A review of recent elastic differential cross section (DCS) measurements for positron–atom scattering is presented. Most of the earlier measurements are relative DCS determinations which only enable the shapes of DCS curves (versus angle at a given energy) to be compared with theory, while the most recent efforts in Bielefeld and Detroit are directed toward determining absolute DCS values such that magnitudes as well as shapes can be compared with theory. For positron–argon scattering, reasonable agreement has been found between experiment and theory at 300 eV and below 9 eV, while between these energies, significant differences exist, which raises interesting questions concerning possible cross-channel-coupling effects where other scattering channels (e.g. positronium formation and/or ionization) may be having appreciable effects on the elastic scattering channel.

1. Introduction

Investigations of positron differential elastic scattering by atoms can be basically divided into two categories which correspond to measurements of relative differential cross sections (DCSs) and absolute DCSs. With the exception of the original absolute DCS measurements by Coleman and McNutt [1], all of the other "first generation" positron DCS measurements were relative in that their significance related to the shapes of the DCS curves versus scattering angle for a given positron impact energy. The "current generation" of positron DCS measurements are absolute determinations allowing the magnitudes of the DCSs to also be compared with theoretical calculations, which provides a much more stringent test of theoretical calculations than was possible with the relative determinations. This paper will focus upon both the recent relative DCS measurements and the current absolute DCS determinations which are in progress.

Up to the present time, all of the positron DCS measurements that have been reported have been for argon atoms (except for preliminary reports [2,3] at a sampling of energies for four other inert gases), because argon is rather inexpensive and has a relatively large scattering cross section. Three distinct energy regions can be identified, which are (1) a low energy region (generally below about 10 eV) where only the elastic scattering channel is open (at least for the inert gases), (2) a high energy region (generally above a few 100 eV) where corresponding high energy calculations (e.g. distorted-wave second Born approximation and optical
model) are found to provide a reasonably accurate description of scattering, and (3) an intermediate energy region (around 10 to a few 100 eV) where much of the challenge remains for theoreticians to perform calculations that can adequately account for the various scattering channels that can effectively be "competing" with each other. In the case of positron–atom scattering, the intermediate energy region is particularly interesting because for many target gases, positronium (Ps) formation becomes a significant contributor to total scattering almost immediately above the Ps formation threshold [4].

2. Relative DCSs

The measurement of relative DCSs for positrons elastically scattered by gases is the most straightforward because one of the main requirements is that the projectile positron beam intensity be only kept constant (or closely monitored) during the accumulation of data for the elastically scattered positrons at the various measured angles of scattering for a given experiment. If the detection efficiency of the detector(s) monitoring the scattered positrons is independent of the scattering angle, it is then possible to obtain relative DCSs within the experimental limitations, such as the angular acceptance (typically about 10°) of the secondary detectors and the energy width (typically 1 to 2 eV) of the projectile positrons.

The highest energy positron DCS measurements that are available were reported by Hyder et al. [5] for 300 eV positron-argon elastic scattering and are shown in fig. 1, where they are compared with the ab-initio optical model calculations of Joachain et al. [6]. Also shown in fig. 1 are the corresponding electron-argon elastic DCS relative measurements [5] and optical model results [6]. The positron (and electron) experimental results and optical model calculations are in good shape agreement at 300 eV. For 200 eV positron-helium elastic scattering, some initial DCS results of the Detroit group [3] are in agreement with an eikonal-Born series method calculation (within the framework of the optical model formalism) by Byron and Joachain [7].

The three experimental groups that have made positron-atom elastic DCS measurements up to the present time can be compared with each other only for positron-argon scattering at 8.7 eV, where the results of Coleman and McNutt [1] (which are the only absolute values), Floeder et al. [8] (made at 8.5 eV) and Smith et al. [9] are compared in fig. 2 with the polarized orbital calculations of McEachran et al. [10] and Montgomery and LaBahn [11]. The relative results of Floeder et al. [8] and Smith et al. [9] are normalized to McEachran et al. [10] at 60° and 120°, respectively. The experimental results are in good shape agreement with each other and also the polarized orbital calculations, clearly showing the presence of structure in the DCS curve. It is to be noted that 8.7 eV is in the purely elastic scattering region, since the lowest energy inelastic scattering threshold for argon is 9.0 eV (for Ps formation).