Spin asymmetry in resonant electron-hydrogen elastic scattering

Ian E. McCarthy and Bo Shang
Electronic Structure of Materials Centre, School of Physical Sciences, Flinders University, GPO Box 2100, Adelaide 5001, Australia
(Received 8 February 1993)

Differential cross sections and asymmetries at 90° and 30° are calculated for electron-hydrogen elastic scattering over the energies of the lowest ^1S and ^3P resonances using a nine-state coupled-channel calculation with and without continuum effects, which are represented by an equivalent local polarization potential. The polarization potential improves agreement with experiment in general for the spin-averaged cross sections. It is suggested that continuum effects would be critically tested by asymmetry measurements at 30° over the ^1S resonance.

PACS number(s): 34.80.Bm, 34.80.Dp

I. INTRODUCTION

It was recently shown [1] that generally good agreement with experiment for electron-hydrogen elastic and inelastic scattering in the resonance region can be obtained by the coupled-channel-optical (CCO) method with the equivalent local polarization potential [2]. In this method enough discrete channels for convergence are explicitly coupled. These channels constitute P space. The coupling potential includes a complex polarization potential that describes the effect of the ionization continuum (Q space).

The coupled channel (CC) method without the effect of the continuum converges as the number of channels is increased. For the present application sufficient convergence is achieved with nine target states: 1,2,3,4s; 2,3,4p; 3,4d. The present method of computation is to solve the coupled Lippmann-Schwinger equations of momentum space [2]. An equivalent coordinate-space technique is the R-matrix method, which was recently calculated for 15 states by Fon, Ratnavelu, and Aggarwal [3], for the resonant region of electron-hydrogen scattering.

The two methods are in close agreement. Since they omit the continuum they do not converge to the full solution of the scattering problem. For $n = 2$ excitations the CC calculation achieves integrated cross sections that are about 20% too high on the average. This discrepancy is corrected by including the continuum [1]. A similar discrepancy has been noted for electron-helium scattering by Fon, Lim, and Sawey [4].

Fon *et al.* [3] noted that the spin asymmetry is more sensitive to resonance effects than spin-averaged cross sections in a calculation that omits the continuum. We include the continuum in a CCO calculation and examine its effect on cross sections and asymmetries in the energy range 9.4–9.8 eV, which includes the lowest ^1S and ^3P resonances.

II. RESULTS AND DISCUSSION

The CCO method with the equivalent local polarization potential is described in Ref. [1].

In Fig. 1 we compare the CCO and CC calculations with the experiment of Williams [5] for the differential

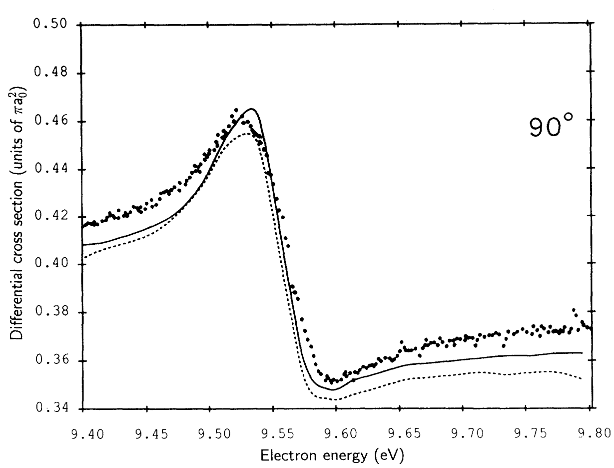

FIG. 1. Electron-hydrogen elastic differential cross section at 90°. Experiment, Williams [5]; solid curve, CCO calculation; curve, CC calculation. The calculations have been folded with the experimental energy-resolution function.

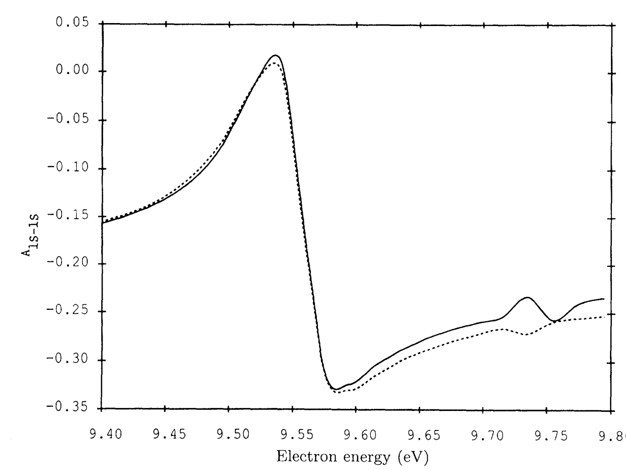

FIG. 2. Electron-hydrogen elastic asymmetry at 90°. Curves as for Fig. 1.

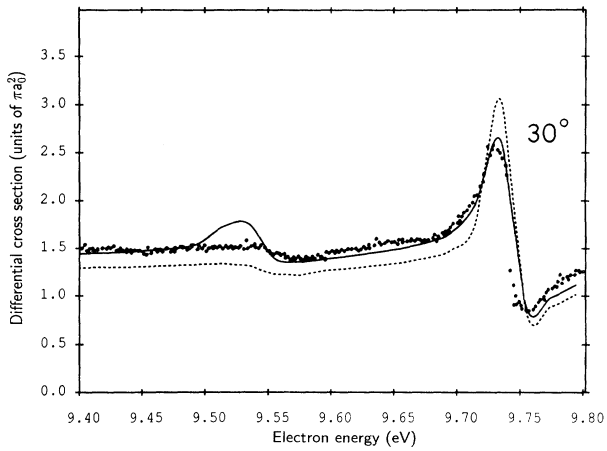

FIG. 3. Electron-hydrogen elastic differential cross section at 30°. For details, see Fig. 1.

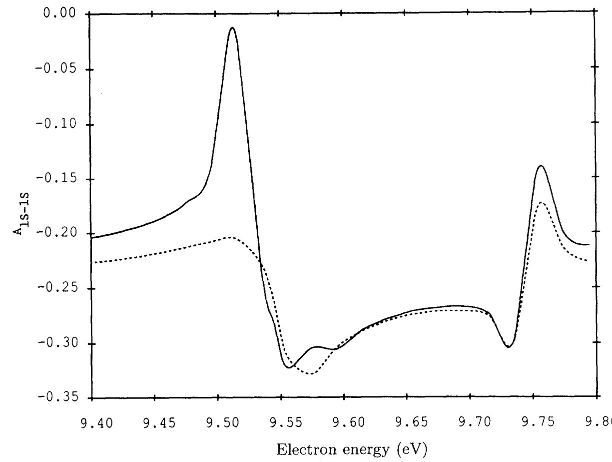

FIG. 4. Electron-hydrogen elastic asymmetry at 30°. For details, see Fig. 1.

cross section at 90°. Here there is no contribution from the ^3P resonance. The CCO calculation does not achieve perfect agreement with experiment, but it improves significantly on the CC calculation without the continuum. There is little to distinguish the calculations in the asymmetry (Fig. 2).

In Fig. 3 we compare the calculations with the differential cross section of Williams [5] at 30°. The CC calculation differs significantly from experiment in the vicinity of the ^3P resonance at 9.74 eV, but again the CCO calculation improves the agreement. It is perhaps surprising that the effect of the isotropic ^1S resonance at 9.55 eV is not seen more strongly in the experiment. There is a somewhat larger effect in an experiment by Warner *et al.* [6] at 33°. The shape of the CC calculation near this resonance agrees with the experiment of Williams, but the CCO calculation does show more of an effect from the resonance. General agreement with the magnitude of the cross section is achieved by use of the CCO calculation, but not with the CC calculation.

At 30° the asymmetry (Fig. 4) distinguishes decisively between the two calculations. Experimental observation of this asymmetry would be a very interesting test of the simple equivalent local polarization potential at low energy.

It is noteworthy that the same CCO model predicts the asymmetry correctly in 20-eV electron-sodium scattering to the 3^2P channel [7], whereas the corresponding CC model gives the wrong sign. The differential cross section does not really distinguish between the two models. Effects due to virtual excitation of the continuum are evidently very important in low-energy electron scattering, showing up particularly in asymmetries.

ACKNOWLEDGMENTS

We acknowledge support from the Australian Research Council. One of us (B. S.) thanks Flinders University and the Australian Federation of University Women–South Australia, Inc. Trust Fund for support. We thank Dr. W. C. Fon for prepublication information.

[1] I. E. McCarthy and B. Shang, Phys. Rev. A **46**, 3959 (1992).

[2] I. E. McCarthy and E. Weigold, Adv. At. Mol. Opt. Phys. **27**, 165 (1991).

[3] W. C. Fon, K. Ratnavelu, and K. M. Aggarwal, Phys. Rev. A **47**, 2968 (1993).

[4] W. C. Fon, K. P. Lim, and P. M. J. Sawey, J. Phys. B (to be published).

[5] J. F. Williams, in *Electron and Photon Interactions with Atoms,* edited by H. Kleinpoppen and M. R. C. McDowell (Plenum, New York, 1976), p. 309.

[6] C. D. Warner, G. C. King, P. Hammond, and J. Slevin, J. Phys. B **19**, 3297 (1986).

[7] I. E. McCarthy, J. Mitroy, and R. Nicholson, J. Phys. B **24**, L449 (1991).