Measurements of the total cross sections for positron scattering from He using an electrostatic high-brightness slow positron beam apparatus

Kazuaki Nagumo\textsuperscript{a,1}, Yuna Nitta\textsuperscript{a}, Masamitsu Hoshino\textsuperscript{b}, Hiroshi Tanaka\textsuperscript{b} and Yasuyuki Nagashima\textsuperscript{a,2}

\textsuperscript{a}Department of Physics, Tokyo University of Science, 1-3 Kagurazaka, Shinjuku-ku, Tokyo 162-8601, Japan

\textsuperscript{b}Department of Physics, Sophia University, 7-1 Kioicho, Chiyoda-ku, Tokyo 102-8554, Japan

E-mail; \textsuperscript{1} kazu_nagumo@yahoo.co.jp, \textsuperscript{2} ynaga@rs.kagu.tus.ac.jp

Abstract. We have measured the total cross sections for positron scattering from He using an electrostatic high-brightness slow positron beam apparatus. Our results are in reasonable agreement with the data by Jaduszliwer \textit{et al} in the energy region below 15 eV, which have been obtained under the influence of the lower axial magnetic field than other groups.

1. Introduction

There have been considerable efforts devoted to positron scattering studies, in particular to the measurements of the total cross sections (TCS) \cite{1,2}. Since the 1970s, several groups have developed magnetically confined or electrostatic slow positron beam systems for the positron scattering studies. Most of the TCS measurements have been performed using the magnetically confined beams in order to transport the slow positrons efficiently.

The values of TCS, $\sigma_{\text{tot}}$, for positron scattering from several gases have been derived by the Beer-Lambert law, in which positrons scattered by target molecules are considered as having been removed from the incident beam. The TCS is obtained from the relationship,

$$\sigma_{\text{tot}} = \frac{k_{\text{B}} T}{p L} \ln \frac{I}{I_0},$$

(1)

where $I$ and $I_0$ are the transmitted beam intensities with and without gas of pressure $p$ and temperature $T$ in the cell, respectively. $L$ is the length of the gas cell and $k_{\text{B}}$ is the Boltzmann’s constant. Since the forward scattered positrons are constrained to follow helical trajectories by the magnetic field, the transmitted intensities with gas in the cell, $I$, is overestimated. This effect has been corrected, for example, using calculated differential cross sections \cite{1}.

In the present work, we have measured the TCS for He using an electrostatic slow positron beam apparatus, where the effect of the forward scattered positrons is smaller than that under the influence of magnetic fields.
2. Experimental Procedure
The apparatus used was an electrostatic high-brightness slow positron beam system [3][4]. Positrons from a $^{22}$Na source of ~250 MBq activity were firstly moderated with a tungsten mesh moderator. The slow positrons emitted from the moderator were transported by several electrostatic lens elements. Then, the slow positrons were focused onto a remoderator at the energy of 5 keV with a diameter of approximately 2-3 mm for brightness enhancement. The remoderator was a tungsten (100) single crystal foil and used in the reflection geometry. Positrons reemitted from the remoderator were deflected and energy selected by an electrostatic hemispherical energy analyzer and then reached a 30.0 mm long gas cell, which had entrance and exit apertures of 2 mm diameter. Finally, the survived positrons through the cell were detected by the Channeltron. In order to prevent the effect of stray magnetic fields, the apparatus was covered with μ-metal shielding.

The pressure of the target gas was determined using an absolute capacitance manometer at the center of the cell. The gas pressure was maintained such that the total positron scattering probability was less than or equal to 20%. The resolution of the slow positron beam for the TCS measurement was about 250 meV (FWHM) [4]. The positron beam intensity was 1.5 e$^+$/s and 0.04 e$^+$/s at 100 eV and 5 eV incident energy, respectively.

3. Results and Discussion
The obtained values of TCS for He without corrections for the positron forward scattering were shown in Fig. 1 together with the prior experimental results [5]-[13] and the recent theoretical results [14][15].

![Figure 1](image-url)  
*Figure 1. Total Cross Sections for positron scattering from He. Experiment: ●, Present results without corrections for the positron forward scattering; □, Jaduszliwer et al [5]-[7]; ■, Detroit group [8][9]; ▲, Mizogawa et al [10]; +, Karwasz et al [11]; ◇, ANU group [12][13]. Theory: ------, Reeth et al [14]; ······, Wu et al [15].*
The present results are in reasonable agreement with the data by Jaduszliwer et al [5]-[7] in the region below 15 eV, which have been obtained under the influence of the lower axial magnetic field (2.75 G) than other groups. However, our results are higher than the measurements by Mizogawa et al [10] and ANU group [12][13], which agree well with the theoretical values of Reeth et al [14] and Wu et al [15], in the region between 4 and 20 eV. Although there should be some causes for the discrepancies, the reason is unknown.

We are presently working on the TCS measurements for Ne. The data will be published soon.

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