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Burke P G & Schey H M. Elastic scattering of low-energy electrons by atomic hydrogen. *Phys. Rev.* 126:147-62, 1962; and **Burke P G & Smith K.** The low-energy scattering of electrons and positrons by hydrogen atoms. *Rev. Mod. Phys.* 34:458-502, 1962.
[Lawrence Radiation Lab., Univ. California, Berkeley; Lawrence Radiation Lab., Univ. California, Livermore, CA; and Argonne National Lab., IL]

The first paper described a 1s-2s-2p close coupling calculation of electron scattering by hydrogen atoms that revealed for the first time a doubly excited resonance at 9.6 eV. It also introduced a new asymptotic expansion that included the long-range multipole potentials and suggested a new pseudo-state expansion to represent short-range and long-range electron correlation effects. The second paper reviewed the experiments and the theory of electron and positron scattering by hydrogen atoms. [The *SCI*® indicates that these papers have been cited in more than 240 and 190 publications, respectively.]

Electron Scattering by Hydrogen Atoms

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This work started when I met Harry M. Schey soon after arriving at the Lawrence Radiation Laboratory, Berkeley, in 1959, to join the Alvarez bubble chamber group. Harry, who was at that time working with Edward Teller at the Livermore Laboratory, told me of their urgent need for accurate electron hydrogen atom cross sections to help interpret their fusion experiments. Having recently been in Sir Harrie Massey's department at University College London, where I had been working with Mike J. Seaton and my wife Val on electron hydrogen atom scattering, I was pleased to try to solve this problem on the new IBM 709 computer installed at Livermore.

The basis of this work was the electron hydrogen atom close coupling theory that had been formulated by I.C. Percival and Seaton.[1] The problem was to program the close coupling equations for the IBM 709 and to calculate the resultant cross sections. At first sight, this seemed straightforward, if rather lengthy. However, after six months of programming, we found that our solutions did not converge at energies just below the 2s and 2p excitation threshold at 10.2 eV. After many phone calls to Sam Mendicino, who was helping with the computer runs at Livermore, since I didn't have the appropriate security clearance, we found that this was due to the long-range dipole potential coupling the 2s and 2p states that had not been properly included.

After introducing a new asymptotic expansion, we found to our great surprise that a doubly excited resonance appeared at 9.6 eV. Later, this resonance was observed experimentally by G.J. Schulz;[2] and M. Gailitis and R. Damburg[3] showed that the long-range dipole potential also modified the threshold behavior of the cross sections from their usual Wigner form. Since then, resonances have been found in the scattering of electrons by almost all atoms and molecules.[4,5]

Schey and I also found that short-range and long-range electron correlation effects were not well represented by the usual close coupling expansion, which includes just bound target eigenstates. We therefore suggested that this expansion should be augmented by adding suitably chosen pseudo-states that would be able to represent the omitted continuum channels. Pseudo-state expansions have been used in the last few years, particularly by Joe Callaway and coworkers,[6] to obtain accurate 1s-2s and 1s-2p excitation cross sections at intermediate energies.

This work with Schey was just one of many experimental and theoretical studies of electron and positron hydrogen atom scattering that were carried out in the late 1950s and early 1960s. Ken Smith, an old friend from my University College London days, who was then at the Argonne National Laboratory, and I therefore decided to write a comprehensive review on this subject that was later published in *Reviews of Modern Physics*.

Electron scattering by hydrogen atoms is still receiving considerable experimental and theoretical attention, particularly because accurate cross-section data are required in many applications from laboratory plasma physics to astrophysics. Although there have been many theoretical advances during the last 30 years, many outstanding questions, particularly involving highly excited states and ionization cross sections, still remain to be answered.

1. **Percival I C & Seaton M J.** The partial wave theory of electron-hydrogen atom collisions. *Proc. Camb. Philol. Soc.* 53:654-62, 1957. (Cited 315 times.)
2. **Schulz G J.** Experiment on the resonance in the elastic scattering of electrons by atomic hydrogen. *Phys. Rev. Lett.* 13:583-5, 1964. (Cited 40 times.)
3. **Gailitis M & Damburg R.** The influence of close coupling on the threshold behaviour of cross sections of electron-hydrogen scattering. *Proc. Phys. Soc.* 82:192-200, 1963. (Cited 155 times.)
4. **Burke P G.** Resonances in electron scattering by atoms and molecules. *Advan. Atom. Mol. Opt. Phys.* 4:173-219, 1968. (Cited 110 times.)
5. **Fano U.** Correlations of two excited electrons. *Rep. Progr. Phys.* 46:97-165, 1983. (Cited 195 times.)
6. **Callaway J.** Scattering of electrons by atomic hydrogen at intermediate energies: elastic scattering and n = 2 excitation from 12 to 54 eV. *Phys. Rev. A—Gen. Phys.* 32:775-83, 1985. (Cited 20 times.)

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