2	3	4	5
0	10, 533. 6(3) 9, 490. 8 *674. 6*	(8, 853)				
1	9, 834. 7(30) 10, 165. 3 *636. 4* *667. 3*	10, 491. 5(4) 9, 528. 9 *664. 8*	(8, 907)			
2	9, 228. 9(20) 10, 832. 6 *638. 9* *655. 1*	9, 807. 3(20) 10, 193. 7 *622. 1* *655. 8*	10, 444. 7(5) 9, 571. 6	(8, 960)		
3		9, 215. 1(5) 10, 848. 8 *621. 4*	9, 775. 0(15) 10, 227. 4 *611. 6* *647. 0*	10, 396. 7(6) 9, 615. 8 *647. 3*	(9, 021)	
4			9, 193. 4(2) 10, 874. 4 *611. 3*	9, 741. 0(5) 10, 263. 1 *595. 4*	10, 339. 8(5) 9, 668. 7 *637. 8*	(9, 078)
5					9, 700. 0(10) 10, 306. 5 *590. 5*	10, 289. 5(5) 9, 716. 0

TABLE 6.—*Arc spectrum of calcium*

Intensity	λ_{air} I. A.	ν_{vac} cm^{-1}	Term combination
4	10, 879. 78	9, 188. 85	$dp\,^3P_1^\circ$–$d^2\,^3P_0$
3	10, 869. 37	9, 197. 65	$dp\,^3P_2^\circ$–$d^2\,^3P_1$
2	10, 863. 72	9, 202. 43	$dp\,^3P_1^\circ$–$d^2\,^3P_1$
3	10, 861. 51	9, 204. 31	$dp\,^3P_0^\circ$–$d^2\,^3P_1$
10	10, 838. 77	9, 223. 61	$dp\,^3P_2^\circ$–$d^2\,^3P_2$
4	10, 833. 12	9, 228. 43	$dp\,^3P_1^\circ$–$d^2\,^3P_2$
3nl	10, 533. 6	9, 490. 8	II 0, 0
4nl	10, 491. 5	9, 528. 9	II 1, 1
5nl	10, 444. 7	9, 571. 6	II 2, 2
6nl	10, 396. 7	9, 615. 8	II 3, 3
500	10, 343. 85	9, 664. 93	$4\,^1P_1^\circ$–$5\,^1S_0$
5n?	10, 339. 8	9, 668. 7	II 4, 4
5n?	10, 289. 5	9, 716. 0	II 5, 5
30nl	9, 834. 7	10, 165. 3	II 1, 0
20nl	9, 807. 3	10, 193. 7	II 2, 1
15nl	9, 775. 0	10, 227. 4	II 3, 2
5n?	9, 741. 0	10, 263. 1	II 4, 3
20	9, 701. 7	10, 304. 6	$dp\,^3D_3^\circ$–$d^2\,^3P_2$
10n?	9, 700. 0	10, 306. 5	II 5, 4
15	9, 688. 6	10, 318. 6	$dp\,^3D_2^\circ$–$d^2\,^3P_1$
5	9, 676. 0	10, 332. 0	$dp\,^3D_1^\circ$–$d^2\,^3P_0$
5p?	9, 664. 0	10, 344. 8	$dp\,^3D_2^\circ$–$d^2\,^3P_2$
20p?	9, 233. 4	10, 827. 3	
20nl	9, 228. 9	10, 832. 6	II 2, 0
5nl	9, 215. 1	10, 848. 8	II 3, 1

TABLE 6.—*Arc spectrum of calcium*—Continued

Intensity	λ_{air} I. A.	ν_{vac} cm^{-1}	Term combination
2p?	9, 193. 4	10, 874. 4	II 4, 2
1, 000	8, 662. 16	11, 541. 30	$3^2D_{1½}$–$4^2P^o_{½}$
20nl	8, 652. 16	11, 554. 64	I 1, 4
2nl	8, 642. 7	11, 567. 3	I 0, 3
1nl	8, 629. 8	11, 584. 6	I 2, 5
1, 500	8, 542. 11	11, 703. 50	$3^2D_{2½}$–$4^2P^o_{1½}$
300	8, 498. 03	11, 764. 20	$3^2D_{1½}$–$4^2P^o_{1½}$
5	8, 169. 8	12, 236. 8	$dp\,^3P^o_1$–$d.d^3S_1$
5p?	8, 167. 2	12, 240. 7	I 2, 4
40nl	8, 152. 96	12, 262. 12	I 0, 2 I 1, 3
3	8, 005. 26	12, 488. 36	
4p?	7, 721. 1	12, 948. 0	I 2, 3
5nl	7, 715. 59	12, 957. 21	I 1, 2
2p?	7, 327. 6	13, 643. 3	I 2, 2
400	7, 326. 11	13, 646. 06	$4^1P^o_1$–4^1D_2
3nl	7, 318. 4	13, 660. 4	I 1, 1
2nl	7, 308. 31	13, 679. 29	I 0, 0
200	7, 203. 17	13, 880. 89	3^1D_2–$dp\,^3F^o_2$
500	7, 148. 12	13, 985. 84	3^1D_2–$dp\,^1D^o_2$
3nl	6, 982. 9	14, 316. 8	I 3, 2
2p?	6, 968. 4	14, 346. 5	I 2, 1
20nl	6, 956. 18	14, 371. 75	I 1, 0
6h	6, 798. 51	14, 705. 05	3^1D_2–$5^3P^o_1$
5h	6, 784. 01	14, 736. 48	
500h	6, 717. 75	14, 881. 84	3^1D_2–$dp\,^1P^o_1$
50	6, 572. 76	15, 210. 12	4^1S_0–4^3P_1

TABLE 7.—*Ca I spectral terms*

Even				Odd			
Singlets		Triplets		Singlets		Triplets	
Symbol	Value	Symbol	Value	Symbol	Value	Symbol	Value
4^1S_0	49, 304. 80	$d^2\,^3F_2$	3, 347. 3	$4^1P^o_1$	25, 652. 49	$4^3P^o_0$	34, 146. 90
3^1D_2	27, 455. 59	$d^2\,^3F_3$	3, 292. 7	$dp\,^1D^o_2$	13, 469. 77	$4^3P^o_1$	34, 094. 74
5^1S_0	15, 988. 2	$d^2\,^3F_4$	3, 243. 0	$dp\,^1P^o_1$	12, 573. 62	$4^3P^o_2$	33, 988. 88
4^1D_2	12, 006. 41	$d^2\,^3P_0$	780. 70			$dp\,^3F^o_2$	13, 574. 72
		$d^2\,^3P_1$	767. 18			$dp\,^3F^o_3$	13, 486. 45
		$d^2\,^3P_2$	741. 23			$dp\,^3F^o_4$	13, 408. 31
		$d.d^3D_1$	−2, 046. 84			$5^3P^o_0$	12, 757. 46
		$d.d^3D_2$	−2, 065. 77			$5^3P^o_1$	12, 750. 38
		$d.d^3D_3$	−2, 091. 30			$5^3P^o_2$	12, 730. 13
		$d.d^3S_1$	−2, 266. 40			$dp\,^3D^o_1$	11, 112. 76
						$dp\,^3D^o_2$	11, 086. 03
						$dp\,^3D^o_3$	11, 046. 02
						$dp\,^3P^o_0$	9, 971. 73
						$dp\,^3P^o_1$	9, 969. 82
						$dp\,^3P^o_2$	9, 965. 05

(*b*) STRONTIUM (Sr, Z=38)

The most prominent feature of the infrared arc spectrum of Sr is the $^2D-{}^2P$ multiplet characteristic of singly ionized Sr atoms. Oxide bands which are so prominent and disturbing in the Ca I spectrum are also strongly developed in the Sr arc at atmospheric pressure, but their number is insufficient for a vibrational analysis. Results from Sr spectrograms in the red and infrared are presented in table 8 and the Sr I spectral terms used here are listed in table 9.

TABLE 8.—*Arc spectrum of strontium*

Intensity	λ_{air} I.A.	ν_{vac} cm^{-1}	Term combination
5	11, 241. 32	8, 893. 32	$5^1P_1^\circ-6^1S_0$
200	10, 914. 83	9, 159. 34	$4^2D_{1\frac{1}{2}}^\circ-5^2P_{\frac{1}{2}}^\circ$
5nl	10, 437. 1	9, 578. 6	
2nl	10, 426. 2	9, 588. 6	
1, 000	10, 327. 29	9, 680. 43	$4^2D_{2\frac{1}{2}}-5^2P_{1\frac{1}{2}}^\circ$
300	10, 036. 59	9, 960. 81	$4^2D_{1\frac{1}{2}}-5^2P_{1\frac{1}{2}}^\circ$
20nl	9, 776. 26	10, 226. 06	
10nl	9, 196. 08	10, 871. 2	
10nl	8, 700. 05	11, 491. 1	
5nl	8, 257. 78	12, 106. 47	
3nl	7, 882. 36	12, 683. 07	
200hv	7, 673. 06	13, 029. 03	$5^1P_1^\circ-5^1D_2$
100	7, 621. 50	13, 117. 17	$4^1D_2-dp^3F_2^\circ$
1	7, 503. 38	13, 323. 66	$5^1P_1^\circ-5^3D_2$
3	7, 438. 42	13, 440. 03	$4^1D_2-dp^3F_3^\circ$
5	7, 408. 12	13, 494. 99	$5^1P_1^\circ-p^2\,{}^3P_0$
500	7, 309. 41	13, 677. 23	$4^1D_2-dp^1D_2^\circ$
20h	7, 287. 41	13, 718. 52	$4^1D_2-6^3P_1^\circ$
100hl	7, 232. 20	13, 823. 25	$4^1D_2-6^3P_2^\circ$
200hl	7, 167. 20	13, 948. 61	$4^1D_2-6^1P_1^\circ$
30	7, 153. 02	13, 976. 26	$5^1P_1^\circ-p^2\,{}^3P_2$
2, 000	7, 070. 10	14, 140. 18	$5^3P_2^\circ-6^3S_1$
200	6, 892. 56	14, 504. 40	$5^1S_0-5^3P_1^\circ$
1, 000	6, 878. 32	14, 534. 43	$5^3P_1^\circ-6^3S_1$
500	6, 791. 00	14, 721. 32	$5^3P_0^\circ-6^3S_1$
200	6, 643. 53	15, 048. 09	$4^3D_2-dp^3F_2^\circ$
300	6, 617. 26	15, 107. 83	$4^3D_1-dp^3F_2^\circ$
200	6, 550. 22	15, 262. 45	$5^1P_1^\circ-p^2\,{}^1D_2$
50	6, 546. 77	15, 270. 50	$4^3D^3-dp^3F_3^\circ$

TABLE 9.—*Sr I spectral terms*

Even				Odd			
Singlets		Triplets		Singlets		Triplets	
Symbol	Value	Symbol	Value	Symbol	Value	Symbol	Value
5^1S_0	45, 925. 6	4^3D_1	27, 766. 83	$5^1P_1^o$	24, 227. 16	$5^3P_0^o$	31, 608. 0
4^1D_2	25, 776. 13	4^3D_2	27, 707. 06	$dp\,^1D_2^o$	12, 098. 97	$5^3P_1^o$	31, 421. 1
6^1S_0	15, 337. 8	4^3D_3	27, 606. 49	$6^1P_1^o$	11, 827. 62	$5^3P_2^o$	31, 026. 8
5^1D_2	11, 198. 1	6^3S_1	16, 886. 8			$dp^3F_2^o$	12, 658. 99
$p^2\,^1D_2$	8, 964. 6	5^3D_1	10, 918. 3			$dp^3F_3^o$	12, 336. 08
		5^3D_2	10, 903. 3			$dp^3F_4^o$	12, 006. 44
		5^3D_3	10, 880. 5			$6^3P_0^o$	12, 072. 47
		$p^2\,^3P_0$	10, 731. 8			$6^3P_1^o$	12, 057. 62
		$p^2\,^3P_1$	10, 525. 5			$6^3P_2^o$	11, 952. 83
		$p^2\,^3P_2$	10, 250. 7				

(c) BARIUM (Ba, Z=56)

The red and infrared arc spectrum of Ba is characterized by a relatively large number of Ba I lines, but the bands associated with oxides are almost absent, and no trace of Ba II lines is found. Results for 150 Ba I lines are displayed in table 10. Nearly all of these lines are accounted for as combinations of Ba I spectral terms shown in table 11.

TABLE 10.—*Arc spectrum of barium*

Intensity	λ_{air} I. A.	ν_{vac} cm^{-1}	Term combination
2h	11, 114. 3	8, 994. 96	$dp^3D_2^o$–$d.s^3D_3$
2h	11, 012. 7	9, 077. 94	$dp^1F_3^o$–$d.d^3G_3$
1	10, 962. 6	9, 119. 43	$dp^3P_1^o$–$p^2\,^3P_1$
3h	10, 888. 6	9, 181. 40	$dp^3P_0^o$–$p^2\,^3P_1$
5h	10, 791. 24	9, 264. 24	$dp^3D_2^o$–$d.s^1D_2$
1h	10, 769. 3	9, 283. 11	
5h	10, 693. 7	9, 348. 74	$dp^1F_3^o$–$d.d^1F_3$
10	10, 649. 07	9, 387. 92	$dp^3P_2^o$–$p^2\,^1D_2$
5	10, 540. 04	9, 485. 03	
2h	10, 487. 3	9, 532. 73	$dp^1F_3^o$–$d.d^3G_4$
100	10, 471. 26	9, 547. 33	$6^3P_2^o$–$d^2\,^1D_2$
2h	10, 409. 6	9, 603. 89	$dp^3D_1^o$–$d.s^1D_2$
10h	10, 370. 34	9, 640. 25	$dp^3P_1^o$–$p^2\,^1D_2$
8hl	10, 349. 03	9, 660. 10	$dp^3P_2^o$–$p^2\,^3P_2$
50hl	10, 274. 04	9, 730. 61	$dp^1D_2^o$–$d.s^3D_1$
400hl	10, 233. 22	9, 769. 42	$dp^3F_4^o$–$d.s^3D_3$
50h	10, 188. 23	9, 812. 56	$dp^1F_3^o$–$d.d^3D_3$
10	10, 129. 68	9, 869. 28	$dp^1D_2^o$–$d.s^3D_2$
5h	10, 115. 14	9, 883. 46	
2h	10, 085. 42	9, 912. 59	$dp^3P_1^o$–$p^2\,^3P_2$
200	10, 032. 12	9, 965. 25	$6^3P_2^o$–$d^2\,^3P_1$
300	10, 001. 09	9, 996. 17	$dp^3F_3^o$–$d.s^3D_2$
500hl	9, 830. 37	10, 169. 77	$6^1P_1^o$–7^1S_0
3h	9, 821. 60	10, 178. 85	$dp^3D_1^o$–$p^2\,^1S_0$
5h	9, 792. 91	10, 208. 67	$dp^3P_2^o$–$d.d^1F_3$

TABLE 10.—*Arc spectrum of barium*—Continued

Intensity	λ_{air} I. A.	ν_{vac} cm^{-1}	Term combination
6h	9, 772. 62	10, 229. 87	$dp\,^3P^\circ_1$–$d.d\,^3D_1$
2h	9, 759. 35	10, 243. 78	$dp\,^3P^\circ_2$–$d.d\,^3D_2$
60	9, 713. 75	10, 291. 86	$dp\,^3P^\circ_0$–$d.d\,^3D_1$ $dp\,^3D^\circ_2$–$p^2\,^3P_1$
20h	9, 704. 42	10, 301. 76	$dp\,^3D^\circ_1$–$p^2\,^3P_0$
10nl	9, 658. 8	10, 350. 4	
100h	9, 645. 72	10, 364. 45	$dp\,^3D^\circ_3$–$p^2\,^1D_2$
300	9, 608. 88	10, 404. 19	$6\,^3P^\circ_2$–$d^2\,^3P_2$
150	9, 589. 37	10, 425. 36	$6\,^3P^\circ_2$–$d^2\,^1D_2$
10h	9, 530. 30	10, 489. 97	$dp\,^3P^\circ_2$–$d.d\,^3S_1$
60h	9, 524. 70	10, 496. 14	$dp\,^3P^\circ_1$–$d.d\,^3D_2$
100	9, 455. 92	10, 572. 49	$6\,^3P^\circ_1$–$d^2\,^3P_0$
15h	9, 450. 05	10, 579. 05	$dp\,^3F^\circ_3$–$d.s\,^3D_3$
4h	9, 414. 6	10, 618. 9	$dp\,^1F^\circ_3$–$8\,^1D_2$
10	9, 403. 53	10, 631. 39	$dp\,^3D^\circ_1$–$p^2\,^3P_1$
6h	9, 398. 8	10, 636. 7	$dp\,^3D^\circ_3$–$p^2\,^3P_2$
500	9, 370. 06	10, 669. 37	$5\,^1D_2$–$dp\,^3F^\circ_2$
80h	9, 367. 45	10, 672. 34	$dp\,^3P^\circ_2$–$d.d\,^3D_3$
100h	9, 324. 58	10, 721. 40	$dp\,^1D_2$–$d.s\,^1D_2$
100	9, 308. 08	10, 740. 41	$dp\,^3F^\circ_2$–$d.s\,^3D_1$
10	9, 306. 52	10, 742. 21	$dp\,^3P^\circ_1$–$d.d\,^3S_1$
15h	9, 253. 08	10, 804. 25	$dp\,^3P^\circ_0$–$d.d\,^3S_1$
1h	9, 245. 6	10, 813. 0	$dp\,^3D^\circ_2$–$p^2\,^1D_2$
100	9, 219. 69	10, 843. 38	$6\,^3P^\circ_1$–$d^2\,^3P_1$
15h	9, 215. 42	10, 848. 40	$dp\,^3F^\circ_3$–$d.s\,^1D_2$
60h	9, 189. 57	10, 878. 92	$dp\,^3F^\circ_2$–$d.s\,^3D_2$
10h	9, 159. 66	10, 914. 44	$dp\,^3D^\circ_3$–$d.d\,^3G_3$
15h	9, 133. 29	10, 945. 95	$dp\,^3P^\circ_2$–$d.d\,^1P_1$
3ln	9, 101. 7	10, 983. 9	
2h	9, 097. 8	10, 988. 7	
3h	9, 018. 63	11, 085. 12	$dp\,^3D^\circ_2$–$p^2\,^3P_2$
2h	8, 975. 6	11, 138. 3	
10h	8, 937. 93	11, 185. 20	$dp\,^3D^\circ_3$–$d.d\,^1F_3$
7hl	8, 927. 41	11, 198. 39	$dp\,^3P^\circ_1$–$d.d\,^1P_1$
150	8, 914. 99	11, 213. 99	$6\,^3P^\circ_0$–$d^2\,^3P_1$
3h	8, 909. 83	11, 220. 48	$dp\,^3D_3$–$d.d\,^3D_2$
100	8, 860. 98	11, 282. 33	$6\,^3P^\circ_1$–$d^2\,^3P_2$
100h	8, 799. 76	11, 360. 83	$dp\,^1F^\circ_3$–$d.d\,^1G_4$
3h	8, 793. 36	11, 369. 10	$dp\,^3D^\circ_3$–$d.d\,^3G_4$
1h	8, 767. 7	11, 402. 4	$dp\,^3D^\circ_2$–$d.d\,^3D_1$
3h	8, 737. 74	11, 441. 47	
3h	8, 710. 82	11, 476. 83	
60	8, 654. 07	11, 552. 09	$5\,^1D_2$–$dp\,^3F^\circ_3$
4hl	8, 593. 48	11, 633. 54	$dp\,^3D^\circ_2$–$d.d\,^1F_3$
50hl	8, 581. 98	11, 649. 13	$dp\,^3D^\circ_3$–$d.d\,^3D_3$
40hl	8, 567. 58	11, 668. 70	$dp\,^3D^\circ_2$–$d.d\,^3D_2$
600h	8, 559. 97	11, 679. 08	$5\,^1D_2$–$d.p\,^1D^\circ_2$
8hl	8, 521. 96	11, 731. 17	$dp\,^3F^\circ_2$–$d.s\,^1D_2$
30hl	8, 514. 23	11, 741. 82	$dp\,^3D^\circ_1$–$d.d\,^3D_1$
4hv	8, 414. 58	11, 880. 87	$dp\,^3P^\circ_2$–$d.d\,^1D_2$
2h	8, 350. 76	11, 971. 67	$dp\,^3P^\circ_1$–$d.d\,^3P_0$

TABLE 10.—*Arc spectrum of barium*—Continued

Intensity	λ_{air} I. A.	ν_{vac} cm^{-1}	Term combination
20h	8, 325. 38	12, 008. 27	$dp^3D_1^o$–$d.d^3D_2$
6hv	8, 285. 00	12, 066. 69	$dp^3P_2^o$–$d.d^3P_1$
3h	8, 264. 01	12, 097. 34	$dp^3D_2^o$–$d.d^3D_3$
5h	8, 224. 41	12, 155. 59	
300h	8, 210. 30	12, 176. 48	$6^1P_1^o$–6^1D_2
10hl	8, 161. 58	12, 249. 17	
3h	8, 158. 12	12, 254. 36	$dp^3D_1^o$–$d.d^3S_1$
30h	8, 147. 78	12, 269. 91	$dp^1D_2^o$–$p^2\ ^1D_2$
30hv	8, 120. 49	12, 311. 15	$dp^3P_2^o$–$d.d^3P_2$
1h	8, 074. 58	12, 381. 14	$dp^3P_0^o$–$d.d^3P_1$
10	8, 018. 23	12, 468. 16	5^3D_3–$dp^3F_2^o$
15hv	7, 982. 40	12, 524. 12	$dp^3D_3^o$–$d.d^3F_3$
10hv	7, 961. 24	12, 557. 41	$dp^3D_2^o$–$d.d^3F_2$
2h	7, 957. 33	12, 563. 58	$dp^3P_1^o$–$d.d^3P_2$
3h	7, 939. 42	12, 591. 92	$dp^3F_4^o$–$d.d^3G_4$
200	7, 911. 31	12, 636. 66	6^1S_0–6^3P_1
500	7, 905. 77	12, 645. 51	$6^3P_2^o$–7^3S_1
20hl	7, 877. 93	12, 690. 20	$6^1P_1^o$–6^3D_2
1h	7, 865. 29	12, 710. 60	$dp^2D_1^o$–$d.d^1P_1$
60h	7, 839. 52	12, 752. 38	$dp^3D_3^o$–$d.d^3F_4$
5h	7, 798. 26	12, 819. 85	$dp^1D_2^o$–$d.d^3G_3$
400	7, 780. 46	12, 849. 18	5^3D_2–$dp^3F_2^o$
10h	7, 775. 37	12, 857. 59	$dp^3D_3^o$–$d.d^1D_2$
10hl	7, 766. 80	12, 871. 78	$dp^3F_4^o$–$d.d^3D_3$
40hv	7, 751. 68	12, 896. 88	$dp^3D_1^o$–$d.d^3F_2$
10h	7, 721. 78	12, 946. 82	$dp^3F_3^o$–$d.d^3G_3$
50hv	7, 706. 51	12, 972. 48	$dp^3D_2^o$–$d.d^3F_3$
600	7, 672. 06	13, 030. 73	5^3D_1–$dp^3F_2^o$
200hl	7, 642. 91	13, 080. 42	$dp^3F_4^o$–$d.d^3G_5$
150hl	7, 636. 90	13, 090. 72	$dp^1D_2^o$–$d.d^1F_3$
50	7, 610. 45	13, 136. 22	5^1D_2–$dp^3D_2^o$
2h	7, 575. 22	13, 197. 31	$dp^3D_3^o$–$d.d^1G_4$
25h	7, 543. 48	13, 252. 84	$dp^3F_3^o$–$d.d^3D_2$
20h	7, 528. 20	13, 279. 73	$dp^3F_2^o$–$p^2\ ^1D_2$
20h	7, 523. 60	13, 287. 85	$dp^3D_3^o$–$d.d^3P_2$
3h	7, 513. 40	13, 305. 89	$dp^3D_2^o$–$d.d^1D_2$
200	7, 488. 04	13, 350. 96	5^3D_3–$dp^3F_3^o$
30h	7, 476. 21	13, 372. 08	$dp^1D_2^o$–$d.d^3S_1$
300hl	7, 459. 78	13, 401. 54	$dp^3F_3^o$–$d.d^3G_4$
100	7, 417. 48	13, 477. 96	5^3D_3–$dp^1D_2^o$
4hl	7, 414. 26	13, 483. 81	$dp^3D_1^o$–$d.d^3P_0$
30hv	7, 409. 97	13, 491. 62	$dp^3D_2^o$–$d.d^3P_1$
400	7, 392. 42	13, 523. 65	$6^3P_1^o$–7^3S_1
50hl	7, 375. 59	13, 554. 50	$dp^1D_2^o$–$d.d^3D_3$
20	7, 359. 29	13, 584. 53	5^1D_2–$dp^3D_3^o$
4h	7, 339. 57	13, 621. 03	$d^2\ ^3P_2$–$dp^3D_3^o$
10h	7, 326. 50	13, 645. 33	$dp^3D_1^o$–$d.d^1D_2$
10h	7, 307. 23	13, 681. 31	$dp^3F_3^o$–$d.d^3D_3$
5h	7, 304. 46	13, 686. 50	
1, 000	7, 280. 29	13, 731. 94	5^3D_2–$dp^3F_3^o$

TABLE 10.—*Arc spectrum of barium*—Continued

Intensity	λ_{air} I. A.	ν_{vac} cm^{-1}	Term combination
2h	7, 272. 33	13, 746. 97	$dp^3F^\circ_4$–$d.d^3F_3$
200hl	7, 228. 84	13, 829. 67	$dp^3F^\circ_2$–$d.d^3G_3$
10	7, 213. 56	13, 858. 97	5^3D_2–$dp^1D^\circ_2$
20h	7, 208. 18	13, 869. 31	$dp^3F^\circ_2$–$d.d^3D_1$
200	7, 195. 22	13, 894. 29	$6^3P^\circ_0$–7^3S_1
80hv	7, 153. 54	13, 975. 25	$dp^3F^\circ_4$–$d.d^3F_4$
4h	7, 133. 16	14, 015. 17	
10h	7, 126. 60	14, 028. 08	
800hv	7, 120. 27	14, 040. 55	5^3D_1–$dp^1D^\circ_2$
100hl	7, 090. 01	14, 100. 47	$dp^3F^\circ_2$–$d.d^1F_3$
1h	7, 072. 38	14, 135. 62	$dp^3F^\circ_2$–$d.d^3D_2$
3	7, 069. 43	14, 141. 52	$dp^3F^\circ_3$–$d.d^3F_2$
2, 000	7, 059. 92	14, 160. 57	5^3D_3–$dp^3F^\circ_4$
5	6, 986. 79	14, 308. 78	5^1D_2–$dp^3P^\circ_1$
2h	6, 961. 63	14, 360. 50	$dp^1D^\circ_2$–8^1D_2
2h	6, 932. 92	14, 419. 96	$dp^3F^\circ_4$–$d.d^1G_4$
100h	6, 867. 85	14, 556. 59	$dp^3F^\circ_3$–$d.d^3F_3$
200	6, 865. 67	14, 561. 21	5^1D_2–$dp^3P^\circ_2$
60h	6, 771. 85	14, 762. 95	$dp^1D^\circ_2$–$d.d^1D_2$
2h	6, 761. 86	14, 784. 76	$dp^3F^\circ_3$–$d.d^3F_4$
2h	6, 714. 03	14, 890. 08	$dp^3F^\circ_3$–$d.d^1D_2$
600	6, 693. 82	14, 935. 04	5^3D_3–$dp^3D^\circ_2$
500	6, 675. 26	14, 976. 56	5^3D_2–$dp^3D^\circ_1$
50	6, 654. 05	15, 024. 30	$dp^3F^\circ_2$–$d.d^3F_2$
1, 000	6, 595. 32	15, 158. 09	5^3D_1–$dp^3D^\circ_1$
20h	6, 580. 73	15, 191. 70	
3h	6, 564. 33	15, 229. 65	$dp^3F^\circ_3$–$d.d^1G_4$

TABLE 11.—*Ba I spectral terms*

Even				Odd			
Singlets		Triplets		Singlets		Triplets	
Symbol	Value	Symbol	Value	Symbol	Value	Symbol	Value
6^1S_0	42, 029. 40	5^3D_1	32, 995. 53	$6^1P_1^\circ$	23, 969. 30	$6^3P_0^\circ$	29, 763. 43
5^1D_2	30, 634. 04	5^3D_2	32, 814. 07	$dp\,^1D_2^\circ$	18, 955. 06	$6^3P_1^\circ$	29, 392. 82
$d^2\,^1D_2$	18, 967. 45	5^3D_3	32, 433. 03	$dp\,^1F_3^\circ$	15, 213. 27	$6^3P_0^\circ$	28, 514. 69
7^1S_0	13, 799. 52	$d^2\,^3P_0$	18, 820. 36			$dp^3F_2^\circ$	19, 964. 83
6^1D_2	11, 792. 73	$d^2\,^3P_1$	18, 549. 43			$dp^3F_3^\circ$	19, 082. 06
ds^1D_2	8, 233. 58	$d^2\,^3P_2$	18, 110. 48			$dp^3F_4^\circ$	18, 272. 54
$p^2\,^1S_0$	7, 658. 70	7^3S_1	15, 869. 22			$dp^3D_1^\circ$	17, 837. 50
$p^2\,^1D_2$	6, 685. 16	6^3D_1	11, 334. 05			$dp^3D_2^\circ$	17, 498. 04
$d.d^1F_3$	5, 864. 32	6^3D_2	11, 279. 02			$dp^3D_3^\circ$	17, 049. 70
$d.d^1P_1$	5, 126. 95	6^3D_3	11, 211. 54			$dp^3P_0^\circ$	16, 387. 49
8^1D_2	4, 594. 45	$d.s^3D_1$	9, 224. 43			$dp^3P_1^\circ$	16, 325. 35
$d.d^1D_2$	4, 192. 08	$d.s^3D_2$	9, 085. 74			$dp^3P_2^\circ$	16, 073. 03
$d.d^1G_4$	3, 852. 48	$d.s^3D_3$	8, 503. 12			$d.p^3D_1^\circ$	5, 533. 75
$d.d^1S_0$	2, 843. 90	$p^2\,^3P_0$	7, 535. 73			$d.p^3D_2^\circ$	4, 966. 22
		$p^2\,^3P_1$	7, 206. 11			$d.p^3D_3^\circ$	4, 489. 38
		$p^2\,^3P_2$	6, 412. 77				
		$d.d^3G_3$	6, 135. 18				
		$d.d^3G_4$	5, 680. 54				
		$d.d^3G_5$	5, 192. 13				
		$d.d^3D_1$	6, 095. 55				
		$d.d^3D_2$	5, 829. 22				
		$d.d^3D_3$	5, 400. 72				
		$d.d^3S_1$	5, 583. 06				
		$d.d^3F_2$	4, 940. 70				
		$d.d^3F_3$	4, 525. 69				
		$d.d^3F_4$	4, 297. 34				
		$d.d^3P_0$	4, 353. 77				
		$d.d^3P_1$	4, 006. 39				
		$d.d^3P_2$	3, 761. 80				

WASHINGTON, February 25, 1933.