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W.L. Wiese
Chairman of Working Group

WORKING GROUP 3: COLLISION PROCESSES

Of the vast array of data on electron and heavy-particle collisions that are produced each year, I select only those that have an obvious immediate bearing on astronomical research. A brief review of recent developments in atomic data for astrophysics has been published (1).

1. Electron Collisions

1.1 ELECTRON IMPACT IONIZATION

Experimental impact ionization (2) and theoretical (3,4) values of the cross sections for electron impact ionization were obtained for the magnesium-like ions S^{4+}, Cl^{5+} and Ar^{6+} and theoretical values were obtained for Al^{+} (3). Experimental cross sections were published for electron-impact ionization of B^{2+} and O^{5+} (5), of N^{4+} and N^{5+} (6), of Fe^{5+}, Fe^{6+} and Fe^{9+}(7), of Fe^{11+}, Fe^{13+} and Fe^{15+} (8), of Ni^{3+}, Cu^{2+}, Cu^{3+} and Sb^{3+} L(9) and of Ti^{2+}, Fe^{2+}, Ar^{2+}, Cl^{2+} and F^{2+} (10). Double ionization cross sections were measured for Ar^{+} and Ar^{4+} (11). Theoretical cross sections for the single ionization of Fe^{13+} were calculated (12). Total ionization and partial ionization cross sections of many systems have been complied by Tawara and Kato (13). A list of ionization rate coefficients for astrophysical applications was compiled by Arnaud and Rothenflug (14).

1.2 ELECTRON IMPACT EXCITATION

An evaluated compilation of data for electron-impact excitation of atomic ions was published as a JILA report (15). Many calculations of varying degrees of sophistication have appeared in the literature: excitation cross sections of transitions of He-like and Be-like ions (16) Li-like ions, outer-shell (17) and inner-shell (18), B-like ions (19), C-like ions (20) and Ne-like ions (21) and singly and multiply-charged ions of carbon and oxygen (22) have all been carried out for He^{+} (23). Li^{+} (24), Be^{+} (25), C^{+} (26), C^{2+} (27), C^{4+} (28), Ne^{+} (20), Ne^{4+} and Mg^{6+} (30), Mg^{10+} (31), Mg^{3+} and Mg^{4+} (32), Al^{+} (33), Si^{3+} (34), Si^{9+} (35), Si^{10+} (36), S^{+} (37), S^{2+} (38), S^{7+} (30), Cl^{5+} (40), Fe^{+} (41), Fe^{6+} and Fe^{22+} (42), Fe^{11+} (43), Fe^{12+} (44), Fe^{14+} (45), Fe^{16+} (46), Fe^{17+} (47), Fe^{19+} (48), Fe^{24+} (49), Ca^{14+} (50), Ca^{18} (51), and Cu^{12+} and Cu^{16+} (52). Excitation to autoionizing states and their contribution to ionization has been investigated for magnesium-like ions (2,3) and for nickel ions (53). Experiments on the excitation of Si^{2+} transitions have been carried out (54).

Electron impact excitation of neutral systems has received less attention. New cross section data are available on He (55) with a list of rate coefficients (56). Collisions with neutral C atoms (57) and with neutral S atoms (58) have been investigated theoretically and with neutral helium (59) and neutral oxygen (60) experimentally.

1.3 RECOMBINATION

An important series of papers by Nussbaumer and Storey (61) has provided theoretical estimates of dielectronic recombination rate coefficients of light elements. An updated tabulation of recombination rate coefficients has been published (14).

1.4 ELECTRON MOLECULE COLLISIONS

Experimental cross sections for electron impact excitations of H_2 are given in (64-67) and theoretical calculations are described in (68). Collisions of electrons with HCN are examined theoretically in (69).

2. Heavy-Particle Collisions

2.1 CHARGE TRANSFER

Calculations at thermal energies for Si^{4+}-He are presented in (70). A compilation of charge transfer of multiply-charged ions colliding with H and H_2 at high energies has been published in (71). Estimates of rate coefficients of charge transfer processes that may be important in HI regions are given in (72).

2.2 PROTON IMPACT

Proton impact induced transitions between fine structure levels of ions are studied in (73) and (48). Proton impact K and L shell ionization are considered in (74) and (75).

2.3 CHEMICAL REACTIONS

Lists of chemical reactions which enter into models of the chemistry of interstellar, circumstellar and shocked regions continue to grow. Listings are found in (76-79).

Many experimental and theoretical investigations of relevant ion-molecule reactions have been carried out. A few of them are described in references (80-98). Particular attention has been given to the behavior at low temperatures of reaction with neteronuclear molecules (99-101). The dependence of reaction rate coefficients on the internal rotational and vibrational level populations has been studied though rarely at the temperatures of astronomical environments. They are too many to list here.

2.4 MOLECULAR EXCITATION

Rotational excitations of astrophysically interesting molecules are investigated in (1-129). A review of calculations was presented by Green (130). Vibrational excitation was studied in (131) and fine and hyperfine structure in (132-134).

2.5 MOLECULAR DISSOCIATION

Detailed calculations have been reported on the collision-induced dissociation of H_2 appropriate to astrophysical environments (135-137).

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A. Dalgarno
Chairman of Working Group

WORKING GROUP 4: LINE BROADENING

There has been quite a renewal of interest in the field of line broadening during the last three years and the proceedings of the Eight International Conference on Spectral Line Shapes (1) showed the general state of progress of this topic. It is not the purpose of this report to be exhaustive, so we will simply give a number of useful results for astrophysical purposes and indicate some new fascinating directions in this research theme.

1. Line Broadening and Shifts in Low to Moderately Dense Plasmas

1.1 HYDROGEN OR HYDROGENIC LINES

The ionic broadening of hydrogen or hydrogenic lines in plasmas has been considered as quasistatic during the last decades. In fact, this quasistatic ion assumption is only valid at quite high densities. At low or moderate densities, ion dynamics play an important role near the center as confirmed by new experimental results (2,3,4) for Lyman and Balmer lines. Computer simulations were employed successfully for investigations of these effects (5-8). In these computations, electron broadening is accounted for using an impact operator; the ionic contribution is obtained by numerical integration of the atomic Schrödinger equation for a set of ionic mocrofield formed by superposition of Debye-screened fields from uncorrelated particles. At typical astrophysical densities (smaller than 10^{14} cm^{-3} for Ly$_\alpha$) these results are in a relatively good agreement with analytic formulae giving the line halfwidth in the impact model (9). New calculations have been performed for the Ly$_\alpha$ profile for detunings ranging from the center to the near line wings (10) (< 10 Å). At these low densities, the fine