ADVANCES IN ATOMIC, MOLECULAR AND OPTICAL PHYSICS. VOLUME 28 (1990) pdf

1: Books by David R. Bates (Author of Pure and Applied Physics, Volume 10)

Advances in Atomic, Molecular, and Optical Physics publishes volume on recent developments in the field which is in a state of rapid growth, as new experimental and theoretical techniques are used on many old and new problems.

The angular distribution of 5-eV electrons ejected from hydrogen atoms by the impact of keV protons that are themselvesscattered through 0. The peak near 30"from the forward direction is the binary peak; that near " is the recoil peak. However, for large scattering angles it is obviously the nucleus-nucleus interaction that plays the dominant role. The effect of this interaction on the structure of differential cross sections for ionization will now be considered. The major effect of the projectile-electron interaction is well known and leads to striking structure in the differential cross section whenever k z vp, the projectile velocity in the laboratory frame. A similar analysis as led to Eq. When integrated over a small finite region of k space as for the finite resolution and acceptance angle of a detector this singular factor gives rise to the well-known cusplike structures in differential cross sections for positive-ion impact Crooks and Rudd, , ; Lucas and Harrison, ; Lucas et al. An example is shown in Fig. Macek A similar normalization factor occurs in the case of negative proton impact. Such a dip structure in the differential cross section for impact ionization by negative protons has been predicted by Garibotti and Miraglia The real parameters fir. The variation with k is contained in the state multipoles via their connection with density-matrix elements and scattering amplitudes given by Eqs. The simplicity of the first Born amplitude for direct ionization and, in particular, its symmetry properties allow certain general statements to be made as to the angular distributions for example, those shown in Fig. Clearly this is a very strong criterion with which to check the applicability of the first Born approximation. Hence the first Born approximation permits no sp, sf, pd, etc. As discussed by Scholler et al. Hence the BL provide the link between the shapes of excited states and the angular distribution in the continuum. The preceding considerations are based on a description of continuum electrons with Irn quantum numbers referred to the target nucleus as origin. An entirely analogous form can be written in terms of angles of emission with respect to a frame fixed in the projectile. Then the cross section, differential in k, the electron momentum in the projectile frame, can be written where now the coefficients PL are defined by Eq. Clearly in the limit that the electron has low momentum with respect to either target or projectile nucleus, where the three-body continuum approximates more nearly to a two-body one, Eq. Indeed, since it is difficult to measure low-energy electrons in the target laboratory frame, most discussion of angular distributions as of early has been in terms of Eq. This description of continuum angular distribution is appropriate to describe ionization of 28 J. Macek electrons into low-momentum projectile states, as in the case of electron loss to the continuum ELC where the electron is initially bound to the projectile, or in the case of ECC, where the electron originates from the target. That the angular distribution of cusp-continuum electrons should extrapolate smoothly below the projectile threshold to connect with the coherent excitation of ELC , or capture into ECC , Rydberg states has been emphasized particularly by Burgdorfer He also provided an analysis of the symmetry properties of the PL coefficients that has proved extremely useful in assessing the extent to which first Born or higher-order theories are capable of describing particular aspects of coherence or angular-distribution asymmetry. Two aspects of the symmetries of the problem are important: This latter symmetry results in the well-known presence of an additional constant of the motion, the Runge-Lenz vector, for two-body Coulomb states. Burgdorfer expresses the anisotropy parameters for bound states in terms of expectation values of O 4 group generators i. This is to be contrasted with the approach based on O 3 group generators angular momentum I in which the parameters PL appear as an infinite sum of multipoles. Hence, although all 1 partial waves contribute at the threshold, the following selection rules can be proved for the threshold PL in first Born approximation either for ionization or capture. This is a consequence of the parity and time-reversal properties of the first Born matrix elements. For capture only Po is nonzero. This can be seen from Eqs. These features are a consequence of the O 4 symmetry of the Coulomb force. One sees that anisotropy and, in particular, forward-backward asymmetry are very sensitive tests of the validity of firstorder theories. We shall return to the point when discussing higher-order theories. The foregoing has referred to initial 1s states, where any anisotropy in angular distributions is a direct result of collision dynamics. For nonisotropic initial states, the low-lying-continuum angular distribution is a complicated mixture of effects of initial anisotropy and collision-induced anisotropy. For example, Burgdorfer has generalized the preceding selection rule b to show that in PWBA the angular distribution for ionization from an initial state nlm has nonzero Br. The coefficients themselves depend strongly on nlm and the projectile velocity. In addition, it has often been emphasized that in the case of cusp electrons, the measured electron distribution depends crucially upon the acceptance aperture of the detector. This is because the calculated cross section is singular and the integral over this singularity depends sensitively on the limits of integration. Such structures have only been studied in first Born theories as of early These features are a peaks due to a single binary collision between projectile and target electron, b peaks due to recoil of slow electrons from the target nucleus, and c peaks due to the strongly enhanced density of states normalization factor for approximate two-body states corresponding to final-state interaction between electrons moving slowly relative to either target or projectile nucleus. It will now be shown that higher-order processes lead to new structures or seriously alter the shape momentum distribution of structures 30 J. Macek already present in the first Born lowest-order description of ionization. The new structures are due to sequences of double binary collisions, obviously arising first of all in the second Born approximation. Since capture to the continuum cannot occur in a single binary collision, it emerges that such higher-order processes have a strong effect on the shape of electronmomentum distributions for ECC processes. Indeed, one sees that, taken in its entirety, the process of ionization can never be considered as a first-order process. Only that part involving very small momentum transfer approximates at all the first Born description. Any large momentum transfer, either to the electron or to the target nucleus, has nonnegligible contributions from highqr-order multiple-scattering collisions. Such multiple-scattering collisions are the subject of this section. Scattering through angles much larger than this requires the nucleus-nucleus potential. One can then ask what happens if the incoming nucleus also scatters off the electron, either before or after the scattering off the target nucleus? As with the PWBA, Eqs 71 and 7 9 , the structure of binary collisions can be analyzed by considering that all propagation during and after the collisions is in plane waves.

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The values in brackets which are accurate to kO. Feagin and Macek , Macek and Feagin , and Lin and Watanabe have also treated the problem analytically; and Freitas et al. The agreement between theory and experiment is good. As the principal quantum number n is increased, the energies of the three systems with respect to the appropriate ionization threshold approach each other. The two-electron orbitals are strikingly large. Both parts of the compound word autoionization are here inappropriate. A search by Nicolaides and Beck did not reveal any other bound states of the ion. At variance with this, the existence of several bound states has been claimed. However, Bunge et al. They did so consequent on an important systematic search for excited states of the negative ions of the atoms H through Ca by performing nonrelativistic fixed-core valence-shell configuration interaction calculations. Their many predictions are consistent with all the results that will be reported here. Accurate configuration interaction calculations by Bunge and Bunge , combined with results of a study of Chung on relativistic and mass polarization effects, give that 1s 2s 2p 4P0 He- lies Chung has calculated the expectation values of the spin-orbit, spin-other-orbit and spin-spin operators. However, calculations by Bunge and Bunge , are against this being correct. These have been confirmed by photodetachment measurements on 1s 2s 2p 4P0 He- by Peterson et af. The peak was located at 1. Again Alton et al. But there is a second bound excited state: In his collision theory work on the EAs of the alkali atoms, Norcross found that 3p2 3P Na- is slightly 0. Norcross obtained a similar result for the other alkali atoms with the exception of lithium. An explanation of the pattern has been provided by Bunge a: By a configuration interaction study Bunge a, b also discovered two excited states of Li- that are metastable toward autodetachment: He calculated that the higher of these states decays mainly by a dipole transition to the lower: Seeking to check his prediction regarding the 1 nm line, Bunge b examined published beam-foil excited lithium spectra. See review by Berry, He noted that there is an unexplained line at His suggestion the first regarding optical emission from an atomic anion has been convincingly confirmed by the laboratory work of Mannervik et al. Several crucial tests were applied: Fine and hyperfine structure calculations on the excited states of Li- have been done Beck and Nicolaides, ; Cheng et al. Laboratory work by Bae and Peterson and by Kvale et al. From the autodetachment decay rate as a function of time the former scientists showed the presence of more than one substrate with the lifetime of the longest greater than loops; and from the center of mass energy of autodetaching electrons, lithium showed the energy below 3P0 Be to be f 90 meV. Configuration interaction computations by Beck and Nicolaides give this energy to be By application of a state-specific theory of electron correlation and relativistic effects in the Breit-Pauli approximation, Aspromallis et al. They explain the wide dispersion of these values as being due to final-state correlation, cancellation, and nonorthonormality.

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