ATOMIC LINE SPECTRA

IN the course of a long history, the branch of physics concerned with the study of optical spectra has been exceedingly fruitful of fundamental results and concepts, and in application. A period of remarkable advance—the golden age of the interpretation of line spectra and extranuclear atomic structure—extended over little more than ten years following the First World War. At the opening of that period, a number of significant regularities had been found empirically in, for the most part, the simpler series spectra, by diligent efforts of a number of workers subsequent to Balmer's discovery, in 1885, of the distribution law of the hydrogen line series which bears his name. In addition, Bohr had produced his postulates for hydrogen-like atoms in 1913, and calculated the Rydberg constant. However, the spectra of most elements consisted of bewilderingly large numbers of lines having little apparent order. The great achievements of the early 1920's resulted from application of the Bohr theory and its elaboration, at the hands of Bohr, Sommerfeld, Landé, Pauli, Russell and others, into the older quantum theory and vector model, and from the provision, in 1922, of the key to the analysis of complex spectra by Catalán's paper on the arc spectrum of manganese. Simultaneously, development of a theoretical background capable of coordinating much of the accumulated observational material stimulated vigorous laboratory investigations, aimed at improved accuracy and methods.

Later in the 1920's, the formulations of quantum mechanics removed much of the *ad hoc* appearance of the older theory. Achievement was, in fact, so rapid and extensive that, by the beginning of the decade following, the impression was widespread that study of atomic spectra had become, in essence, a closed field; correspondingly, though with notable exceptions, the vigour of laboratory investigations faded, and the number of active workers declined. The view that a particular field is exhausted of further basically important discoveries is of a risky nature; in the case of line spectra, much of fundamental interest may repay investigation of the finer details of even, at present, well analysed spectra. In some cases—for example, those of the complicated rare-earth and transuranic spectra—little more than a start has been made in analysis. Measurements of line intensities and oscillator-strengths, while of fundamental significance, are beginning to receive the attention needed largely because of the demands of the astrophysicist. A similar position is probably arising regarding Stark and other line-broadening effects, in relation to spectroscopic study of discharge plasmas. Again, interconfiguration interactions and autoionization phenomena are little understood—and the theme can be developed.

The present position and current directions of work on atomic spectra received excellent demonstration at the recent "Rydberg Centennial Conference", held during July 1–5 in the Physical Laboratory of the University of Lund. The meeting was organized, under the auspices of the International Union of Pure and Applied Physics, by the Swedish National Committee of Physics, and marked the centenary of the birth of Johannes Robert Rydberg (1854–1919). Rydberg, while holding the chair of physics at Lund, successfully applied a genius for the handling of numerical data to the search for regularities in line spectra.

The conference met under the presidency of an eminent contributor to line-analysis, Dr. W. F. Meggers, of the U.S. Bureau of Standards, and owed much for initiation and excellence of organization to Prof. B. Edlén, the present occupant of Rydberg's chair, whose work on the spectra of stripped atoms and of the solar corona is renowned. During the four days a total of more than sixty papers was read, most centres of currently active research on line spectra being well represented.

The proceedings of the first day, devoted to the general structure and analysis of atomic spectra, were distinguished by review addresses by N. Bohr (Copenhagen) on "Rydberg's Discovery of the Spectral Laws", W. Pauli (Zurich) on "Rydberg and the Periodic System" and A. G. Shenstone (Princeton) on "Series in Line Spectra". B. Edlén (Lund) discussed improvements in spectral series representation, and showed that all series in alkali arc spectra and in Ca II can be accurately represented by addition of one or two terms to the usual Ritz denominator. Present accepted values of the ionization potentials of ions up to the nineteenth stage were reviewed by W. Finkelnburg (Erlangen), who indicated improved methods of extrapolation along isoelectronic sequences. C. C. Kiess (Washington) described results of the analysis of Mo II; with the aid of new wave-length and Zeeman effect observations, 80 per cent of the observed lines are classifiable. The analyses of Os I and II, utilizing Zeeman patterns at 85,000 gauss, were discussed by J. C. van den Bosch (Amsterdam). Papers by S. Glad (Lund) and by O. Garcia-Riquelme and R. Velasco (Madrid) described work on the astrophysically important spectra of Fe III and Ni III, respectively. In dealing with complicated spectra, search for real constant-frequency intervals is extremely time consuming; in this connexion L. F. H. Bovey (Harwell) discussed the applicability of standard computing equipment to term analysis.

A number of interesting papers on methods and results of high-resolution spectroscopy were presented during the second and third days. H. Kopfermann (Heidelberg) reviewed past contributions and present trends of investigations on optical hyperfine structures and isotope-shifts in relation to nuclear properties, namely, spin, magnetic and quadrupole moments. This kind of work has always made great demands on instrumental refinement and technical skill; the elegance of some of the experimental arrangements outlined indicated that progress in these respects continues. Thus, P. Jacquinot (Bellevue, S. et O.) described a recording Fabry–Perot interferometer which employs a photomultiplier or photo-conductive detector placed behind an annular exit-slit, upon which the ring system is focused concentrically; scanning of the pattern is performed by moving the fringes across the slit, by cyclic variation of either the gas pressure in the interferometer housing or of the étalon spacing. This type of instrument has been used by H. Chantrel, who reported an investigation of the abundance-ratio of lead and neodymium isotopes and a determination of the quadrupole-moment of mercury-201, and by J. Blaise, who described results on hyperfine structure, in Pb I and II and the first measurement of a hyperfine structure pattern of a line lying beyond the photographic limit in the infra-red. Other work of high refinement consisted in combination of an atomic-beam light source and a large-gap étalon; described by K. W. Meissner (Lafayette, Ind.), this apparatus has been used to obtain wave-lengths of eight lines of germanium to an estimated $\pm 4 \times 10^{-5}$ A. Successful measurements of very small isotope shifts in Sn II and Cd II were reported by H. G. Kuhn (Oxford); in this work enriched isotope samples were employed. E. Rasmussen (Copenhagen) gave results on isotope shifts in krypton; here, the isotopes, separated in a mass-spectrometer, were collected on aluminium foil from which the gas could afterwards be released by radio-frequency heating. Description of the measurement of isotope shifts in the spectra of the lightest elements by J. E. Mack (Madison) included a discussion of their interpretation in terms of the specific mass contribution. Work at Amsterdam on the spectra of plutonium-239 was described by P. F. A. Klinkenberg; high-resolution studies have led to the conclusion that this isotope has a nuclear spin of $\frac{1}{2}$. High-resolution work at the Oak Ridge Laboratories of the U.S. Atomic Energy Commission, described by J. R. McNally, has included isotope-shift and abundance studies in the heavy elements and transuranics; for example, uranium-233 and 235 were stated to have probable nuclear spins of 5/2 and 7/2, respectively. Two papers were concerned with the important topic of the Lamb–Retherford shift, both being marked by the skill of the techniques employed. G. W. Series (Oxford) had studied the fine structure of He II λ4686, using two étalons in series and a discharge-tube cooled in liquid hydrogen; he reported that the results departed appreciably from Dirac theory expectations, and possibly also showed a smaller departure from predictions of the new quantum electrodynamics. G. Herzberg (Ottawa) described measurements of the wave-length of the first line of the Lyman series of deuterium; for this work, the fifth-order of a three-metre vacuum grating was employed, and the line obtained in absorption by the partially dissociated gas drawn from a Wood tube; again, there are indications that the shift of the ground-level of deuterium shows a small departure from theory.

A welcome feature of the conference was the presence of a number of prominent workers on theoretical spectroscopy—this especially since the most recent monograph available is the monumental effort of Condon and Shortley, now some twenty years old. The scope of current theory applied to actual classification problems was reviewed by G. Racah (Jerusalem), with particular mention of complex ($l^m d^n$-configuration) and very complex ($l^m f^n$-configuration) spectra. Several papers referred to features of two-electron spectra; E. A. Hylleraas (Oslo) gave results of new calculations of singlet and triplet series, and P. Pluvinage (Strasbourg) presented new results for the ground-state and first-excited state of He I. The interesting question of the effect of interconfiguration interaction in He I-like spectra was dealt with by L. C. Green (Haverford, Pa.). L. Biermann (Göttingen) reported theoretical calculations of f-values, and directed attention to the importance of interconfiguration perturbations; thus, in the case of the singlet resonance line of Ca I, the theoretical value of $f = 2 \cdot 2$ is reduced to $1 \cdot 48$ when the effect of $4pmp$ terms is included.

Several papers formed general or specific reports on laboratory methods. Infra-red atomic spectroscopy was comprehensively reviewed by C. J. Humphries (Corona, Cal.) with particular emphasis on the use of modern photoconductive detectors; the certain usefulness of these techniques in the investigation of rare-earth spectra was indicated. R. A. Fisher (Evanston, Ill.) described a use of Edser–Butler fringes for facilitating wave-length calibration of recording spectrometers. Experience with the use of multilayer highly reflecting films on Fabry–Perot plates was described by F. A. Jenkins (Berkeley). In a paper on stigmatic concave gratings, F. Zernike (Groningen) proposed the novel solution of replacing the usual straight ruling by a system of concentric circular arcs. E. Hulthén (Stockholm) described experiments made with plane gratings immersed in liquids as a means of raising resolving power and dispersion. Several developments of light sources were described; for example, convenient forms of demountable hollow-cathode tubes (H. Schüler, Hechingen), the 'vacuum sliding-spark' (N. Astoin and B. Vodar, Bellevue) and the pulsed high-frequency electrodeless discharge (L. Minnhagen, Lund). All these sources are useful in the study of spectra of the lower ionization stages, the 'sliding spark' being the most energetic; the use of this source was illustrated by K. Bockasten (Lund) for C III and IV.

The study of line intensities and f-values was well represented. W. F. Meggers (Washington) reported measurements of arc intensities of 30,000 lines from seventy elements introduced as small admixtures in a base of powdered copper; copper lines used as intermediate intensity standards were finally compared with radiation from a tungsten lamp. Use of a King furnace at Amsterdam, for measurement of relative f-values of Fe I lines, was described by C. J. Bakker. The promising technique of rotation-stabilized arcs, which makes possible the realization of a portion of matter in thermal equilibrium at a temperature of up to 50,000° K., was described by H. Maecker (Erlangen). R. H. Garstang (London) reviewed theoretical computations of atomic transition probabilities, and presented the results of his own calculations and their comparison with experiment.

The final day of the conference was occupied with papers on miscellaneous experimental topics, compilations of data, and astrophysical applications. Autoionization phenomena were discussed by W. R. S. Garton (London) in connexion with vacuum ultra-violet absorption spectra. Two papers dealt with elegant experimental techniques developed at the École Normale Supérieure, Paris. A. Kastler described applications of a method involving optical detection of the partial spatial orientation produced in an atomic beam which is subjected to a perpendicular magnetic field and, parallel to this, a beam of circularly polarized resonance radiation. J. Brossel and J. E. Blamont described measurements on the Stark effect of the 6 $^3P_1$ state of Hg I, based on observation of the change in the magnetic resonance curve following superposition of an electric on the main magnetic field. Statistical Stark broadening in the spectra of discharge plasmas was discussed by W. Lochte-Holtgreven (Kiel), with particular reference to determination of ion concentrations in the high-power arcs developed at Kiel. L. Herman (Bellevue) compared experimental and theoretical contours of Balmer series lines exhibiting strong ionic Stark broadening. Use of a statistical theory, based on a Lennard-Jones potential function, was suggested by B. Vodar (Bellevue) to account for the results of experiments on the shifts of resonance lines of the alkalis, mercury and xenon, occasioned by high pressures of foreign gases. Features of time-resolved spectra of long sparks in air, and of pulsed centimetre-wave discharges in rare gases, were described respectively by A. Vassy (Paris) and by I. Eyraud and J. Janin (Lyons). Measurements of wave-length standards by means of a reflecting échelon were described by T. A. Littlefield (Newcastle), who directed attention to the necessity for certain corrections; P. Risberg (Lund) explained the establishment of accurate vacuum ultra-violet wave-length standards by application of the combination principle to newly measured long wave-length lines of Mg II and Ca II.

Mrs. C. E. Moore-Sitterly (Washington) spoke on one of the several valuable compilations of data for which all spectroscopists are indebted to her, namely, a second revision of Rowland's Solar Wave-length Table. Announcement of the preparation of a useful table of forbidden multiplets of astrophysical significance was made by J. W. Swennson (Liège). Of the specifically astrophysical papers, that of E. Finlay-Freundlich (St. Andrews) on his well-known hypothesis in explanation of the general red-shift in celestial spectra produced much discussion; the possibility of fluorescence by line-coincidence was illustrated by J. Gauzit (Lyon), and Mrs. C. Payne-Gaposchkin (Cambridge, Mass.) contributed results of a spectrometric study of a rotating star. The conference ended with a general discussion, under Prof. Edlén, concerning proposals for defining the metre in terms of the wave-length of a chosen spectral line produced under specific conditions.

Limitations of space preclude a fuller account of the many important contributions to this conference, which demonstrated that the study of line spectra continues to flourish.

W. R. S. GARTON
L. F. H. BOVEY

RIDERLESS MICROCHEMICAL BALANCES

AT the recent symposium on analytical chemistry held in the University of Birmingham by the Midlands Society for Analytical Chemistry, one of the most interesting features in the display of modern laboratory apparatus was the adoption of the riderless beam principle by the firm of L. Oertling, Ltd. (Cray Valley Road, St. Mary Cray, Orpington, Kent), in the construction of its two new microchemical balances.

There is little doubt that one of the most serious sources of error in weighing on a microchemical balance (apart from the personal factor) is associated with the use of the rider. These errors have been attributed to variations in the mass of the rider, its angular placement on the beam, the shape of the notch and the accurate location of the notches on the beam. The cumulative effect of these errors over the several weighing operations involved in a gravimetric analysis may result in considerable inaccuracy. Some workers have estimated the probable error of any one reading on a microchemical balance at $\pm$ 3 μgm., while work undertaken for the American Chemical Society by others gave values of 0·9–23·3 μgm. for the standard deviation of thirty-two different microchemical balances used with a 1-gm. load. The elimination of every possible source of error is therefore highly desirable.

Few fundamental advances have been made in the design of microchemical balances since the evolution of the original Kuhlmann model, but the elimination of the rider error in these two new microbalances by Messrs. Oertling will undoubtedly be hailed as such by many.

In place of the conventional rider system, a plain beam is used in conjunction with a series of fractional rider weights. These fractional riders are loaded on to a special carrier bar, attached to the pan-suspension system, by means of levers operated by a calibrated dial attached to the right-hand side of the balance case. In the more sensitive of the two balances, these fractional riders have a displacement value equivalent to 9 mgm., so that when the 1-mgm. range of the graduated optical scale is added, a total displacement of 10 mgm. can be observed, rendering the use of weights less than 10 mgm. superfluous.

Needless to say, the possibility of errors of another nature is introduced by the riderless beam principle, and one still has to reckon with variation in the weights of the fractional riders; but nevertheless weighing operations are speeded up considerably, and the inherent errors involved would seem to be less serious, for the manufacturers claim that for the first time in microchemical weighing it is possible to weigh with certainty to the nearest microgram.

T. S. WEST

ACTIVITIES OF THE INTERNATIONAL UNION OF BIOLOGICAL SCIENCES

THE Policy Board of the International Union of Biological Sciences met in Paris during June 28–30 and made a number of recommendations regarding the future structure of the Union. The Board consisted of Prof. P. Weiss (United States) and six other members: Prof. A. Frey-Wyssling (Switzerland), Prof. J. Monod (France), Dr. L. Harrison Matthews, representing Prof. C. F. A. Pantin (United Kingdom), Prof. B. Rensch (German Federal Republic), Prof. John Runnström (Sweden) and Prof. M. J. Sirks (Netherlands); a number of officers of the Union and of other International Unions were also in attendance for parts of the meeting. One of the principal recommendations was that the Union should consist of eleven Sections, as follows: Biochemistry, Biometry, Botany, Cell Biology, Developmental Biology (including embryology), Ecology (including limnology), Genetics, Microbiology, Physiology, Experimental Psychology and Zoology (including entomology). This would involve setting up four new Sections—those of Biochemistry, Developmental Biology, Physiology and Experimental Psychology—and incorporating the present Sections of Embryology and Entomology as indicated.

The work of the Union is of a varied nature. Research institutes available to workers of all nationalities have been supported or founded: for example, a culture collection of wild species of *Drosophila* at Pavia; Centres for the Biological Control of the Pests of Plants at Geneva and Mentone; the International Depot of Microscopical Preparations at Louvain; the International Bureau of Human Heredity at Copenhagen; and the Serological Museum at Rutgers University, New Brunswick. The Union organizes and partly finances symposia for the discussion of current research