



ATOMIC SPECTRA and RADIATION PROCESSES

A Report on the Oxford Conference by L. C. Bradley III and H. M. Foley

The Conference on Atomic Spectra and Radiation Processes (April 12-14, 1965) brought together in Oxford some 160 participants from 13 countries. This attendance reflected the recent increase of interest in the topics of the conference.

Conference sessions were held in the Clarendon Laboratory. Most of the guests were housed and boarded very pleasantly in St. John's College, close to the laboratory. The gardens of the Oxford colleges were lovely in spring bloom, and the weather was characteristically fickle, alternating soft sunshine with soft rain.

The contributed papers were mostly in the areas of "coherence effects" (optical pumping, double resonance, level crossing), isotope effects, and line shapes, as well as "classical" spectroscopy. It was necessary to hold parallel sessions on the first day, but for the remainder of the sessions the conference succeeded in one of its aims: to bring together people with a wide range of interests to consider the problems of modern spectroscopy.

At the beginning of each morning or afternoon session an introductory paper was given by a worker prominent in that field. This was followed by shorter contributions. Some of the latter were read; others were intended to be "taken as read" with a brief discussion, but the distinction became blurred in the later sessions.

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The first day's session, on atomic structure and interpretation, was introduced by B. R. Judd (Berkeley) who reviewed developments in the theory of atomic levels since the classical book of Condon and Shortley. He emphasized the contributions of Racah, particularly the value of the concept of fractional parentages. Judd expressed the belief that with this concept, together with a fuller exploitation of group concepts than has been customary, much progress can still be made in understanding the terms even of complicated many-electron configurations.

Some of the succeeding speakers were less hopeful about prospects for the success of such a direct attack on the problem of many-electron configurations. B. G. Wybourne (Argonne) discussed the actinide levels characterized by the configuration $5f^N$ where N runs from 1 to 14. The numerous terms of these configurations show much mixing of multiplicities and sufficient 'repulsion' of levels that the level splittings seem to follow closely the Wigner statistical law. The g_J values are also distributed statistically; hence Zeeman splittings do not serve to identify the levels very well. Wybourne concluded that in such cases one must probably be satisfied with a statistical description of the levels.

C. W. Allen (London) described a program to characterize atomic spectra by statistical intensity distributions for which empirical formulas may be found and which would be of value in astrophysics.

Attempts to find collective oscillations in atoms



J. P. Barrat, A. Kastler, J. Vanier, P. F. A. Klinkenberg

were related by A. Herzenberg (Manchester). The collective resonance for photon absorption should occur in a broad region at a few hundred electron volts. Such a resonance may have been observed in xenon. In general, however, sum-rule analysis applied to the known oscillator strengths gives little excess available for such resonances.

To open the afternoon session, Novick (Columbia) reviewed our knowledge of autoionizing states in light atoms. He described atomic-beam and other methods of measuring lifetimes of metastable states which undergo delayed Auger processes because of selection rules.

Gabriel (UKAEA, Culham) described some of the spectra emitted by high-temperature plasmas, which extend very significantly our knowledge of the spectra of highly ionized atoms.

T. Carver (Princeton) reported experimental results on nuclear spin polarization of ^3He through collisions with optically pumped polarized rubidium. The large cross section found for this process is presumably accounted for by the induction during collisions of some spin polarization in the $1s$ shell of ^3He , and the consequent nuclear spin flips through the magnetic "contact" interaction.

In one of a series of spectroscopy papers from the Heidelberg group (G. zu Putlitz et al.) it was reported that the use of Sternheimer corrections to evaluate the Rb nuclear quadrupole moments from the $5p$, $6p$, $7p$, $8p$, states brought the calculated moments into definitely better mutual agreement than were the uncorrected values.

A group of papers on isotope effects in atomic spectra showed that this is still a lively field to work. The most activity is concentrated on the study of long sequences of isotopes and on the relations of neighboring elements. Separated isotopes or radioactive species are almost invariably used in modern work, and high-resolution measurements have been made with as few as 10^{12} atoms. The paper of H. Stroke (New York Uni-

versity) told of work with radioactive atoms, and emphasized the usefulness of nuclear information that can be derived from such studies. D. A. Jackson (Bellevue) described recent measurements of high precision of isotope shifts in seven isotopes of Ba in two spectral lines. A careful analysis of the shifts in the three energy levels involved showed that a consistent description to good accuracy can be given by taking into account simultaneously volume effects and mass effects. Considerable odd-even staggering remained.

S. Devons (Columbia) described recent and proposed isotopic and hyperfine measurements throughout the periodic tables with mu-mesic atoms. He pointed out the difficulty in analyzing isotopic effects because of the complexity of atomic structures in many cases which makes absolute measurements of nuclear sizes impossible. The solution, he said, was to "make your own atoms" with mu mesons, which are hydrogenic in nature. The two approaches thus complement each other; mu-mesic studies permit absolute determination of nuclear size variations, while optical techniques use far smaller quantities of material for relative measurements.

The session on Tuesday, on radiation processes, opened with an introductory paper of Brossel (Ecole Normale Supérieure), who spoke of optical-pumping experiments in Hg, Cd, and Zn. The experiments on Hg and Cd had been successful, while those on Zn had not. Brossel gave an admirably lucid explanation, showing that, since the hyperfine splitting in the upper state was smaller than the natural width, the electronic field did not have enough time to flip the nucleus. That a similar difficulty exists in hydrogen was pointed out by Alley (University of Maryland), who couched his argument in terms of interference effects among the levels. Related effects were reported by Kruger and Kleinpoppen (Tübingen) in the light emitted by one-electron atoms polarized by electron impact. Bradley (MIT Lincoln Laboratory) reported on a calculus working directly with the multipole polarization, which is the quantity actually observed in optical pumping or resonance fluorescence.

The afternoon session was introduced by Franken (University of Michigan), who gave a reactionary view of the interaction of light with matter. Franken proposes to exile the photon from consideration in dealing with atomic spectra, conceding only its possible usefulness in such remote subjects as quantum electrodynamics. He pointed out that it is possible to reproduce all the well-known results for the interaction of light and mat-

ter by postulating that quantum mechanics applies only to the matter and not to the light. Franken appealed to the experiments of the well-known Professor Gedanken (which according to Franken, were so beautiful that one is surprised he never received the Nobel prize). To some hearers these remarks seemed to sketch a phenomenology rather than a theory.

As if to illustrate Franken's thesis, his paper was followed by a series of papers on the interaction of laser radiation with plasmas. Katzenstein (Culham) and Ramsden (NRC Ottawa) illustrated the use of lasers in plasma diagnosis, while Hughes (National Physical Laboratory) showed how a laser could be used in producing a very hot plasma.

A group of papers was devoted to what are usually termed coherence phenomena, such as the modulation of resonance fluorescence. In spite of the number of papers on this topic, one had the feeling that recent work is more in the nature of elaboration of known principles than of exploration of new phenomena. Particularly interesting, however, was the work of Series (Oxford) on the forward scattering of resonance radiation, of Skalsinski (Polish Academy of Science, Warsaw) on the production of coherent states by modulated light and the carry-over of coherence in optical pumping cycles, and of Dodd (Otago, New Zealand) on pulse excitation of atoms.

The third day was largely devoted to line intensities and line shapes. In an introductory paper H. Griem (Maryland) outlined a systematic method for calculating pressure broadening effect which is an extension of the previous work on electron- and ion-collision effects to the case of neutral atoms. This is essentially an elaboration of the theory of P. W. Anderson which was originally worked out for microwave absorption.

J. M. Vaughan then reported on the very precise measurement of resonance broadening in He done at Oxford in the laboratory of H. Kuhn. Whether there remains a small discrepancy of the line width with theory was left unsettled in the discussion.

The foreign-gas broadening and shift of Cs resonance lines by various inert gases were described by S. Y. Chen (Oregon). The pressure range studied was in general greater than contemplated by present impact theories. Chen pointed out the curious feature that the line shift is linear in the pressure over two pressure ranges, but with slopes that are different in the two ranges.

W. R. Hindmarsh (Newcastle upon Tyne) reported on the evaluation of van der Waals force constants from the shift and broadening by foreign gases of a number of spectral lines, principally Ca lines broadened by inert gases. The inclusion of a repulsive R^{-12} potential term, in addition to the R^{-6} attractive potential, seems to give more self-consistency to the results.

M. A. Mazing (Moscow) described measurements of the broadening and shift in transitions to levels of very large principal quantum number, under conditions in which the size of the orbits was larger than the mean distance from the radiating atom to the foreign-gas perturber. The observations can be understood, following Fermi, as a combination of polarization effects on the perturbers and elastic collisions of the orbital electrons with the perturbers. R. Wilson (UKAEA, Culham) introduced the final afternoon session with a comprehensive review of radiation transfer processes, referring particularly to non-thermal plasmas, such as are encountered in controlled thermonuclear research. In general there is not even local thermodynamic equilibrium in these cases, and Kirchhoff's law is invalid. A detailed study of the actual electron-ion radiation processes is necessary. He pointed out that the electrons and ions may have quite different effective temperatures, and that because of the short lifetimes of the plasmas transient effects in the growth and decay of ionization are important.

A final group of papers was largely concerned with the effects of configuration mixing in atomic spectra. Penkin (Leningrad) discussed intensity anomalies in group II and III spectra, Tomkins (Argonne) showed impressive photographs of the apparatus used to obtain radium spectra by "flash pyrolysis" (heating), and Garton (Imperial College) reviewed some of his extensive work on autoionizing levels.

The banquet was held on Tuesday night in the baroque hall of St. John's College, with the portraits of worthies of the College looking down upon the proceedings. The principal features were a graceful informal welcome from H. Kuhn and an impromptu response from the gallery, delivered by Peter Franken, who could not resist the opportunity of speaking from "the highest table in Oxford".

The local committee, headed by G. Series and H. Kuhn, is to be congratulated on its efficient organization of the conference and for the felicitous idea of housing most of the participants in a single Oxford College.