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B. COLLISIONAL CROSS SECTIONS

Because of the magnitude and diversity of material on electron and heavy-particle collisions, I gave references only to published papers of obvious immediate relevance to astronomical research.

1. Electron Collisions

1.1 ELECTRON IMPACT IONIZATION

A valuable compilation of semi-empirical cross sections and rate coefficients for electron impact ionization of a wide range of ions, expressed in convenient analytical form has been prepared(1). An empirical formula for K-shell ionization cross sections was derived(2). Theoretical estimates ''233 for the ionization of complex ions were given (3,4). Experimental values were obtained for Al^+(5), He(6), Fe^+(7), Mg^+, Ca^+ and Sr^+(8), Be^+(9), Ne^{3+}, Ar^{3+}, Kr^{3+}, Xe^{3+}(10a), Mg^+, Al^{2+} and Si^{3+}(10b), and B^+, C^{2+} and O^{4+}(11). Ionization rate coefficients were measured for NeVI, NeVII, OVI and Ti IX(12) and for nitrogen ions(13). Distorted wave calculations for the ionization of FeX and the iron ions from FeXV through FeXXVI were reported(14).

2. Electron Impact Excitation

An extensive bibliography of data on electron impact excitation (and ionization) was published(15). Many calculations of excitation cross-sections of varying degrees of sophistication were carried out for positive ions since the last IAU report: Inner shell excitation of helium-like ions(16), lithium-like ions(17a,b) and beryllium-like ions(18) were studied. More detailed calculations were performed for SiIX(19,20), OIV(21), NeV(20,22), CaXV(23), CaXVII(24), SIII(25), SiX(26), SXII(27), OVII(28,29), CV and MgXI(30), SV(31), FeXXV(32), Li-like ions (33), SIII(34), MgVII(35), OII and OIII(36), OIII(37), SII(38), FeX and FeXV-XXVI(14), NeIII(39), NIII(40), FeXX(41), CaXVII(42) and CII(43). Cross sections for excitation to high n states of hydrogenic ions have been obtained using the Born approximation(44). Excitation of hydrogen, helium, lithium and beryllium-like ions has been studied(45) and of sodiuim-like ions in(46).

Electron impact excitation rates for neutral helium are given in(47-50) and for neutral hydrogen in(51,52). Fits to many excitation rate coefficients are given in(53-55). Studies of excitation to auto-ionizing levels and satellite line emission are described in(56-67). Experimental work on electron impact excitation may be found in(64-68).

A valuable compilation of electron impact excitation rate coefficients of astrophysically interesting systems has been assembled by Mendoza(69) and a useful survey of low energy collisions with complex atoms and ions has been presented by Burke and Eissner(70).

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1.2 RECOMBINATION

Dielectronic recombination of selected ions has received considerable experimental attention(71-73). Theoretical work has continued also(61,74-82). A tabulation of recombination coefficients by Nussbaumer and Storey(83) is of particular importance to models of astrophysical nebulae. Empirical values of the recombination coefficients of Fe X-Fe XIX have been inferred from an analysis of plasma electron densities(84).

Several measurements of the rate coefficients for the dissociative recombination of molecular ions have been reported(85-90). Theoretical studies of H_2^+(91) and H_3^+(92) recombination were performed with the conclusion that both are unusually slow.

1.3 ELECTRON-MOLECULE COLLISIONS

I list only references to the rotational, vibrational and electronic excitation and dissociative attachment of molecular hydrogen by electron impact(93-100).

4. Heavy-Particle Collisions

4.1 CHARGE TRANSFER AT LOW ENERGIES

Some further calculations on low energy charge transfer cross sections of multicharged ions in collisions with atomic hydrogen and helium(101-116) have been completed. Empirical values for O^{3+} in H were derived from observations of planetary nebulae(117). Estimates of charge transfer between ions of oxygen and sulphur with the neutral parents were made (118). Several measurements were reported(119-126) though only those of Church and Holzscheiter(126) refer to thermal energies.

Major reviews of theoretical charge transfer cross sections for partially and fully-stripped ions in hydrogen have appeared(127,128).

4.2 PROTON IMPACT EXCITATIONS

A review of proton impact cross sections was published(129) and calculations of the excitation cross-sections for fine-structure excitation were carried out(130,131).

4.3 CHEMICAL REACTIONS

Lists of chemical reactions which play a role in interstellar circumstellar and shock region chemistry have been assembled in many papers(132-147). Extensive experimental investigations of relevant ion-molecule reactions have been reported(148-171). Theoretical analyses of the important reaction of C^+ with H_2 have been done (172,173). The possible significance of reactions producing and being driven by hot ions or atoms in cold clouds has been raised(174). The connection between endothermic and association reactions has been explored(175).

Radiative association processes are important in molecular clouds. The theory has been developed in(176-180).

A great variety of neutral reactions that may be important in astronomical environment has been studied experimentally(181). A partial listing is references(181-196). Useful reviews are found in(197) and (198). Theoretical considerations are presented in(199-202) and the dependence of the reaction rate on the rotational populations has been investigated(204). Many studies have been made of the reaction of atomic hydrogen and deuterium with H_2, HD and D_2, and of the influence of rotational and vibrational excitation(205-224).

4.4 MOLECULAR EXCITATION

Rotational, vibrational and fine-structure excitation of astrophysically interesting molecules are discussed in(225-252). Transitions in OH are investigated in(253-258).

Collisions of ions with heteronuclear molecules have been studied particularly by Sakimoto(259) (see also 260-263).

4.5 MOLECULAR DISSOCIATION

The collision-induced dissociation of H_2 and of CO has been investigated theoretically(264-267) and the rate coefficients have been shown to depend on density.

4.6 EXCITATION BY NEUTRAL ATOM IMPACT

The cross section for the excitation of $O(^3P)$ to $O(^1D)$ by hydrogen atom impact has been calculated by Federman and Shipsey(268).

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WORKING GROUP 4: STRUCTURE OF ATOMIC SPECTRA

A. Recent Laboratory Results and Research in Progress

A Bibliography on Atomic Energy Levels and Spectra covering the period July 1979 through December 1983 is scheduled for publication in late 1984(1). The references in Table 1 are thus limited to papers published or known to be in press in 1984; the selection was made from references giving data on energy levels, wavelengths, and line classifications for spectra of the elements Z $\leq$ 30. S. Johansson notes that the spectra under investigation in the Physics Department of Lund University, Sweden, include S III, IV, VII, VIII, IX; Cl VI, VII, VIII, X; Sc V; the (Ne I) isoelectronic spectra Sc XII-Fe XVII; Ti I; Cr I, II, V; Fe II, III; and several high-ionization spectra of Ni, the work on Fe III and the Ni spectra being done in collaboration with researchers in the Zeeman Laboratory, Amsterdam. Term analyses in progress at the Lund Institute of Technology, as reported by W. Persson, include Ne III and K II, III. This group has recently completed analyses for Kr IV, Rb V, Sr V, VI and has papers in preparation for Rb IV, Y VI, and Xe II. Fourier-transform spectrometric observations at the National Solar Observatory (Kitt Peak) by J. Brault and collaborators are yielding more accurate and complete line lists for the first and second spectra of several elements, including Mg, Al, Ti, V, Cr, Fe, and Ni. Ongoing extensions of the term analyses for some of these spectra were mentioned above; similar work is underway for Mg I, II, Al I, II, and V I, II (E. Biémont, University of Liège) and for Fe I (R. C. M. Learner, Imperial College, London). B. C. Fawcett's current research at the Rutherford Appleton Laboratory, Oxfordshire, England, includes work on the oxygen-like spectra P VIII through Fe XIX.

B. Compilations, Isoelectronic-Sequence Observations and Predictions

The NBS Atomic Energy Levels Data Center published energy-levels compilations for all the spectra of Fe(29) and Si(30). Revised and updated energy-levels compilations for the 235 spectra of the ten iron-group elements K through Ni will appear in a single volume in 1985[31]. A compilation of levels for the P spectra has also been submitted(32), and C. E. Moore has prepared new tables of levels and multiplets for O IV and O III(33).

R. L. Kelly's revised compilation of atomic lines below 2000 Å is scheduled for publication in 1985(34). These tables supersede a similar 1973 compilation and cover the same elements, H through Kr. Fawcett's review(28) includes tables of observed forbidden lines for ions stripped to the n=2 and n=3 shells. Some of the tables of atomic wavelengths in the CRC Handbook were revised and updated for the latest edition(35); about 45000 lines from the first five spectra of all elements in all wavelength ranges are included.