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Technical Note 116

ASTROPHYSICAL AND PLASMA PHYSICS RESEARCH AT THE NATIONAL BUREAU OF STANDARDS

HIGHLIGHTS FOR 1961

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

THE NATIONAL BUREAU OF STANDARDS

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NATIONAL BUREAU OF STANDARDS
Technical Note

116

OCTOBER 1961

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HIGHLIGHTS FOR 1961

L. M. Branscomb, K. E. Shuler, J. A. Suddeth

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Astrophysical and Plasma Physics Research at the National Bureau of Standards - Highlights for 1961

Abstract: Highlights of astrophysical and plasma physics research at the National Bureau of Standards are given for the period of July 1960 through June 1961. Included as appendices are a selected list of papers published by NBS participants during the period 1955-1960 and a partial list of Bureau participants. The technical objectives of the program can be found in NBS Technical Note 59.

1. INTRODUCTION

This is the second report on astrophysical and plasma physics research at the National Bureau of Standards. The first report, which has been published as NBS Technical Note 59, July 1960, contained a detailed discussion of the background of this program and of the program areas. Since the work to be reported on here is one of growth and implementation, rather than of change of direction or emphasis, it was felt that it could be published as a short progress report without the detailed discussion of scientific and technical objectives presented in NBS Technical Note 59. This report is consequently limited to: (1) a write-up of various new and/or continuing projects within the program area, (2) a bibliography of selected papers published by NBS authors during the past few years, and (3) a partial biographical list of scientists engaged in research within the area of the astrophysical and plasma physics program. The work described in this report is supported jointly by the National Bureau of Standards and various contract offices of the Department of Defense.

2. PROGRAM HIGHLIGHTS (JULY '60 thru JUNE '61)

2.1. Atomic Spectra

At the Washington Laboratories, work has centered on the observation, description, and analysis of atomic spectra, with special attention to selected spectra of the rare-earth elements in the lanthanide group. Observation of these spectra with suitable sources is urgently needed to secure the data for Volume IV of "Atomic Energy Levels".

The spectra of Ce II and Ce I have been observed from 4800A to 5900A, with an a‾ c arc, a hollow cathode and an electrodeless lamp as sources. Measurements have been completed in this range. These sources have provided the most complete cerium spectra ever obtained.

The spectra of Pr II and Pr I have been observed and measured from 2600A to 9000A. Preliminary observations in the range 2200A to 2600A have been made, and Zeeman patterns have been measured from 3500A to 7000A. More than 1500 lines have been classified in Pr III, in collaboration with Dieke and his staff at Johns Hopkins. The regularities include terms and levels from three configurations. Theoretical work on Pr III has been of great assistance in the interpretation of known levels and in predictions of the positions of missing levels.

Some 80 classified lines are known in Dy II, but further observations are needed to extend this work. The analysis of Yb II is nearly finished. In Yb I there are about 2000 observed lines, 70 new levels, and approximately 300 classified lines.

The analysis of Br I is essentially complete. Practically all of the 1300 lines observed in the range from 2000A to 13000A, are classified. All leading configurations are known, and extended series have been observed. In Br II improved values of previously known energy levels have been reported, together with observed magnetic dipole transitions in the $4p^4$ ground configuration.

The analysis of Hf I is nearing completion. There are new energy levels and a revised interpretation is in progress.

The analysis of Ta II has been completed from observations in the interval 2000A to 7813A, including extensive Zeeman data. The leading configurations are known and 1890 lines are classified. Here again theoretical investigations have been of great assistance in the interpretation of the spectrum.

More general theoretical work has also been carried out on the parameters α and β in the spectra of the Iron Group.

2.2. Spectroscopic Tables

The NBS tables of spectral-line intensities are in press. The temperature and ionization in the copper arc used as the light source have been determined. Work is in progress on the calculation of gf-values from the intensities.

Section 3 of NBS Circular 488, "An ultraviolet multiplet table" has been completed. This circular will be concluded with two finding lists, which are also in press. Section 4 is the finding list for Sections 1 and 2 of the multiplet table, hydrogen through niobium (Z = 1 to 41). Section 5 is similarly arranged and is the finding list for Section 3 of the multiplet table, molybdenum through lanthanum (Z = 42 to 57) and hafnium through actinium (Z = 72 to 89).

Press copy is being prepared for the current revision of the 1928 edition of the solar spectrum table. The measured solar equivalent widths furnished by Minnaert and his staff extend from λ3061A to λ8770A, and have been completed.

2.3. Collision Cross Sections

The Bureau program of measurement and calculation of low energy collision cross sections has continued, with efforts concentrated on apparatus construction and refinement of instrumentation. Special emphasis is being given to the development of sources of low energy mono-energetic beams for use in measurement of elastic and inelastic collision cross sections.

Theoretical studies of the use of refined wave functions in the calculation of electron scattering and photodetachment are continuing. Several high vacuum instruments for measuring electron collision cross sections are essentially completed.

The photodetachment of electrons from carbon negative ions has been observed and studied. Careful measurements for detachment near threshold for the process lead to a value for the electron affinity of carbon of 1.25 ± .03 ev (28.6 kilocalories). Values for upper limits for the photodetachment cross sections of several of the important atmospheric negative ions have been determined at 4000A wavelength.

High precision studies of the dependence of drift velocities of argon ions in the parent gas on the electric field have been completed. The results raise doubts about the validity of current theories describing the motions of charged particles in gases.

A data center has been established to gather and index all published information on collision cross sections. A complete file of reprints of papers on low energy electron cross sections has been collected. A code has been worked out to place the large number (over 800) of references on punch cards. The data collection will be kept up to date and will be extended to cover other atomic cross sections as manpower allows.

2.4. Photoionization

A study has been made of the oscillator strength distribution of rare gas atoms in the ground states. Emphasis on this study has been on the overall spectral distribution, and the study thus includes both photoionization cross sections and transition probabilities. Numerical calculations of the oscillator strength distribution indicate that the neutral atoms or positive ions can be grouped into two classes, depending on whether or not the wave function of the outer electron is nodeless.

The effects of configuration interaction in continuous spectra have been investigated, and refinements and extensions made to an earlier theory. The new theory treats the interaction of one or more discrete levels with one continuum or of one level with the continua.

These considerations are useful in obtaining line widths from the resonance peaks observed experimentally, which correspond to states which undergo autoionization. Surprisingly, it appears that line widths can be obtained with fair accuracy even for lines whose widths are an order of magnitude less than the experimental resolution of the apparatus.

2.5. Transition Probabilities

A data center has been established to gather and index all published information on atomic transition probabilities. An exhaustive survey has been made of the literature, and a primary reference file of approximately 600 references has been catalogued. Work is now in progress to prepare selected bibliographies and tables of available data.

A wall-stabilized high current arc source has been constructed, and has been used to study transition probabilities of atomic hydrogen and oxygen. This apparatus will be used to measure transition probabilities of a large number of the elements. A study of the hydrogen line profiles indicates that a measurement of these profiles can be used to calculate a temperature for the arc plasma tnat is reliable to about ± 2 percent.

A set of tables containing spectral intensities for 39,000 lines of 70 elements, as observed in a copper matrix in a d.c. arc has also been completed and published. Studies of the intensity data published in these tables indicate that they may be converted to approximate transition probabilities. These data are not of the precision obtainable by the methods mentioned above, but the vast number of approximate values available will be useful in many areas.

2.6. Molecular Spectroscopy

Molecular spectroscopic studies have concentrated on free radicals and molecular fragments containing fluorine. The short-lived molecule CF_2, which is an important intermediate in flames and electric discharges involving fluorine, was studied by flash photolysis and matrix isolation techniques. In the former method the ultraviolet absorption spectrum was recorded during the very small fraction of a second in which the molecule exists; in the latter the CF_2 molecules were stabilized by isolating them in an inert matrix at a very low temperature. Related studies were carried out on the emission spectrum of CF from flames and discharges. Finally, an intensive investigation of the recently-discovered radical NF_2 was begun. The measurement and analysis of the infrared spectrum of NF_2 permitted the structure and vibrational frequencies of this interesting free radical to be established.

2.7. Vacuum Ultraviolet Photochemistry

Following the observation here in 1960 that ethane molecules lose molecular hydrogen when subjected to far ultraviolet light, work has been continued on the photolysis of other simple molecules. Ethylene was found to decompose by a similar process, and experiments on the gamma radiolysis of ethylene showed that molecular detachment of hydrogen also occurs under the action of gamma rays. Such experiments give valuable insight into the detailed processes induced by high energy radiation and information on the origin of radiation damage. The formation of molecular hydrogen by the action of far ultraviolet radiation on water vapor has also been observed; this may account for the presence of hydrogen molecules in the upper atmosphere.

In another investigation, excited hydrogen atoms, which must be present in the upper atmosphere, have been produced in the laboratory in sufficient concentrations for the study of their reactions. They are extremely active chemically; for example, they react rapidly with nitrogen molecules to form ammonia, and may produce small amounts of this gas at very high altitudes.

2.8. Transport Properties of Air

A six-year study of the transport properties of air at elevated temperatures has been completed. A significant effect discovered during the study is the existence of Prandtl numbers reaching values of more than unity in the nitrogen dissociation region. Another effect discovered is the large coefficient of thermal diffusion tending to separate nitrogen from the oxygen when temperature differences straddling the nitrogen dissociation region are present. The results of the study, based on collision integrals computed from the latest critically evaluated data on intermolecular forces in air, will be reported in the form of a table of viscosity, thermal conductivity, thermal diffusion, and diffusion coefficients at temperatures of 1000 to 10,000°K and of logarithm of pressure in atmospheres from 10^{-8} to 10^{3} times normal density.

2.9. Statistical Mechanics of Plasmas

During the past year, a study of plasma oscillations under various conditions was undertaken. A particular point investigated was the fact that a local total excess of charge is not conserved but oscillates in magnitude and sign with the plasma frequency. Investigations were carried out also on the plasma transport equation, in particular, on the combined effect of long and short range forces.

2.10. Statistical Thermodynamics of Ionized Gases

Types of constituents of high temperature gases for which intrinsic properties have been considered include diatomic molecules, atoms and atomic ions. For diatomic molecules, various alternative approaches to the partition function have been studied. These include not only the cluster integral or second virial approach, but also the more customary state sum, with a detailed study of placement of high energy levels including rotational-vibrational interaction effects, and a theoretical form of contributions up to the cut-off in the dissociation region. To elucidate the cut-off problem for atoms and atomic ions, the classical distribution of states in a Debye-screened hydrogenic system has been obtained. A definite number of states is thus found to which the quantized atom should also conform according to the correspondence principle. The classical distribution of states in the continuum has been examined also and is found, in the leading term of its expression, to correspond to the source of the Debye-Huckel screening according to the original Poisson equation derivation.

An extensive study of real gas corrections in ionic systems has been made using a pair potential function involving the 1/R Coulomb repulsion between positive ions, the $1/R^4$ induction energy due to dipole polarizability near ions, the $1/R^6$ instantaneous dipole-dipole effects (London forces) plus the quadrupole induction energy, and a close approach repulsion potential taken as $1/R^{12}$. An analytic expression for the second virial for poly-term extensions of the Lennard-Jones potential has also been obtained. This has been used for some of the second virial calculations which have been made.

2.11. Plasma Properties

Calculations of partition functions for atoms and atomic ions have been formulated preparatory to the computation of thermodynamic properties of metals suitable for exploding wire studies. The structure of the plasma shock has been investigated. In particular, the solutions of the Vlasov equation for large amplitude collisionless disturbances have been investigated in an attempt to understand the part of the shock phenomena which takes place on the scale of the Debye length rather than the mean free path.

2.12. Plasma Thermometry

Temperature and composition profiles have been obtained as a function of radius for high current, atmospheric pressure, electric arcs burning in a specially designed wall-stabilized or cascade arc chamber. Gas mixtures of hydrogen with oxygen, nitrogen, and argon were used yielding transition probabilities for several spectral lines of these elements as well as experimental evidence for the demixing or separation of the elements of these mixtures due to the temperature gradients present. The experimental results also suggest departures from local thermodynamic equilibrium in the outer parts of the arc discharge.

A study of helium arcs at currents up to 100 amperes has revealed extensive and unexpected departures from equilibrium everywhere in the arc. It is anticipated that equilibrium conditions will prevail at the higher electron densities attainable at higher currents. However, to reach higher currents a new arc chamber with improved cooling is required. Such a device has been designed, partially constructed, and tested at 300 amperes.

A transistorized current controller was designed for 300 amperes and has been used for manual fine current control at arc currents up to 100 amperes. This will now be incorporated in a fully automatic current regulator using an error signal feed-back for control.

A number of improvements have been made in a 3000°C graphite tube furnace blackbody to improve its economy, reliability, and convenience as a radiation standard for use in connection with the arc spectroscopic measurement.

Theoretical work has been carried out in three areas. First, the applicability and form of the Saha equation was investigated with a view to improving the accuracy of the temperature determinations. In particular, a calculation was begun on the correct value of the ionization potential to be incorporated in the partition function. Second, a study of the demixing effect was begun and a detailed calculation of the trace element case was completed. Third, a critical study of the applicability of many-body statistical mechanics and field theory to a partially ionized plasma was undertaken.

2.13. Plasma Thermodynamics

An electromagnetic shock tube has been assembled and tried out. Several small changes were made to improve its performance. An attachment was designed and built for a glass three-prism Steinheil spectrograph which allows simultaneous photoelectric recording of the intensities at two separate wavelengths. Shock velocities of one to three centimeters per microsecond were measured with the framing camera. Time integrated spectra taken with the three prism spectrograph showed an electron density of 10^{16} per cm^3 in order of magnitude and many impurities from the electrodes and the tube. The preliminary measurements indicate that the temperature achieved is of the order of 30,000°K.

A steady state plasma facility based on the magnetically confined low pressure gas arc was designed. Construction of this facility is well advanced, and it is expected to be in operation in late 1961. The facility will consist of a reasonably high speed kinetic vacuum system and a vacuum chamber within which arcs as well as cylindrical plasma rods up to about 60 cm long can be operated in a magnetic field up to 5000 gauss which is uniform over the arc length to ± 3 percent.

2.14. Radiation Produced from a Plasma

Plasmas produced by a high velocity shockwave travelling at speeds in excess of Mach 100 in helium have been studied in the laboratory in the presence of a transverse magnetic field. Radio frequency radiations resulting from the hydromagnetic interaction between the shockwave and the magnetic field have been observed. This creation in the laboratory of electromagnetic radiation from plasmas is a major step towards duplicating under controlled conditions electromagnetic processes which occur in the upper atmosphere. An additional important advance has been the development of a high-speed camera, capable of operating at a framing rate in excess of one hundred million frames per second and designed to study the luminous phenomena in the shockwaves.

2.15. Plasma Rate Coefficients

A detailed theoretical analysis of the problem of the interaction of the electromagnetic fields in a helix with a plasma has been continued. Although construction of a suitable plasma discharge tube incorporating helix structure has not been completed, further familiarization was developed with high speed pulse techniques.

2.16. Gas-solid Reactions at High Temperature

The failure of metals at high temperature due to corrosive attack of hot gases is often a limiting factor in the development of equipment to be used at high temperatures. The reaction between chlorine atoms and a polycrystalline surface of nickel heated to temperatures between 1100 and 1600°K has been extensively investigated and relative reactivities of different crystal planes of copper and nickel crystals towards halogens are now being determined. Special equipment for molecular-beam research was developed for these studies.

2.17. Thermodynamic Data

Thermodynamic properties of light elements are essential for evaluating compounds of these elements as high energy fuels. "Best" values for the heats of formations of a variety of boron compounds containing hydrogen, oxygen, fluorine, chlorine, and bromine were selected and tables of thermodynamic functions for selected compounds have been prepared. Codes were also prepared for high-speed digital computer calculation of thermodynamic functions and were used to extend these functions to 6000°K for over forty compounds in the boron-oxygen-hydrogen-halogen-nitrogen system.

2.18. Thermodynamic Properties of Light-Element Compounds

The compounds being specially investigated are those of lithium, beryllium, aluminum, and zirconium with hydrogen, oxygen, fluorine, and chlorine. During the past year the program extended its emphasis to include compounds of "mixed" type (such as intermetallic compounds, double fluorides of two metals, and oxyfluorides) whose use may lead to substantial gains in propulsion efficiency. A series of measurements established accurately the heats of formation of three alkali-metal perchlorates and ammonium perchlorate. Measurements on nitronium perchlorate are underway. Another recent achievement was the successful development of a method for the complete combustion in a bomb calorimeter of a metal in fluorine when the product is relatively non-volatile. This work gave a heat of formation of aluminum fluoride which closely substantiates a value which had been determined by a less direct method, and raises this property to 15 percent above that accepted a few years ago. Similar measurements are being initiated to resolve a large discrepancy in the heat of formation of beryllium fluoride.

The development and testing of new apparatus to measure other properties is nearing completion. In one of these, an exploding-wire device to study systems thermodynamically up to 6000°K and 100 atmosphere pressure was achieved. The accuracy of measuring the total electrical energy entering an exploding wire during a few microseconds was verified when two independent types of comparison with the heat energy produced, had an uncertainty of less than 2 percent.

2.19. Laboratory Measurements of Interstellar Radio Spectra

Besides the well-known hydrogen line at 21 cm wavelength, the spectra of extra-terrestrial radio sources may contain sharp lines characteristic of other atoms, ions, and small molecules. The detection and study of such line spectra would add considerably to present information on interstellar gas clouds and, perhaps, planetary atmospheres. Among the most likely producers of detectable radio line spectra are the light diatomic hydrides OH and CH; somewhat less likely sources are the heavier hydrides SH, SiH, and ScH. Very small concentrations of these hydrides should be detectable; in interstellar gas, concentrations as low as 10^{-6} molecule/cm^3 may be sufficient, as compared to the 10^{-2} hydrogen atom/cm^3 required for detection of the 21 cm line.

High sensitivity in radio telescopes is achieved by reducing the bandwidth of the receiver; therefore, only with precise foreknowledge of the line frequencies is an astronomical search for the radio spectra of these molecules feasible. To secure precise measurements of these frequencies, a research program in free radical microwave spectroscopy has been started. Since conventional methods are insensitive at the low frequencies of these molecular transitions, the paramagnetic resonance method is being used instead. This involves the application of a strong magnetic field to the radical vapor, which shifts the low frequency spectra to a conveniently high microwave range, where they may be measured with optimum sensitivity.

The first diatomic hydride investigated by the paramagnetic resonance method was the OH radical. Results of this experiment include the frequencies of the two strong spectral lines by which OH may be identified in interstellar gas; the frequencies are 1665.32 ± 0.10 Mc/s and 1667.36 ± 0.10 Mc/s. Success in observing these spectral lines has so far, apparently, been confined to the laboratory; extra-terrestrial observations have yet to be reported. Preparations are being made for similar experiments on CH and SH radicals.

2.20. Stellar Atmospheres

The program of research on the physics of stellar atmospheres continues at the Boulder Laboratories, with primary emphasis on the stellar atmosphere as a laboratory for the study of gaseous physics under conditions not easily reproducible terrestrially. The two principal directions of current interest lie in the study of non-equilibrium thermodynamics in the presence of a radiation field and the study of aerodynamic motions under the environment characteristic of stellar atmospheres.

A systematic investigation into the physical state of solar prominances and the physical structure of solar flares has been continued in collaboration with the Sacramento Peak Observatory.

A series of theoretical investigations of the rocket UV coronal lines have been initiated.

2.21. Studies of the Interplanetary Medium

A study of the relation of solar emission of medium-energy particles to other types of solar activity, has revealed new facts about the interplanetary medium. First suspected as a typical solar event in 1956, the presence of these solar particles in the earth's atmosphere has been detected and their effects studied by means of VHF forward-scatter signals. These data and others, measuring the ionospheric effects of the solar particles, show that around the time of maximum solar activity the solar cosmic ray particles take much longer to reach the earth from the sun than they do near minimum activity. Comparison with characteristics of solar particles of higher and lower energies show that these medium-energy particles must move in the interplanetary magnetic field, not as single particles, but as a group. Consideration of directly-observed energy spectra of the various solar particles show that this behavior is to be expected if the interplanetary field is regular but weak near solar minimum activity, but contains regions where the magnetic field intensity is 10^{-4} or 10^{-5} gauss near maximum of the solar activity cycle. Linear dimensions, field strength, and frequency of occurrence of these regions of enhanced magnetic field, estimated from the behavior of the solar particles, are found to be consistent with the hypothesis that the clouds are formed through the action of clouds of low-energy solar particles. The effect of these outward-moving magnetic clouds on the velocity distribution of cosmic rays accounts for the main features of solar modulation of cosmic rays.

3. APPENDIX

3.1. Bibliography (Selected papers during the period 1955-1961)

a. Atomic and Molecular Properties

(1) Atomic Energy Levels and Spectra

Barger, R. L. and Kessler, K. G., Correction for systematic wavelength shifts in atomic beam devices, J. Opt. Soc. Am. 50, No. 4, 352 (1960).

Beaty, E. C. and Bender, P. L., Hyperfine transitions in rubidium 87 vapor, Proc. 13th Ann. Symp. on Frequency Control, 668-675 (May 1959).

Bozman, W. R. and Trees, R. E., Matrices of spin-orbit interaction of the electron configuration d^4s, J. Research NBS 58, 95 (1957) RP2739.

Corliss, C. H. and Meggers, W. F., Improved description of hafnium spectra, J. Research NBS 61, 269 (1958) RP2904.

Kessler, K. G., Analysis of the first spectrum of ruthenium, J. Research NBS 63A (Phys. and Chem.), No. 3, 213-254 (Nov.-Dec. 1959).

Kessler, K. G., Prusch, S. B. and Stegun, I. A., Analysis of atomic spectra with electronic digital computers, J. Opt. Soc. Am. 46, No. 12, 1043 (1956) 1624.

Kiess, C. C. and Corliss, C. H., Description and analysis of the first spectrum of iodine, J. Research NBS 63A (Phys. and Chem.), No. 1, 1-18 (1959).

Kiess, C. C., Rubin, V. C. and Moore, C. E., Faint lines in the arc spectrum of iron (Fe I), J. Research NBS 65A (Phys. and Chem.), No. 1, 1-29 (Jan.-Feb. 1961).

Kiess, C. C. and Thekaekara, M. P., Revised term values of Ti I, Astrophys. J. 130, No. 3, 1008 (1959).

Margoshes, M. and Scribner, B. F., The plasma jet as a spectroscopic source, Spechtrochem. Acta XIV, No. 2, 138 (1959).

Martin, W. C., Atomic energy levels and spectra of neutral and singly ionized phosphorus, J. Opt. Soc. Am. 49, (PI and PII), No. 11, 1071 (1959).

Martin, W. C., Energy levels and spectrum of neutral helium (^{4}He I), J. Research NBS 64A (Phys. and Chem.), No. 1, 19-28 (Jan.-Feb. 1960).

Martin, W. C., New wavelengths for some helium (He I) lines, J. Opt. Soc. Am. 50, No. 2, 174 (1960).

Martin, W. C., Value of the Rydberg constant, Phys. Rev. 116, No. 3, 654 (1959) 3109.

Martin, W. C., and Corliss, Charles H., The spectrum of singly ionized atomic iodine (I II), J. Research NBS 64A (Phys. and Chem.), No. 6, 443-479 (1960).

Meggers, W. F., The present experimental status of rare-earth spectra, Optics and Spectroscopy (USSR) 6, 429 (1959) 3090.

Meggers, W. F., Catalan, M. A., and Sales, M., Term analysis of the second spectrum of rhenium (Re II), J. Research NBS 61, 441 (1958) RP2914.

Meggers, W. F., Fred, M. and Tomkins, F. S., Emission spectra of actinium, J. Research NBS 58, 297 (1957) RP2763.

Meggers, W. F. and Stanley, R. W., Wavelengths from thorium-halide lamps, J. Research NBS 61, 95 (1958) RP2891.

Moore, C. E., A multiplet table of astrophysical interest (Revised edition). Part I, Table of multiplets and Part II, Finding list of all lines in the table of multiplets, NBS Tech. Note 36, (1959) PB151395.

Moore, C. E., Atomic energy levels III (42 Mo-57 La; 72 Hf-89 Ac), NBS Circ. 467, (1958).

Moore, C. E., "Vistas in astronomy", Book: Atomic Spectra-Their Role in Astrophysics, Vol. 2, Chptr. 13, p. 1209 (Pergamon Press, London 1955) (Pergamon Press, New York, N. Y. 1956) 1974.

Moore, C. E. and Merrill, P. W., Appendix A "Lines of the chemical elements in astrophysical spectra", Book: Partial Grotrian Diagrams of Astrophysical Interest, 610, (Carnegie Institute of Washington 1956).

Radford, H. E. and Hughes, V. W., Microwave Zeeman spectrum of atomic oxygen, Phys. Rev. 114, No. 5, 1274 (1959).

Russell, H. N. and Moore, C. E., The first spectrum of barium, Ba I, J. Research NBS 55, 299 (1955) RP2633.

Shenstone, A. G. and Meggers, W. F., The second spectrum of ruthenium (Ru II), J. Research NBS 61, 373 (1958) RP2908.

Tech, J. L. and Corliss, C. H., Wavelengths and intensities in the first spectrum of bromine, 2000 to 13000A, J. Research NBS 65A (Phys. and Chem.), No. 3, 159-166 (May-June 1961).

Trees, R. E., Comparison of first, second, and third approximations in Bacher and Goudsmit's theory of atomic spectra, J. Opt. Soc. Am. 48, 293 (1958) 2492.

Trees, R. E., Low even configurations in the first spectrum of ruthenium (Ru I), Part 1, J. Opt. Soc. Am. 49, 838 (1959); Part 2, J. Research NBS 63A (Phys. and Chem.), No. 3, 255-260 (1959).

(2) Molecular Spectra

Allen, H. C., Jr., Cross, P. C., Plyler, E. K. and Blaine, L. R., Infrared spectrum of hydrogen sulfide from 2200-2800 cm^{-1}, J. Chem. Phys. 24, No. 1, 35 (1956) 1741.

Allen, H. C., Jr. and Plyler, E. K., Ethane carbon-carbon distance obtained from infrared spectra, J. Chem. Phys. 31, No. 4, 1062 (1959).

Allen, H. C., Jr. and Plyler, E. K., Infrared spectrum of hydrogen sulfide, J. Chem. Phys. 25, No. 6, 1132 (1956) 1740.

Allen, H. C., Jr., Plyler, E. K. and Blaine, L. R., The emission spectrum of OH from 2.8 to 4.1μ, Spectrochem. Acta 9, 126 (1957) 2356.

Broida, H. P. and Moore, C. E., Molecules in the solar spectrum, Mem. Soc. Roy. Sci., Series 4, Vol. 18, 217 (Liege, Belgium 1957) 2205.

Broida, H. P. and Peyron, M., Emission spectra of N_2, O_2, and NO molecules trapped in solid matrices, J. Chem. Phys. 32, No. 4, 1068 (1960).

Comeford, J. J. and Gould, J. H., Infrared spectra of solid hydrocarbons at very low temperatures, J. Mol. Spectroscopy 5, No. 6, 474 (1960).

Dressler, K. and Schnepp, O., Absorption spectra of solid methane ammonia and ice in the vacuum ultraviolet, J. Chem. Phys. 33, No. 1, 270-274 (1960).

Fallona, J. P., Ferguson, H. I. S. and Nicholls, R. W., An f/6 Littrow grating spectrograph, J. Opt. Soc. Am. 51, No. 3, 353 (1961).

Griffing, V., Jackson, J. L. and Ransil, B. J., The magnetic interaction of H_3, J. Chem. Phys. 30, 1066 (1959) 3084.

Harvey, K. B. and Bass, A. M., Infrared absorption of oxygen discharge products and ozone at 4°K, J. Mol. Spectroscopy 2, No. 2, 405 (1958).

Herman, R. and Rubin, R. J., Determination of the dipole moment function from infrared band intensities of diatomic molecules, J. Chem. Phys. 32, No. 5, 1393 (1960).

Kiess, N. H. and Broida, H. P., Analysis of the (0.1) and (1.2) bands of the $^2\Delta$-$^2\Pi$ system of CH, Astrophys. J. 123, No. 1, 166 (1956) 1625.

Kiess, N. H. and Broida, H. P., Spectrum of the C_3 molecule between 3600A, and 4200A, Can. J. Phys. 34, 1471 (1956) 1885; Mem. Soc. Roy. Sci. 18, 544 (Liege, Belgium 1957) 2313.

Krauss, M., Electronic structure of some diatomic hydrides, J. Chem. Phys. 28, 1021 (1958) 2543.

Krauss, M., Use of gaussian orbitals for atoms-in-molecule calculations, J. Chem. Phys. 34, No. 2, 692 (1961). Letter to the Editor.

Maki, A. and Decius, J. C., Vibrational spectrum of cyanate ion in various alkali halide lattices, J. Chem. Phys. 31, No. 3, 772 (1959).

Mann, D. E. and Thrush, B. A., On the absorption spectrum of CF_2 and its vibrational analysis, J. Chem. Phys. 33, No. 6, 1732 (1960).

Mann, D. E., Thrush, B. A., Lide, D. R., Jr., Ball, J. J. and Acquista, N., Spectroscopy of fluorine flames, I. Hydrogen-fluorine flame and the vibration-rotation emission spectrum of HF, J. Chem. Phys. 34, No. 2, 420 (1961).

Maryott, A. and Birnbaum, G., Non-resonant microwave absorption and relaxation frequency at elevated pressures, J. Phys. Chem. 64, 1778 (1960).

Moore, C. E. and Broida, H. P., Rotational lines of CH, OH, and CN in the solar spectrum, Mem. Soc. Roy. Sci., Liege 7th Intern. Astrophys. Symp. Proc., Belgium, Series 4, Vol. 18, 252 (1957) 2292.

Nicholls, R. W., Interpretation of intensity distributions in the N_2 Lyman-Birge-Hopfield and CO fourth positive systems, Nature Letter 186, 715 (1960).

Nicholls, R. W. and Krishnamachari, S. L. N. G., On the excitation on the emission spectrum of NCO in solid matrices condensed at 4°K., Can. J. Chem. 38, 1652 (1960).

Plyler, E. K., Allen, H. C., Jr. and Tidwell, E. D., Emission spectrum of carbon monoxide from 2.3 to 2.5 microns, J. Research NBS 61, 53 (1958) RP2883.

Plyler, E. K. and Blaine, L. R., Transmittance of materials in the far infrared, J. Research NBS 64C (Engrg. and Instr.), No. 1, 55 (1960).

Plyler, E. K., Danti, A., Blaine, L. R. and Tidwell, E. D., Vibration-rotation structure in absorption bands for the calibration of spectrometers from 2 to 16 microns, J. Research NBS 64A (Phys. and Chem.), No. 1, 29 (1960) NBS Mono. 16.

Plyler, E. K. and Tidwell, E. D., Infrared emission spectra of flames under high resolution, J. Research NBS 61, 263 (1958) RP2903.

Plyler, E. K. and Tidwell, E. D., The precise measurement of the infrared spectra of molecules of the atmosphere, Mem. Soc. Roy. Sci. 28, Quantrieme Ser., Inst. Astrophys., 426 (Liege, Belgium 1957) 2377.

Plyler, E. K., Tidwell, E. D. and Allen, H. C., Near infrared spectrum of nitrous oxide, J. Chem. Phys. 24, No. 1, 95 (1956) 1782.

Plyler, E. K., Tidwell, E. D. and Blaine, L. R., Infrared absorption spectrum of methane from 2470 to 3200 cm^{-1}, J. Research NBS 64A (Phys. and Chem.), No. 3, 201 (1960).

Radford, H. E., The microwave Zeeman effect of free hydroxyl radicals, Phys. Rev. 122, 114 (1961).

Ransil, B. J., The electronic structure of the H_3 molecule complex, J. Chem. Phys., (1957).

Schnapp, O., The absorption spectra of magnesium and manganese atoms in solid rare gas matrices, J. Phys. Chem. Solids 17, 188-195 (1961).

Schnapp, O. and Dressler, K., Absorption spectra of solid xenon, krypton, and argon in the vacuum ultraviolet, J. Chem. Phys. 33, No. 1, 49-55 (1960).

Schoen, L. J. and Broida, H. P., Effect of structure of the spectra emitted by solid nitrogen during electron bombardment, J. Mol. Spectroscopy 5, 416-419 (1960).

Stair, R., Measurement of ozone in terms of its optical absorption, advances in chemistry (Series of the American Chemical Society) 21, 269 (1959).

White, D., Mann, D. E., Walsh, P. N. and Sommer, A., Infrared emission of gaseous HBO_2, J. Chem. Phys. 32, No. 2, 488 (1960).

White, D., Mann, D. E., Walsh, P. N. and Sommer, A., Infrared emission spectra of gaseous B_2O_3 and B_2O_2, J. Chem. Phys. 32, No. 2, 481 (1960).

Zwanzig, R. W., Intermolecular forces from optical spectra of impurities in molecular crystals, Mol. Phys. 3, No. 4, 305-311 (1960).

(3) Line Shapes, Intensities, and Transition Probabilities

Broida, H. P. and Carrington, T., Fluorescence and average lifetime of excited OH ($^2\Sigma^+$) in flames, J. Chem. Phys. 32, 2202 (1955) 1348.

Carrington, T., Line shape and F value in the OH $^2\Sigma^+$ - $^2\Pi$ transition, J. Chem. Phys. 31, No. 5, 1243 (1959) 2976.

Fano, U., Normal modes of a lattice of oscillators with many resonances and dipolar coupling, Phys. Rev. 118, No. 2, 451 (1960).

Herman, R., Rothery, R. W. and Rubin, R. J., Line intensities in vibration-rotation bands of diatomic molecules, J. Mol. Spectroscopy 2, 369 (1958).

Kostkowski, H. J. and Bass, A. M., Slit function effects in the direct measurement of absorption line half-widths and intensities, J. Opt. Soc. Am. 46, No. 12, 1060 (1956) 1867.

Kostkowski, H. J. and Kaplan, L. D., Absolute intensities of the 721 and 742 cm^{-1} bands of CO_2, J. Chem. Phys. 26, 1252 (1957) 2007.

Mizushima, M., Theory of the stark effect of the NO molecule, Phys. Rev. 109, No. 5, 1557 (1958) 2840.

Nicholls, R. W., Franck-Condon arrays of high vibrational quantum numbers for the O_2 Schuman-Runge band system, Can. J. Phys. 38, 1705 (1960).

Nicholls, R. W., Fraser, P. A., Jarmain, W. R., and McEachran, R. P., Vibrational transition probabilities of diatomic molecules: Collected results IV, BeO, BO, CH^+, CO, NO, SH, O_2, $O^+{}_2$, Astrophys. J. 131, No. 2, 399 (1960).

Rohrlich, F., Theoretical multiplet strengths, Astrophys. J. 129, No. 2, 441 (1959).

Shuler, K. E. and Zwanzig, R., Quantum-mechanical calculations of harmonic oscillator transition probabilities in a one-dimensional impulsive collision, J. Chem. Phys. 33, No. 6, 1778 (1960).

(4) Photoionization, Photodetachment

Branscomb, L. M., The program at the National Bureau of Standards, Book: Optical Spectrometric Measurement of High Temperatures, Session V., ed. Philip J. Dickerman, p. 235 (University of Chicago Press, Chicago, Ill. 1961).

Branscomb, L. M., Burch, D. S., Smith, S. J. and Geltman, S., Photodetachment cross section and the electron affinity of atomic oxygen, Phys. Rev. 111, No. 2, 504 (1958) 2683.

Branscomb, L. M. and Smith, S. J., Experimental cross section for photodetachment of electrons from H^- and D^-, Phys. Rev. 98, No. 4, 1028 (1955) 1338.

Branscomb, L. M. and Smith, S. J., Negative oxygen ions in the upper atmosphere: The affinity and radiactive attachment coefficient of atomic oxygen, Trans. Am. Geophys. Union 36, No. 5, 755 (1955) 1413.

Branscomb, L. M., Smith, S. J., Burch, D. S. and Geltman, S., Photodetachment studies of negative ions, 3d Intern. Conf. Ionization Phenomena in Gases, (Venice, Italy 1957) 2246. Socita Italiana di Fiscia.

Burch, D. S., Smith, S. J. and Branscomb, L. M., Photodetachment of O_2^-, Phys. Rev. 112, 171 (1958) 2684.

Fano, U., McVoy, K. W. and Albers, J. R., Interference of orbital and spin currents in bremsstrahlung and photoelectric effect, Phys. Rev. 116, No. 5, 1159 (1959).

Fano, U., McVoy, K. W. and Albers, J. R., Sauter theory of the photoelectric effect, Phys. Rev. 116, No. 5, 1147 (1959).

Geltman, S., Theory of threshold energy dependence of photodetachment of diatomic molecular negative ions, Phys. Rev. 112, No. 1, 176 (1958) 2841.

McVoy, K. W. and Fano, U., Bremsstrahlung and the photoelectric effect as inverse processes, Phys. Rev. 116, No. 5, 1163 (1959) 2905.

Smith, S. J., Photodetachment cross section for the negative ion of atomic oxygen, Proc. 4th Intern. Conf. Ionization Phenomena in Gases, p. 1C219 (North Holland Publ. Co., Amsterdam, The Netherlands 1960).

Smith, S. J. and Branscomb, L. M., Atomic negative-ion-photodetachment cross-section and affinity measurements, J. Research NBS 55, 165 (1955) RP2615.

Smith, S. J. and Burch, D. S., Photodetachment cross section of the negative hydrogen ion, Phys. Rev. Letters 2, No. 4, 1645 (1959) 3012.

(5) Negative Ion Binding Energies

Branscomb, L. M., "Negative Ions", Book: Advances in Electronics and Electron Physics (Academic Press, New York, N. Y. 1957) 2210.

Branscomb, L. M., The electron affinity of atomic oxygen, Nature 182, 248 (1958) 2812.

Branscomb, L. M. and Smith, S. J., Electron affinity of atomic oxygen, Phys. Rev. 98, No. 4, 1127 (1955) 1334.

Branscomb, L. M. and Smith, S. J., Electron affinity of atomic sulfur and empirical affinities of the light elements, J. Chem. Phys. 25, No. 3, 598 (1956) 1698.

Johnson, H. R. and Rohrlich, F., Negative atomic ions, J. Chem. Phys. 30, No. 6, 1608 (1959).

Rohrlich, F. and Johnson, H., Atomic electron affinities, Nature 183, 4656, 244 (1959) 2900.

(6) Collision Cross Sections

Branscomb, L. M., Calculated calibration points for negative ion appearance potentials, J. Chem. Phys. 29, 452 (1958) 2481.

Carrington, T., Rotational transfer in the fluorescence spectrum of OH ($^2\Sigma^+$), J. Chem. Phys. Letter to Editor, 31, 1418 (1959).

Dibeler, V. H. and Reese, R. M., Multiple ionization of sodium vapor by electron impact, J. Chem. Phys. 31, 282 (1959) 2996.

Geltman, S., Electron detachment from the negative hydrogen ion by electron impact, Proc. Phys. Soc. LXXV, No. 1, 67 (1960).

Geltman, S., "Ionization" of the hydrogen negative ion, Proc. 4th Intern. Conf. Ionization Phenomena in Gases (North Holland Publ. Co., Amsterdam, The Netherlands) Uppsala 17-21, 1A19 (1960).

Herron, J. T. and Dibeler, V. H., Electron impact study of the cyanogen halides, J. Am. Chem. Soc. 82, 1555 (1960).

Krauss, M. and Kropf, A., Vibrational structure in the ionization efficiency curves of hydrogen and deuterium molecules, J. Chem. Phys. 26, 1776 (1957) 2410.

Leder, L. B., Inelastic scattering of 20-kev electrons in metal vapors, Phys. Rev. 107, No. 6, 1569 (1957) 2158.

Marton, L., Schubert, D. C. and Mielczarek, S. R., Electron optical image of an atomic beam, J. Appl. Phys. 27, No. 4, 419 (1956) 1704.

Mielzarek, S. R., Schubert, D. C. and Marton, L., Apparatus for electron optical study of low density gas flow, Proc. 6th Natl. Symp. Vacuum Techniques (1960).

Milford, S. N., Approximate cross-sections for inelastic collisions of electrons with atoms: I. Allowed transitions, Astrophys. J. 131, No. 2, 407 (1960).

Potter, R. F., Ion-atom interchange in air, J. Chem. Phys. 23, No. 12, 2462 (1955) 1379.

Ruthberg, S., Microwave double-sweep method for analysis of time-dependent cavity characteristics, Rev. Sci. Instr. 29, No. 11, 999 (1958) 2636.

Wacks, M. E. and Dibeler, V. H., Electron impact studies of aromatic hydrocarbons: I. Benzemen naphthalene, anthracene, and phenanthrene, J. Chem. Phys. 31, No. 6, 1557 (1959) 2938.

Wallenstein, M. B. and Krauss, M., Interpretation of the appearance potentials of secondary ions, J. Chem. Phys. 34, No. 3, 929 (1961).

b. Transport Properties and High Temperature Chemical Physics

(1) Theory of Non-Equilibrium Rate Processes and Statistical Mechanics

Bazley, N. W., Montroll, E. W., Rubin, R. J. and Shuler, K. E., Studies in non-equilibrium rate process, III. The vibrational relaxation of a system of anharmonic oscillators, Errata in J. Chem. Phys. 28, 700 (1958) 2786.

Green, M. S., A comment on a paper of Mori on time-correlation expressions for transport properties, Phys. Rev. 119, No. 3, 829-830 (1960).

Green, M. S., A topological derivation of the Mayer density series for the pressure of an imperfect gas, J. Math. Phys. 1, 291-294 (1960).

Green, M. S., On the theory of the critical point of a simple fluid, J. Chem. Phys. 33, No. 5, 1403-1409 (1960).

Green, M. S., "Some applications of the generating functional of molecular distribution functions", Book: Lectures in Theoretical Physics, (Lectures delivered at the Summer Institute for Theoretical Physics, University of Colorado, Boulder, Colo. 1960), III, 195-200 (Interscience Publishers, Inc., New York, N. Y. 1961).

Herman, R. and Rubin, R. J., Model for vibrational relaxation of diatomic gases behind shock waves, Phys. Fluids 2, 547 (1959).

Herman, R. and Rubin, R. J., Vibrational energy exchange between diatomic molecules and a surface, J. Chem. Phys. 29, 591 (1958) 2862.

Herman, R. and Shuler, K. E., Studies in non-equilibrium rate processes, IV. The rotational and vibrational relaxation of a system of rotating oscillators, J. Chem. Phys. 29, 366 (1958) 2787.

Jackson, J. L., Electric field distribution in a dense plasma, Phys. Fluids 3, 927-931 (1960).

Mazur, J. and Rubin, R. J., Quantum-mechanical calculation of the probability of an exchange reaction for constrained linear encounters, J. Chem. Phys. 31, No. 5, 1395 (1959) 3025.

Montroll, E. W. and Shuler, K. E., "Application of the theory of stochastic processes to chemical kinetics", Book: Advances in Chemical Physics I, (Interscience Publishers, New York, N. Y., 1959) Vol. 1, p. 361, 2898.

Montroll, E. W. and Shuler, K. E., Studies in non-equilibrium rate processes I: The relaxation of a system of harmonic oscillators, J. Chem. Phys. 26, 454 (1957) 2324.

Oppenheim, I., Statistical mechanical theory of transport processes, Proc. Midwestern Conf. on Theoretical Phys., 142 (Wash. U., St. Louis, Mo., 1958) 2278.

Oppenheim, I. and Mazur, P., Density expansions of distribution functions, I. Virial expansion for finite closed systems; canonical ensemble, Physics 23, 197 (1957) 2077; II. Density expansions in the grand canonical ensemble, Physica 23, 216 (1957) 2078.

Oppenheim, I. and Ross, J., Temperature dependence of distribution functions in quantum statistical mechanics, Phys. Rev. 107, No. 1, 28 (1957) 2340.

Rice, S. A., Kirkwood, J. G., Ross, J. and Zwanzig, R. W., Statistical mechanical theory of transport processes, XII. Dense rigid sphere fluids, J. Chem. Phys. 31, No. 3, 575 (1959).

Rubin, R. J. and Shuler, K. E., On the dissociation of polyatomic molecules, J. Chem. Phys. 33, No. 2, 438 (1960).

Rubin, R. J. and Shuler, K. E., On the relaxation of vibrational non-equilibrium distributions: I. Collisional relaxation of a system of harmonic oscillators, J. Chem. Phys. 25, 59 (1956); II. The effect of the collisional transition probabilities on the relaxation behavior, J. Chem. Phys. 25, 68 (1956); III. The effect of radiative transitions on the relaxation behavior, J. Chem. Phys. 26, 137 (1957).

Shuler, K. E., Analysis of vibrational relaxation data in shock wave experiments, J. Chem. Phys. Note 30, 1631 (1959) 2896.

Shuler, K. E., On the kinetics of elementary gas phase reactions at high temperatures, 5th Intern. Symp. on Combustion (Reinhold Publ. Corp., New York, N. Y., 1955) 56, 1433.

Shuler, K. E., On the perturbation of the vibrational equilibrium distribution reactant molecules by chemical reactions, 7th Intern. Symp. on Combustion, 87 (Butterworth, London, England, 1958) 2671.

Shuler, K. E., On the specification of transient non-equilibrium systems, 6th Intern. Symp. on Combustion (Reinhold Publ. Corp., New York, N. Y., 1957) 371, 2237.

Shuler, K. E., Relaxation of an isolated ensemble of harmonic oscillators, J. Chem. Phys. 32, No. 6, 1692 (1960).

Shuler, K. E., Relaxation processes in multistate systems, Phys. Fluids 2, No. 4, 442 (1959).

Shuler, K. E., Studies in non-equilibrium rate processes, II. The relaxation of vibrational non-equilibrium in distributions in chemical reactions and shock waves, J. Phys. Chem. 61, 849 (1957) 2325.

Zwanzig, R., Ensemble method in the theory of irreversibility, J. Chem. Phys. 33, No. 5, 1338-1341 (1960).

Zwanzig, R., Intermolecular forces from optical spectra of impurities in molecular crystals, Molecular Physics 3, No. 4, 305-311 (1960).

Zwanzig, R., "Statistical mechanics of irreversibility", Book: Lectures in Theoretical Physics, (Lectures delivered at the Summer Institute for Theoretical Physics, University of Colo., Boulder, Colo., 1960), III, (Interscience Publ. Inc., New York, N. Y., 1961).

(2) Chemical Kinetics

Bass, A. M. and Broida, H. P., Editors of the Book: "Formation and Trapping of Free Radicals", 522 pages (Academic Press, Inc., New York, N. Y., 1960).

Broida, H. P., "Spectroscopic studies of solids, condensed at 4.2°K from electric discharge through nitrogen, oxygen, hydrogen, water and ammonia", Proc. Conf. on Chem. Astronomy, Book: The Threshold of Space, (Pergamon Press, London, England, 1957) 2309.

Broida, H. P. and Nicholls, R. W., Phosphorescence of nitrogen and nitrogen-argon deposited films at 4.2°K, J. Chem. Phys. 32, No. 2, 623 (1960).

Garvin, D., Broida, H. P. and Kostkowski, H. J., Chemically induced vibrational excitation: hydroxyl radical emission in the 1-3 micron region produced by the $H+O_3$ atomic flame, J. Chem. Phys. 32, No. 3, 880 (1960).

Herron, J. T., Rate of reaction of nitrogen atoms with ethylene, J. Chem. Phys. 33, 1273 (1960). Letter to the Editor.

Herron, J. T. and Dibeler, V. H., Ionization potential of fluorine, J. Chem. Phys. 32, 1884 (1960). Letter to the Editor.

Herron, J. T. and Dibeler, V. H., Mass spectra and appearance potentials of tetrafluorohydrazine, J. Chem. Phys. 33, 1595 (1960). Letter to the Editor.

Herron, J. T., Franklin, J. L. and Brandt, P., Mass spectrometric study of the reactions of some hydrocarbons with active nitrogen, Can. J. Chem. 37, 579 (1959).

Herron, J. T., Franklin, J. L., Brandt, P. and Dibeler, V. H., Kinetics of nitrogen atom recombination, J. Chem. Phys. Letter 29, No. 1, 230 (1958); J. Chem. Phys. 30, 879 (1959) 2972.

Horl, E. M., Electron bombardment of solid acetone, J. Chem. Phys. 31, 564 (1959). Letter to the Editor.

Horl, E. M., The absorption spectrum of solid α-oxygen, J. Mol. Spectroscopy 3, 548 (1959).

Jackson, J. L., Dynamic stability of frozen radicals, I. Description and application of the model, J. Chem. Phys. 31, No. 1, 154 (1959).

Jackson, J. L., Dynamic stability of frozen radicals, II. The formal theory of the model, J. Chem. Phys. 31, No. 1, 154 (1959).

Klein, R., Adsorption, diffusion, and evaporation of carbon monoxide on tungsten, J. Chem. Phys. 31, No. 5, 1306 (1959) 2888.

Klein, R. and Horl, E. M., Isotope exchange processes in solid nitrogen under electron bombardment, J. Chem. Phys. 32, 307 (1960). Letter to the Editor.

Klein, R., McNesby, J. R., Scheer, M. D. and Schoen, L. J., Kinetics of D atom reactions with H_2, J. Chem. Phys. 30, No. 1, 58 (1959) 2971.

Klein, R. and Scheer, M. D., Hydrogen atom reactions with propane at 77°K disproportionation and recombination, J. Phys. Chem. 65, 324 (1961).

Klein, R. and Scheer, M. D., Reaction of hydrogen atoms with solid oxygen at 20°K, J. Chem. Phys. 31, 278 (1959). Letter to the Editor.

Klein, R., Scheer, M. D. and Walker, J., The reaction of hydrogen atoms with solid propane at low temperatures, J. Phys. Chem. 64, 1247 (1960).

McKinley, J. D., Jr. and Shuler, K. E., Kinetics of the high temperature heterogeneous reaction of chlorine and nickel between 1,200 and 1,700°K, J. Chem. Phys. 28, No. 6, 1207 (1958), 2608.

McNesby, J. R., Scheer, M. D. and Klein, R., Isotope effect in the hydrogen atom-formaldehyde reaction, J. Chem. Phys. 32, No. 6, 1814 (1960).

Meijer, P. H. E., Line shape of ultraviolet absorption in solid noble gases, J. Chem. Phys. 34, No. 6, 2078-2082 (1961).

Okabe, H. and McNesby, J. R., Vacuum ultraviolet photolysis of ethane: Molecular detachment of hydrogen, J. Chem. Phys. 34, No. 2, 668 (1961).

Ruehrwein, R. A. and Hashman, J. S., Formation of ozone from atomic oxygen at low temperature, J. Chem. Phys. 30, No. 3, 823 (1959) 2954.

Ruehrwein, R. A., Hashman, J. S. and Edwards, J. W., Chemical reactions of free radicals at low temperature, J. Phys. Chem. 64, 1317 (1960).

Scheer, M. D. and Klein, R., The double bond isomerization of olefins by hydrogen atoms at -195°, J. Phys. Chem. 63, 1517 (1959).

Schoen, L. J. and Broida, H. P., Spectra emitted from rare gas-oxygen solids during electron bombardment, J. Chem. Phys. 32, No. 4, 1184 (1960).

(3) Gas Phase Chemiluminescence

Beale, G. E., Jr. and Broida, H. P., Spectra study of a visible short-duration afterglow in nitrogen, J. Chem. Phys. 31, No. 4, 1030 (1959).

Broida, H. P., Experimental temperature measurements in flames and hot gases, Book: Temperature, Its Measurement and Control in Science and Industry 2, 264 (1955) (Reinhold Publ. Corp., New York, N. Y.) 1340.

Broida, H. P. and Heath, D. F., Luminous reaction between carbon monoxide and atomic nitrogen, J. Chem. Phys. 26, 1352 (1957) 2183.

Dressler, K., Absorption spectrum of vibrationally excited N_2 in active nitrogen, J. Chem. Phys. 30, 1621 (1959) 2887. Letter to the Editor.

Ferguson, R. E., On the origin of the electronically excited C_2 radical in hydrocarbon flames, J. Chem. Phys. 23, No. 11, 2085 (1955).

Kiess, N. H. and Broida, H. P., Emission spectra from mixtures of atomic nitrogen and organic substances, 7th Symp. on Combustion, (Butterworth, London, England, 1958) 207, 2544.

Kostkowski, H. J. and Broida, H. P., Spectra absorption method for determining population "temperatures" in hot gases, J. Opt. Soc. Am. 46, No. 4, 246 (1956) 1882.

Kurzweg, U. H., Bass, A. M. and Broida, H. P., Spectra of afterglows and discharges from nitrogen-oxygen mixtures, J. Mol. Spectroscopy 1, 184 (1957) 2307.

Kurzweg, U. H. and Broida, H. P., Vibrational intensity distributions in the nitrogen afterglow, J. Mol. Spectroscopy 3, 388 (1959).

McKinley, J. D., Jr. and Polyanyi, J. C., Chemiluminescence in the system atomic sodium plus atomic hydrogen, Can. J. Chem. 36, 107 (1958) 2486.

(4) Spectroscopic Temperature Measurements

Broida, H. P. and Heath, D. F., Spectroscopic survey of energy distributions of OH, C_2, and CH radicals in low-pressure acetylene-oxygen flames, J. Chem. Phys. 26, 223 (1957) 2316.

Broida, H. P. and Kostkowski, H. J., Experimental proof for the existence of non-thermal rotational distributions of OH ($^2\Sigma^+$) in flames, J. Chem. Phys. 25, No. 4, 676 (1956) 1709.

Carrington, T., Electronic quenching of OH ($^2\Sigma^+$) in flames and its significance in the interpretation of rotational relaxation, J. Chem. Phys. 30, 1087 (1959) 2941.

Carrington, T. and Broida, H. P., Wall effects on rotational population of OH$^2\Sigma^+$ in a microwave discharge, J. Mol. Spectroscopy 2, No. 3, 273 (1958) 2865.

Ferguson, R. E. and Broida, H. P., Atomic flames: Spectra "temperatures" and products, 5th Intern. Symp. on Combustion (1955).

Herzfeld, C. M., Incomplete equilibrium and temperature measurement, J. Wash. Acad. Sci. 46, 269 (1956) 1735.

Kostkowski, H. J., The accuracy and precision of measuring temperatures above 1000°K, Proc. 2d Intern. Symp. on High Temperature Technology, Stanford Research Institute, (Oct. 1959), 33 (McGraw-Hill Book Co. Inc., New York, N. Y., 1960).

Maki, A. G., Stair, R. and Johnson, R. G., Apparatus for the measurement of the normal spectral emissivity in the infrared, J. Research NBS 64C (Eng. and Instr.), No. 2, 99 (1960).

Parkinson, W. H. and Nicholls, R. W., Spectroscopic temperature measurements in a shock tube using CN as a thermometric molecule, Can. J. Phys. 38, 715 (1960).

Thomas, R. N., Effect of departures from local thermodynamic equilibrium on inferences of stellar atmospheric temperatures, Optical Spectrometric Measurements of High Temperatures (University of Chicago Press, Chicago, Ill., 1960).

Zirker, J. B. and Thomas, R. N., Departures from the Saha equation for ionized helium, I. Condition of detailed balance in the resonance lines, Astrophys. J. 133, No. 2, 588 (1961).

(5) Thermodynamic Properties of Ionized Gas

Hilsenrath, J., Green, M. S. and Beckett, C. W., The internal energy of highly ionized gases, Proc. 9th Intern. Astronautical Congr. (Amsterdam, Holland, 1958). Springer Verlag (Vienna, Austria, 1959) p. 120, 3081.

Hilsenrath, J., Klein, M. and Sumida, D. Y., Mechanized computation of thermodynamic tables at the NBS: The calculation of the equilibrium composition and thermodynamic properties of dissociated and ionized gaseous system, Proc. Symp. Thermodynamic and Transport Properties of Gases, Liquids, and Solids, Am. Soc. Mech. Engrs., 416 (Reprinted from Thermodynamic and Transport Properties of Gases, Liquids, and Solids, 1959) 2988.

Hilsenrath, J., Klein, M. and Woolley, H. W., Tables of thermodynamic properties of air including dissociation and ionization from 1500°K to 15000°K, USAF Report AEDC-TR-59-20 (Dec. 1959).

Woolley, H. W., Effects of intermolecular interactions of thermodynamic properties of gases at high temperatures and pressures, Proc. 4th Hypervelocity Impact Symp., Eglin Air Force Base, Florida (June 1960).

Woolley, H. W., Empirical intermolecular potential for inert gas atoms, J. Chem. Phys. 32, No. 2, 405 (1960).

Woolley, H. W., Thermodynamic functions for atomic ions, ASTIA Document AD 96302 (Apr. 1957).

Woolley, H. W., Thermodynamic properties of gases at high temperature, I. Chemical equilibrium among molecules, atoms, and atomic ions considered as clusters, J. Research NBS 61, 469 (1959) RP2916.

c. Plasma Physics and Astrophysics

(1) Plasma Physics

Gallet, R. M., Propagation and production of electromagnetic waves in a plasma, II. Nuova Cimento Suppl. 13, No. 1, 234 (1959) 3023.

Gallet, R. M., Richardson, J. M., Wider, B., Ward, G. D. and Harding, G. N., Microwave whistler mode propagation in a dense laboratory plasma, Phys. Rev. Letter 4, No. 7, 347 (1960).

Jackson, J. L., Electric field distribution in a dense plasma, Phys. Fluids 3, 927-931 (1960).

Tchen, C. M., Approximate theory on the stability of interfacial waves between two streams, J. Appl. Phys. 27, No. 12, 1533 (1956) 1632.

Tchen, C. M., Kinetic equation for a plasma with unsteady correlations, Phys. Rev. 114, No. 2, 394 (1959).

Tchen, C. M., Stability of oscillations of superposed fluids, J. Appl. Phys. 27, No. 7, 760 (1956) 1890.

(2) Astrophysics

Branscomb, L. M. and Pagel, B. E. F., Atomic and molecular negative ions in stellar atmospheres, Mo. Notices Roy Astron. Soc. 118, No. 3, 258 (1958) 2463.

Bur. Standards Tech. Note 30, Aerodynamic phenomena in stellar atmospheres--A bibliography (PB15389).

Burgers, J. M. and Thomas, R. N., Preface to Proc. 3rd Symp. on Cosmical Gas Dynamics, Cambridge, Smithsonian Astrophys. Observatory, (June 1957), Rev. Modern Phys. 30, 908 (1958) 2697.

Chapman, S., Thermal diffusion in ionized gases, Proc. Phys. Soc. (London, England, 1958) 72, 353, 2844.

Gallet, R. M., Aerodynamical mechanisms producing electronic density fluctuations in turbulent ionized layers, Proc. IRE 43, 1240 (1955) 1254.

Gallet, R. M., and Utlaut, W. F., Evidence on the laminar nature of the exosphere obtained by means of guided high-frequency wave propagation, Phys. Rev. Letter to Editor 6, No. 11, 591-594 (June 1, 1961).

Jefferies, J. T., Source function in a non-equilibrium atmosphere, VII. The interlocking problem, Astrophys. J. 132, No. 3, 775 (1960).

Jefferies, J. T. and Pottasch, S., The nova outburst, III. The ionization of hydrogen gas by an exciting star, Ann. Astrophys. J. 22, 318 (1959) 3085.

Jefferies, J. T. and Thomas, R. N., Source function in a non-equilibrium atmosphere, II. Depth dependence of source function for resonance and strong subordinate lines, Astrophys. J. 127, No. 3, 667 (1958) 2767.

Jefferies, J. T. and Thomas, R. N., Source function in a non-equilibrium atmosphere, III. The influence of a chromosphere, Astrophys. J. 129, No. 2, 401 (1959).

Jefferies, J. T. and Thomas, R. N., The source-function in a non-equilibrium atmosphere, V. Character of the self-reversed emission cores of Ca+ H and K, Astrophys. J. 131, 695 (1960).

Jefferies, J. T. and White, O. R., Source function in a non-equilibrium atmosphere, VI. The frequency dependence of the source function for resonance lines, Astrophys. J. 132, 767 (1960).

Kiess, C. C., Corliss, C. H. and Kiess, H. K., High dispersion spectra of Jupiter, Astrophys. J. 132, 221 (1960).

Kiess, C. C., Corliss, C. H., Kiess, H. K. and Corliss, E. L. R., High-dispersion spectra of Mars, Astrophys. J. 126, No. 3, 579 (1957) 2152.

Pottasch, S. R., Bright rims in diffuse nebulae, Rev. Modern Phys. 30, No. 3, 1053 (1958) 2479.

Pottasch, S. R., Balmer decrements, the diffuse nebulae, Astrophys. J. 131, No. 1, 202 (1960).

Pottasch, S. R., The nova outburst, I. The nova outburst, Ann. Astrophys. J. 22, 297 (1959) 3085.

Pottasch, S. R., The nova outburst, II. The radiative cooling of an expanding shell, Ann. Astrophys. J. 22, 310 (1959) 3085.

Pottasch, S. R., The nova outburst, IV. The intensity of Hα, Ann. Astrophys. J. 22, 394 (1959) 3085.

Pottasch, S. R., The nova outburst, V. The temperature and radius of the central exciting star and observation of elements other than hydrogen, Ann. Astrophys. J. 22, No. 4, 412 (1959) 3085.

Pottasch, S. R. and Thomas, R. N., Departures from the Saha equation under varying conditions of Lyman continuous opacity, Astrophys. J. 130, No. 3, 941 (1959) 2926.

Thomas, R. N., Effect of departures from local thermodynamic equilibrium on inferences of stellar atmospheric temperatures, Book: Optical Spectrometric Measurements of High Temperatures, ed. by Philip J. Dickerman, Session 1, p. 14 (University of Chicago Press, Chicago, Ill., 1961).

Thomas, R. N., The source-function in a non-equilibrium atmosphere, IV. Evaluation and application of the net radiative bracket, Astrophys. J. 131, 429 (1960).

(3) Solar Physics

Athay, R. G. and Thomas, R. N., On the use of the early balmer lines to extend the photospheric model, Astrophys. J. 127, No. 1, 96 (1958).

Athay, R. G. and Thomas, R. N., The chromosphere near active regions, Astrophys. J. 125, 788 (1957).

Moore, C. E. and Broida, H. P., OH in the solar spectrum, J. Research NBS 63A (Phys. and Chem.), No. 3, 279 (1959).

Pottasch, S. R., Departures of hydrogen from L.T.E. in a stellar atmosphere and the consequent structure of the solar chromosphere, Comm. de l'Observatoire Royal de Belgique No. 157, entitled "The emperical determination of the stellar photospheric structures", Paper 11, 67 (1959).

Pottasch, S. R., Use of the equation of hydrostatic equilibrium in determining the temperature distribution in the outer solar atmosphere, Astrophys. J. 131, 68 (1960).

Pottasch, S. R. and Thomas, R. N., Thermodynamic structure of the outer solar atmosphere, VI. Effect of departures from the Saha equation on infrared properties of the low chromosphere, Astrophys. J. 132, (1960).

Tandberg-Hanssen, E., Curtis, W. and Watson, K., The emission of Hel I, γ10830, during the great flare of August 26, 1958, Astrophys. J. 129, No. 1, 238 (1959).

Thomas, R. N. and Athay, R. G., Physics of the solar chromosphere (Interscience Publishers, New York, N. Y., 1961).

Warwick, C. S., Green coronal line intensity and geomagnetism, J. Geophys. Research 64, 527 (1959).

Warwick, C. S. and Hansen, R. T., Geomagnetic activity following large solar flares, J. Atmospheric and Terrest. Phys. 14, 287 (1959).

Warwick, C. S. and Warwick, J. W., Flare-associated bursts at 18 MC/S, Paris Symp. on Radio Astronomy (IAU Symp. No. 9 and URSI Symp. No. 1), p. 203 (1959).

Warwick, C. S. and Wood, M. B., A study of limb flares and associated events, Astrophys. J. 128, 801 (1959).

(4) Upper Atmosphere Physics - Airglow and Aurorae

Agy, V., Ionospheric effects produced by solar flare radiation, Phys. Rev. 102, 917 (1956).

Chamberlain, J. W., Oxygen red lines in the airglow, I. Twilight and night excitation processes, Astrophys. J. 127, No. 1, (MacMillan and Co., London, England, 1958).

Chapman, S., The aurora in middle and low latitudes, Nature 179, No. 4549, (1957).

Chapman, S. and Davies, K., On the approximate daytime constancy of the absorption of radio waves in the lower ionosphere, J. Atmospheric and Terrest. Phys. 13, 86 (1958).

Dunn, R. B., Jefferies, J. T. and Orrall, F. Q., The line and continuous emission observed in two limb flares, Observatory 80, 31 (1960).

Finney, J. W. and Smith, E. K., Jr., Report on the IGY oblique-incidence sporadic-E and F-scatter program, NBS Tech. Note 48, (PB151407) (1960).

Gallet, R. M., The spectrum of the electron density fluctuations in the ionosphere, J. Atmospheric and Terrest. Phys. Special Suppl. (1957); Proc. Polar Atmosph. Symp., (Oslow, Norway, 1957 - July 2-8, 1956) Part II, 165.

Gallet, R. M., The very low-frequency emissions generated in the earth's exosphere, Proc. IRE 47, 211 (1959).

Gates, D. M., Radio, ionosphere and air-glow observations during IGY, IGY Bull. 29, No. 1 (1959).

Gates, D. M. and Jones, E., OH emission in the earth's atmosphere, Proc. 2d Natl. Infrared Information Symp. 4, 145 (1959).

Hunten, D. M., Roach, F. E. and Chamberlain, J. W., A photometric unit for the airglow and aurora, J. Atmospheric and Terrest. Phys. 8, 345 (1956).

McCaulley, J. W., Roach, F. E. and Matsushita, S., A study of local geomagnetic influence on the (OI) 5577 night-glow emission at Fritz Peak, J. Geophys. Research 65, No. 5 (May 1960).

Megill, L. R., Photometric observations of the twilight glow (OI) 5577 and (OI) 6300, J. Atmospheric and Terrest. Phys. 17, 276 (1960).

O'Brien, B. J., Van Allen, J. A., Roach, F. E. and Gartlein, C. W., Correlation of an auroral arc and a subvisible monochromatic 6300A arc with outer-zone radiation on November 28, 1959, J. Geophys. Research 65, No. 9, 2759-2766 (Sept. 1960).

Rees, M. H., Absolute photometry of the aurora, I. The ionized molecular nitrogen emission and the oxygen green line in the dark atmosphere, J. Atmospheric and Terrest. Phys. 14, 325 (1959).

Rees, M. H., Absolute photometry of the aurora, II. Molecular nitrogen emission in the sunlit atmosphere, J. Atmospheric and Terrest. Phys. 14, 338 (1959).

Roach, F. E., The intensity of (OI) 5577 in the subauroral region as a function of magnetic activity, J. Geophys. Research 65, No. 5, 1495 (1960).

Roach, F. E., The night airglow, Proc. IRE 47, 267 (1959).

Roach, F. E., McCaulley, J. W. and Marovich, E., Origin of (OI) 5577 in the airglow and the aurora, J. Research NBS 63D (Radio Prop.), No. 1, 15-18, (July-Aug. 1959).

Roach, F. E., McCaulley, J. W., Marovich, E. and Purdy, C. M., A comparative study of absolute Zenith intensities of (OI) 5577, J. Geophys. Research 65, No. 5, 1503 (1960).

Roach, F. E., McCaulley, J. W. and Purdy, C. M., Comparison of absolute intensities of (OI) 5577 in the auroral and subauroral zones, J. Research NBS 63D (Radio Prop.), No. 1, 19-20 (July-Aug. 1959).

Roach, F. E. and Marovich, E., A monochromatic low-latitude aurora, J. Research NBS 63D (Radio Prop.), No. 3, 297-301 (Nov.-Dec. 1959).

Roach, F. E. and Marovich, E., Aurora of October 22/23, 1958 at Rapid City, South Dakota, J. Research NBS 64D (Radio Prop.), No. 2, 205-209 (March-Apr. 1960).

Roach, F. E., Megill, L. R., Rees, M. H. and Marovich, E., The height of nightglow 5577, J. Atmospheric and Terrest. Phys. 12, 171 (1958).

Roach, F. E. and Meinel, A. B., The height of the nightglow by the Van Rhijn method, Astrophys. J. 122, No. 3, 530 (1955).

Roach, F. E. and Rees, M. H., The absolute Zenith intensity of (01) 5577 at College, Alaska, J. Geophys. Research 65, No. 5, 1489 (1960).

Roach, F. E., Tandberg-Hanssen, E. and Megill, L. R., Movements of airglow cells, J. Atmospheric and Terrest. Phys. 13, 122 (1958).

Roach, F. E., Tandberg-Hanssen, E. and Megill, L. R., The characteristic size of airglow cells, J. of Atmospheric and Terrest. Phys. 13, 113 (1958).

Smith, S. J., Burch, D. S. and Branscomb, L. M., Experimental photodetachment cross section and the ionospheric detachment rate of O_2^-, Ann. Geophys. Tome 14, No. 2, 225 (1958).

Tandberg-Hanssen, E. and Roach, F. E., Excitation mechanisms of the oxygen 5577 emission in the upper atmosphere, J. Research NBS 63D (Radio Prop.), No. 3, 319-324 (Nov.-Dec. 1959).

Thomas, J. A. and Smith, E. K., A survey of the present knowledge of sporadic-E ionization, J. Atmospheric and Terrest. Phys. 13, 295 (1959).

(5) Ionosphere

Agy, V. and Davis, K., Ionospheric investigations using the sweep-frequency pulse technique at oblique incidence, J. Research NBS 63D (Radio Prop.), No. 2, 151-174 (Sept.-Oct. 1959).

Brandt, J. C. and Chamberlain, J. W., Interplanetary gas, I. Hydrogen radiation in the night sky, Astrophys. J. 130, 670 (1959).

Chapman, S., The earth and its environment, Proc. IRE 47, No. 2, 137 (1959).

Chapman, S. and Little, C. G., The nondeviative absorption of high-frequency radio waves in auroral latitudes, J. Atmospheric and Terrest. Phys. 10, 20-31 (1957).

Gates, D. M., Atmospheric research, Americana Annual, p. 62 (1958).

Gallet, R. M. and Helliwell, R. A., Origin of "very-low-frequency" emissions, J. Research NBS 63D (Radio Prop.), No. 1, 21-27 (July-Aug. 1959).

Little, C. G. and Lawrence, R. S., The use of polarization fading of satellite signals to study the electron content and irregularities in the ionosphere, Proc. COSPAR Space Symp. Part II (North Holland Publ. Co., Amsterdam, The Netherlands, 1960).

McDonald, N. and Knecht, R. W., A possible effect of lower atmosphere divergence on the local electron density in the ionosphere, High Altitude Observatory Institute of Solar-Terrestrial Research, NBS Tech. Note (1960).

Smith, E. K. and Finney, J. W., Peculiarities of the ionosphere in the Far East, A report on IGY observations of Es and F-region scatter, J. Geophys. Research 65, 885 (1960).

White, M. L., Atmospheric tides and electro ionospheric dynamics, J. Geophys. Research 65, No. 1, 153 (1960).

Wright, J. W. and Fine, L. A., Mean electron density variations of the quiet ionosphere I - March 1959, NBS Tech. Note 40-1 (PB151399-1).

Wright, J. W. and Fine, L. A., Mean electron density variations of the quiet ionosphere I - March 1959, NBS Tech. Note 40-2 (PB151399-2).

3.2. Partial List of Participants

There follows a partial list of scientists engaged in activities described in this note, with indications of their research fields and organizational location within the National Bureau of Standards. The latter may be helpful in making contact with individuals for the purpose of obtaining reprints or further technical information:

ALLEN, Harry C., Jr: Ph.D., University of Washington (Seattle), 1951; theory of molecular structure; Chief, Analytical and Inorganic Chemistry Division.

BASS, Arnold M.: Ph.D., Duke University, 1949; spectroscopy with emphasis on the spectra of molecules in solids at low temperature, and on the use of spectroscopic methods in high temperature measurement; Heat Division.

BEATTY, Earl C.: Ph.D., Washington University, 1956; atomic mobilities and optical pumping, atomic clocks; Atomic Physics Division, Atomic Physics Section.

BECKETT, Charles W.: Ph.D., University of California, 1945; dynamic and transfer properties and related structural properties of matter throughout the temperature range from ordinary temperatures up to millions of degrees; Assistant Chief, Heat Division.

BRANSCOMB, Lewis M.: Ph.D., Harvard University, 1949; ionic physics and atomic collision phenomena, upper atmosphere physics; Chief, Atomic Physics Division.

BROIDA, Herbert P.: Ph.D., Harvard University, 1949; molecular spectroscopy, chemical physics, spectra of condensed radicals; Office of the Director, Senior Research Fellow.

BROWN, Lawrence M.: Ph.D. candidate, Catholic University; equation of state of gases, shock waves, exploding wire phenomena, compilation of properties of isotopic hydrogen compounds, review of isotope effects on chemical reaction rates; Heat Division, Equation of State Section.

CARRINGTON, Tucker: Ph.D., California Institute of Technology, 1952; spectroscopic study of molecular collisions; Physical Chemistry Division, Molecular Kinetics Section.

COOPER, J. W.: Theoretical physics; photoionization cross sections; Office of the Director.

CORLISS, Charles H.: Spectrochemical analysis, description of atomic spectra, measurement of spectral intensity, development of spectroscopic light sources; Atomic Physics Division, Spectroscopy Section.

DIBELER, Vernon H.: Ph.D., Columbia University, 1950; application of mass spectrometry to molecular physics, electron impact phenomena in molecular gases; Physical Chemistry Division, Chief, Mass Spectrometry Section.

FANO, U.: Dr. Sc., University Torino, Italy, 1929-34; theoretical physics, scattering theory, radiation transfer through materials; Office of the Director, Senior Research Fellow.

GELTMAN, Sydney: Ph.D., Yale University, 1952; theory of ionic mobilities, atomic scattering, ionization, and photodetachment; Atomic Physics Division, Atomic Physics Section.

GREEN, Melville S.: Ph.D., Princeton, 1951; statistical mechanics of time-dependent phenomena, quantum statistical mechanics of many-body systems; equilibrium transport properties at high temperatures; Heat Division, Chief, Statistical Physics Section.

HERRON, John T.: Ph.D., McGill University, 1957; appearance potentials of positive and negative ions in halogen molecules; Physical Chemistry Division, Mass Spectrometry Section.

HILSENRATH, Joseph: Thermodynamic properties of gases, liquids, and solids, high pressure thermodynamics, equation of state of highly ionized gases; Heat Division, Chief, Equation of State Section.

JACKSON, J. L.: Ph.D., New York University, 1950; application of statistical methods to various fields of physics, in particular - plasmas, trapped radicals, irreversible statistical mechanics, crystallization of polymers, and electrical noise; Heat Division, Statistical Physics Section.

KESSLER, Karl G.: Ph.D., University of Michigan, 1947; atomic spectra, wavelength standards of length; Atomic Physics Division, Chief, Spectroscopy Section.

KIEFFER, L. J.: Ph.D., St. Louis University, 1958; pressure broadening spins and moments in radioactive nuclei, atomic beams, electron scattering; Atomic Physics Division, Atomic Physics Section.

KLEIN, M.: Ph.D. candidate, University of Maryland; transport and equilibrium properties of gases; Heat Division, Statistical Physics Section.

KOSTKOWSKI, Henry J.: Ph.D., Johns Hopkins University, 1954; infrared spectroscopy, temperatures of flames, optical pyrometry, plasma thermometry; Heat Division, Temperature Physics Section.

KRAUSS, Morris: Ph.D., University of Utah, 1955; molecular orbitals, mass spectra; Physical Chemistry Division, Thermochemistry Section.

KUYATT, C. E.: Ph.D., University of Nebraska, 1960; atomic collisions, electron scattering in gases; Atomic Physics Division, Electron Physics Section.

MARTIN, William C.: Ph.D., Princeton, 1956; atomic spectra; Atomic Physics Division, Spectroscopy Section.

MARTON, L.: Ph.D., University of Zurich, 1924; electron optics, interferometry, electron scattering in solids and gases; Atomic Physics Division, Chief, Electron Physics Section.

McLANE, C. K.: Ph.D., Harvard, 1949; reaction kinetics, low temperature physics, plasma physics, spectroscopy; Heat Division.

McKINLEY, John D., Jr.: Ph.D., New York University, 1953; kinetics of heterogeneous reactions; Physical Chemistry Division, Molecular Kinetics Section.

MEIJER, Paul, H. E.: Ph.D., Leydon University, 1950; theoretical physics, statistical mechanics, and quantum theory; Consultant, Heat Division and Professor at Catholic University.

MENDLOWITZ, Harold: Ph.D., University of Michigan, 1954; characteristic electron energy losses in solids, electron optics, electron-nuclear scattering, plasmas in solids, electron polarization, oscillator strengths, optical properties of solids, atomic scattering; Atomic Physics Division.

MOHLER, Fred L.: Ph.D., Johns Hopkins University, 1917; atomic physics, ionization potentials, physics of the cesium positive column plasma, mass spectrometry; Atomic Physics Division, Retired.

PICCIRELLI, R. A.: Ph.D., Catholic University, 1956; statistical mechanics, evaluation of the quantum partition function, generalization of the Boltzmann equation to higher densities and to include inhomogeneities, derivation of a kinetic equation for plasmas which includes all collision effects; Heat Division, Statistical Physics Section.

PLYLER, Earle K.: Ph.D., Cornell University, 1924; infrared emission and absorption spectra; Atomic Physics Division, Chief, Infrared Spectroscopy Section.

REESE, Robert M.: Measuring excitation functions of multiply charged ions near the threshold; Physical Chemistry Division, Mass Spectrometry Section.

RUBIN, Robert J.: Ph.D., Cornell University, 1951; plastic wave propagation in materials exhibiting strain-rate effects, vibrational relaxation and its influence on relative line intensities of diatomic molecules, chemical exchange reaction probabilities, models for Brownian motion; Heat Division, Temperature Physics Section.

SCHEER, Milton D.: Ph.D., New York University, 1951; kinetics of surface ionization and low temperature chemistry; Physical Chemistry Division, Molecular Kinetics Section.

SCHUBAUER, Galen B.: Ph.D., Johns Hopkins University, 1934; aerodynamics, hydrodynamics, and hydraulics, specific field - turbulence and boundary layer research; Mechanics Division, Chief, Fluid Mechanics Section.

SHULER, Kurt E.: Ph.D., Catholic University, 1949; theoretical chemical physics, energy transfer in inelastic collisions, relaxation phenomena, non-equilibrium statistical mechanics; Consultant to the Director.

SHUMAKER, John B., Jr.: Ph.D., Yale University, 1952; spectroscopic measurements in arc plasmas; Heat Division, Temperature Physics Section.

SIMPSON, J. Arol: Ph.D., Lehigh University, 1953; characteristic energy losses, electron spectroscopy; Atomic Physics Division, Electron Physics Section.

SITTERLY, Charlotte M.: Ph.D., University of California, 1931; compilation of atomic energy levels, preparation of multiplet tables, study of atomic spectra, identification of solar lines; Atomic Physics Division, Spectroscopy Section.

SMITH, Stephen J.: Ph.D., Harvard University, 1954; photodetachment of negative ions, electron-atom interaction; Atomic Physics Division, Chief, Atomic Physics Section.

TCHEN, Chan Mou: Dr. of Tech. Sci., Technical University, Delft, 1947; hydrodynamics, stochastic processes, theoretical plasma physics; Applied Mathematics Division, Mathematical Physics Section.

THOMPSON, R.: Experimental plasma physics; Heat Division.

TREES, Richard E.: Ph.D., University of Pennsylvania, 1951; atomic energy levels; Atomic Physics Division, Spectroscopy Section.

TSAI, D.: Sc.D., Massachusetts Institute of Technology, 1952; aircraft pneumatics, high temperature pvt measurement; Heat Division, Equation of State Section.

WIESE, Wolfgang L.: Ph.D., University of Kiel, Germany, 1957; plasma physics, atomic transition probabilities; Atomic Physics Division, Spectroscopy Section.

WOOLLEY, H. W.: Ph.D., University of Michigan, 1955; thermodynamic properties of hydrogen isotopes, ortho-para effects, ideal gas properties, gas imperfection effects, third virial coefficient, equations of state, thermodynamic functions for atoms and atomic ions at high temperature, equilibrium properties of gases at high temperatures; Heat Division, Statistical Physics Section.

ZWANZIG, R.: Ph.D., California Institute of Technology, 1952; statistical mechanics; Physical Chemistry Division.

ZALUBAS, R.: Ph.D., Georgetown University, 1955; description and analysis of atomic spectra; Atomic Physics Division, Spectroscopy Section.

Participants in the Boulder Laboratories:

BAILEY, D. K.: Ionospheric physics, scatter propagation, physics of the lower ionosphere and cosmic rays; Upper Atmosphere and Space Physics Division.

BARGER, R. L.: Atomic and molecular spectroscopy, hyperfine structure, wavelength standards of length; Radio Standards Laboratory, Radio Plasma Group.

BRITTIN, W. E.: Ph.D., University of Alaska, 1957; Statistical Mechanics quantum theory, relativity theory; Consultant, Radio Standards Laboratory.

EARNSHAW, K. B.: Electronic and microwave training, mass spectrometry, laboratory plasma physics; Upper Atmosphere and Space Physics Division, Upper Atmosphere and Plasma Physics Section.

ESTIN, A. J.: Electromagnetic theory, microwave physics and engineering, RF diagnostics; Radio Standards Laboratory, Radio Plasma Group.

GALLET, R. M.: Certificates in philosophy, physics, and mathematics, University of Sorbonne, 1942-43; theory of the exosphere, plasma physics, radio astronomy; Upper Atmosphere and Space Physics Division, Chief, Upper Atmosphere and Plasma Physics Section.

GATES, D. M.: Ph.D., University of Michigan, 1948; infrared spectroscopy of the upper atmosphere; Director's Office.

JEFFERIES, J. T.: Theory of stellar atmospheres, radiative transfer, solar physics; Director's Office, Astrophysics Section.

LITTLE, C. G.: Ph.D., University of Manchester, 1952; Ionospheric physics, radio-wave propagation, radio astronomy, auroral ionosphere; Chief, Upper Atmosphere and Space Physics Division.

MEGILL, L. R.: Ph.D., Colorado University, 1959; upper atmospheric physics, physics of the airglow, atmospheric spectroscopy, artificial heating of electrons and inelastic collision processes with inert gases; Upper Atmosphere and Space Physics Division.

POWERS, R. S.: Ph.D., University of Wisconsin, 1960; scattering theory and transport properties of gases, beam plasma interaction; Radio Standards Laboratory, Radio Plasma Group.

RICHARDSON, J. M.: Ph.D., Harvard University, 1951; microwave standards, microwave spectroscopy of O_2 with application to atomic frequency standards, millimeter wave measurements and interferometry, plasma physics with regard to the interaction of microwave radiation with plasmas; Chief, Radio Standards Laboratory.

ROACH, F. E.: Ph.D., University of Chicago, 1934; upper atmosphere physics, physics of the airglow; Upper Atmosphere and Space Physics Division, Chief, Airglow and Aurora Section.

RUNDLE, H. N.: Ph.D., University of Saskatchewan, 1958; physics of the airglow and upper atmosphere; Director's Office, Physics of the Atmosphere Section.

THOMAS, R. N.: Ph.D., Harvard University, 1948; theory of stellar atmospheres and radiation transfer in hot gases, gas dynamics; Consultant, Director's Office.

VanZANDT, T.: Ph.D., Yale University, 1954; upper atmosphere theory, physics of the F2 layer; Ionosphere Research and Propagation Division, Sun-Earth Relationships Section.

WACKER, P. F.: Ph.D., Catholic University, 1954; microwave spectroscopy and molecular structure; Consultant, Radio Standards Laboratory.

WARWICK, C.: Ph.D., Radcliffe, 1952; solar physics and related ionospheric physics; Ionosphere Research and Propagation Division, Sun-Earth Relationships Section.

WIEDER, B.: Ionospheric physics, microwave interaction with plasmas and plasma RF radiation; Radio Standards Laboratory, Radio Plasma Group.

YARGER, F. L.: Ph.D., Ohio State University, 1960; plasma physics and radio wave propagation; Upper Atmosphere and Space Physics Division, Upper Atmosphere and Plasma Physics Section.

U. S. DEPARTMENT OF COMMERCE
Luther H. Hodges, *Secretary*

NATIONAL BUREAU OF STANDARDS
A. V. Astin, *Director*

THE NATIONAL BUREAU OF STANDARDS

The scope of activities of the National Bureau of Standards at its major laboratories in Washington, D.C., and Boulder, Colorado, is suggested in the following listing of the divisions and sections engaged in technical work. In general, each section carries out specialized research, development, and engineering in the field indicated by its title. A brief description of the activities, and of the resultant publications, appears on the inside of the front cover.

WASHINGTON, D.C.

Electricity. Resistance and Reactance. Electrochemistry. Electrical Instruments. Magnetic Measurements. Dielectrics.

Metrology. Photometry and Colorimetry. Refractometry. Photographic Research. Length. Engineering Metrology. Mass and Scale. Volumetry and Densimetry.

Heat. Temperature Physics. Heat Measurements. Cryogenic Physics. Equation of State. Statistical Physics.

Radiation Physics. X-ray. Radioactivity. Radiation Theory. High Energy Radiation. Radiological Equipment. Nucleonic Instrumentation. Neutron Physics.

Analytical and Inorganic Chemistry. Pure Substances. Spectrochemistry. Solution Chemistry. Standard Reference Materials. Applied Analytical Research.

Mechanics. Sound. Pressure and Vacuum. Fluid Mechanics. Engineering Mechanics. Rheology. Combustion Controls.

Organic and Fibrous Materials. Rubber. Textiles. Paper. Leather. Testing and Specifications. Polymer Structure. Plastics. Dental Research.

Metallurgy. Thermal Metallurgy. Chemical Metallurgy. Mechanical Metallurgy. Corrosion. Metal Physics. Electrolysis and Metal Deposition.

Mineral Products. Engineering Ceramics. Glass. Refractories. Enameled Metals. Crystal Growth. Physical Properties. Constitution and Microstructure.

Building Research. Structural Engineering. Fire Research. Mechanical Systems. Organic Building Materials. Codes and Safety Standards. Heat Transfer. Inorganic Building Materials.

Applied Mathematics. Numerical Analysis. Computation. Statistical Engineering. Mathematical Physics. Operations Research.

Data Processing Systems. Components and Techniques. Digital Circuitry. Digital Systems. Analog Systems. Applications Engineering.

Atomic Physics. Spectroscopy. Infrared Spectroscopy. Solid State Physics. Electron Physics. Atomic Physics.

Instrumentation. Engineering Electronics. Electron Devices. Electronic Instrumentation. Mechanical Instruments. Basic Instrumentation.

Physical Chemistry. Thermochemistry. Surface Chemistry. Organic Chemistry. Molecular Spectroscopy. Molecular Kinetics. Mass Spectrometry.

Office of Weights and Measures.

BOULDER, COLO.

Cryogenic Engineering. Cryogenic Equipment. Cryogenic Processes. Properties of Materials. Cryogenic Technical Services.

Ionosphere Research and Propagation. Low Frequency and Very Low Frequency Research. Ionosphere Research. Prediction Services. Sun-Earth Relationships. Field Engineering. Radio Warning Services.

Radio Propagation Engineering. Data Reduction Instrumentation. Radio Noise. Tropospheric Measurements. Tropospheric Analysis. Propagation-Terrain Effects. Radio-Meteorology. Lower Atmosphere Physics.

Radio Standards. High Frequency Electrical Standards. Radio Broadcast Service. Radio and Microwave Materials. Atomic Frequency and Time Interval Standards. Electronic Calibration Center. Millimeter-Wave Research. Microwave Circuit Standards.

Radio Systems. High Frequency and Very High Frequency Research. Modulation Research. Antenna Research. Navigation Systems.

Upper Atmosphere and Space Physics. Upper Atmosphere and Plasma Physics. Ionosphere and Exosphere Scatter. Airglow and Aurora. Ionospheric Radio Astronomy.

NBS