NUMERICAL GREEN'S FUNCTIONS IN OPTICAL POTENTIAL CALCULATIONS FOR POSITRON SCATTERING FROM ARGON AND NEON

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ABSTRACT

We have applied an optical potential method to the calculation of positron scattering from the noble gases in order to determine the effect of open excitation channels on the shape of differential scattering cross sections.

THEORY

In positron–atom scattering the usual close-coupling expansion for the total wavefunction in terms of the sum of products of the bound-state wavefunctions of the target atom and the one-projectile scattering wavefunctions leads to the following set of integro-differential equations for the radial parts \( F_i \) of the scattering wavefunctions:

\[
\left( \frac{d^2}{dr^2} \frac{1}{r^2} - \frac{l(l+1)}{r^2} - 2V_{\text{opt}}(r) + k^2 \right) F_i(r) = 2 \sum_{j} V_{ij}(r) F_j(r) \tag{1}
\]

Here the potential terms \( V_{ij} \) are given by

\[
V_{ij}(r) = \frac{Z}{r} \delta_{ij} - \sum_{k=1}^{N} \frac{\langle \Phi_i | \frac{1}{|r_k - r|} | \Phi_j \rangle}{k^2 - \frac{l(l+1)}{r^2}} \tag{2}
\]

and the \( \Phi_i \) are the bound-state wavefunctions of the \( N \)-electron target.

In practice only a finite number of bound target states can be included in the close-coupling expansion. Hence, we approximate the effect of the higher discrete target states as well as the ionisation continuum by means of an optical potential. We divide the space of scattering functions into \( P \)- and \( Q \)-spaces. We choose for the \( P \)-space the elastic channel only and thus the \( Q \)-space contains all inelastic channels. In the \( Q \)-space we neglect all couplings between different channels but retain the couplings between the \( P \)- and \( Q \)-spaces. Thus our method requires the solution of the inhomogeneous differential equation

\[
\left( \frac{d^2}{dr^2} \frac{1}{r^2} - \frac{l(l+1)}{r^2} - 2V_{\text{opt}}(r) + k^2 \right) F_i(r) = 2 V_{00}(r) F_0(r) \tag{3}
\]

for the radial functions \( F_i \) belonging to the \( Q \)-space. Here \( F_0 \) is the \( P \)-space (elastic) channel wavefunction. In our previous work\(^1\) we ignored the diagonal term \( V_{ii} \) above and solved equation (3) by means of the free-particle Green's function involving the standard Riccati-Bessel functions.

In either case the solution to equation (3) can be written as

\[
F_i(r) = -2 \int_0^\infty dr' G_i(r, r') V_{00}(r') F_0(r') \tag{4}
\]

where the Green's function \( G_i(r, r') \) is given by

\[
G_i(r, r') = \frac{1}{k_i^2} f_i(k_i r') \left[ g_i(k_i r') + i f_i(k_i r') \right] \tag{5}
\]

The functions \( f_i \) and \( g_i \) are the regular and irregular solutions of equation (3) with the right-hand-side put to zero.

Upon substitution of equation (4) into the \( P \)-space form of equation (1) we obtain

\[
\left( \frac{d^2}{dr^2} \frac{1}{r^2} - 2V_{00}(r) + k^2 \right) F_0(r) = -U_{\text{opt}}^0(r) F_0(r) \tag{6}
\]

where the optical potential is given by

\[
U_{\text{opt}}^0(r) F_0(r) = 4 \sum_{l \geq 0} \int_0^\infty dr' V_{00}(r') G_i(r, r') V_{00}(r') F_0(r') \tag{7}
\]

The real part of the optical potential represents polarisation while the imaginary part represents absorption due to the inelastic channels.

When the \( V_{ii} \) are ignored, \( f_i \) and \( g_i \) are the Riccati-Bessel functions.\(^1\) However, if we retain the diagonal potentials in equation (3), then \( f_i \) and \( g_i \) have to be found by a numerical solution of the homogeneous differential equation.

RESULTS

We have extended our previous work on argon\(^1\) by using the numerical Green's functions in the optical potential. We have also carried out similar calculations for positron scattering from neon.

The overall effect of retaining the diagonal potentials and hence using numerical Green's functions is quite small, i.e. of the order of a few percent of the differential cross sections at all angles.
The results of using optical potentials for positron-neon scattering yields cross sections whose behaviour is very similar to that of argon. In particular, the distinct minimum in the differential cross section which we obtained in our previous polarized-orbital calculations is no longer present when the optical potential is used. Below we present some typical results for positron scattering from argon and neon.

![Figure 1](image1)

**FIG. 1.** Positron scattering from argon at 30 eV. (—), ten-state optical potential using free-wave Green's functions; (— — —), ten-state optical potential using numerical Green's functions; (---), polarized-orbital approximation; ⋆, experimental data normalized at 60°.

Figure 2 illustrates similar results for positron scattering from neon at 20 eV. Finally in figure 3 we show positron scattering from argon at 8.5 eV. At this energy only the elastic channel is open. Here the experimental data clearly show a minimum and agree well with the shape of the polarized-orbital calculations.

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FIG. 2. Positron scattering from neon at 20 eV. (---), fourteen-state optical potential using free-wave Green's functions; (- - -), fourteen-state optical potential using numerical Green's functions; (---), polarized-orbital approximation; *, experimental data normalized at 90°.

FIG. 3. Positron scattering from argon at 8.5 eV. (- -), polarized-orbital approximation; *, experimental data normalized at 45°.