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Electron (Positron) Impact Ionization of Xenon

KEYWORDS: Electron, Positron, Ionization, Born approximation

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ABSTRACT *In this paper, we have computed the differential cross section (DCS) and total ionization cross section (TICS) for ionization of Xenon by impact of electron and positron. We have used truncated coupled state Born approximation method for calculation of the results. High quality Hartree-Fock Slater orbitals are used to model the target wave function. We have already computed ionization results [1, 2 & 3] for noble gas series (Ne, Ar, Kr and Xe), but here we are presenting only for Xenon atom. Full orthogonalization significantly improves agreement with available experimental data for the noble gas series. We have compared our results with available theoretical as well as experimental measurements. Our present results are found in excellent agreement with other calculations. However some discrepancies suggested that more theoretical as well experimental work is required.*

INTRODUCTION

The investigation of charged particle scattering from noble gases provides a vital meeting point for contemporary quantum scattering theory and experiment. The noble gas systems have some of the simplest targets to study experimentally due to their inert nature and consequent ease of handling. With their closed valence shells, they have also relatively simple collision systems to approach theoretically, although the level of complication increases with atomic number. The aim of this work was to provide benchmark cross sections for atomic noble gas targets. Through a detailed comparison of the results with other available results, we also hope to critically evaluated results with a view to establishing an accepted set of cross sections for these gases. Despite more than half a dozen groups independently investigating these systems, considerable disparity remains, even for measurements of the total cross section, though considerable effort was made to understand possible sources of systematic errors [4]. Many improvements have been made in both the techniques employed and the equipment available, such that this problem may be better approached now. The broader intent in understanding these relatively simple scattering cases, both experimentally and theoretically, is to further refine our understanding of positron interactions in general and thus eventually allows theoretical treatment of problems which cannot easily be tackled experimentally. Examples of such systems might be large molecules of biological interest that may play a role in positron emission tomography, a medical imaging technology [5].

The electron impact ionization of atoms plays an important role in a wealth of areas in physics and chemistry, including mass spectrometry, the upper atmosphere, plasma processes, gas discharges, and radiation. Accurate cross sections are not only of fundamental importance for understanding the mechanism of the ionization process, but they are also required for many modeling applications, ranging from studies of fusion plasmas to investigations into radiation effects in materials science and medicine. Also the study of positron impact ionization of Xenon atom is an essential aspect of atomic physics because it provides complete knowledge of atomic structure and scattering process. In fact, the collision processes have the paramount importance for understanding various branches of science and advanced technology. In recent years, much progress has been made in the theoretical as well as experimental treatment of positron impact ionization processes.

Khare *et al* [6] have been calculated cross sections for ionization of Xenon by impact of electron and positron using the plane wave Born approximation method. Moxom [7] have presented ionization cross section results of Xenon by positron impact. Pindzola *et al* [8] have been reported the distorted wave calculations for electron impact ionization of Xenon. Using the distorted wave Born approximation (DWBA), Kheifets *et al* [9] have been performed calculations of electron impact ionization of noble gas atoms. Recently, Absolute cross sections for electron impact ionization of Xenon have been measured using the crossed beam technique by Borovik Jr *et al* [10].

THEORY

In the case of the electron impact ionization of a target atomic orbital, the truncated coupled state Born approximation is given by

$$d\sigma = \frac{4k'K^2}{kq^4}\left|\left(e^{-iq.r}\right)_{nlm\,K}\right|^2 d\Omega\, d\Omega_K\, dK \quad --(1)$$

where is the ionization cross section, and are elements of solid angle about the scattered and ejected electrons respectively. *n, l* and *m* are the usual orbital, angular and magnetic quantum numbers, *k* is the incident electron momentum (directed along the positive z axis), is the scattered electron momentum, *K* is the ejected electron momentum and is momentum transfer. The matrix element is given by

$$\left(e^{-iq.r}\right)_{nlm\,K} = \int \psi_K^{(-)*} e^{-iq.r}\, \phi_{nlm} d^3r \quad --(2)$$

Where is the target orbital wave function and is the ejected electron wave function. To evaluate equation (1), all momenta in the equation must be expressed in terms of the known variables and the integration variables. These are given by

$$k = \sqrt{2E} \quad --(3)$$

$$k' = \sqrt{2\left(E - E_0 - \frac{K^2}{2}\right)} \quad --(4)$$

$$q = \sqrt{k^2 + k'^2 - 2kk'\cos\theta} \quad --(5)$$

Where E is the incident electron energy, E_0 is the ionization energy of the target orbital and θ is the angle between k' and positive z axis.

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Using equation (1), the DCS is given as

$$\frac{d\sigma}{d\Omega} = \frac{4k'K^2}{kq^4} \left|\left(e^{-iq\cdot r}\right)_{nlm,K}\right|^2 d\Omega_K dK \quad --(6)$$

and the total ionization cross section (TICS) of an atom is the sum of the ionization of each of the occupied orbital,

$$\sigma = \sum_{nlm} \frac{N_{nl}\sigma_{nlm}}{2l+1} \quad --(7)$$

Where is the number of electrons in the *n l* orbital and it is named that the electrons are equally shared amongst the stable *m* quantum states.

RESULTS AND DISCUSSION

We have computed differential cross section (DCS) and total ionization cross section (TICS) for ionization of noble gas atom (i.e. Xenon) by impact of electron as well as positron using truncated coupled Born approximation (TCBA) method. These computed results of electron (P_1) and positron (P_2) are compared with other available data.

DCS for Ionization of Xenon

Using equation (6), we have obtained DCS for electron and positron impact ionization of noble gas atoms at 100eV impact energy. In the figure [1], we have shown the computed DCS results of ionization of Xenon by impact of electron and positron at 100eV. Here DWBA results of Brunger [11] are also plotted. For comparison the present theoretical results, experimental data of Gibson *et al* [12] is also plotted. As far as Xenon gas, a complicated variation of DCS with scattering angle can be seen in all theoretical results and experimental data. Our results P_1 give two sharp dip at about 30^0 and than 120^0. However this feature can also be seen in other theoretical result DWBA. The positron impact DCS P_2 also shows an abnormal feature. As scattering angle increases result P_2 decreases rapidly becomes constant and again decreases rapidly showing a dip at about 130^0. Further it increases with increase of scattering angle.

TICS for Ionization of Xenon

Using equation (7), we have obtained TICS for electron (positron) impact ionization of noble gas atoms. Figure [2] represents the variation of TICS for higher noble gas Xenon with incident energy. The experimental results of Sorokin *et al* [13] and Freund et *al* [14] are also plotted. It appears that the present theoretical results P_1 give higher cross section in comparison to experimental data. More theoretical as well as experimental results shall be required to check the accuracy of present results.

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DIFFERENTIAL CROSS SECTION FOR XENON AT 100eV

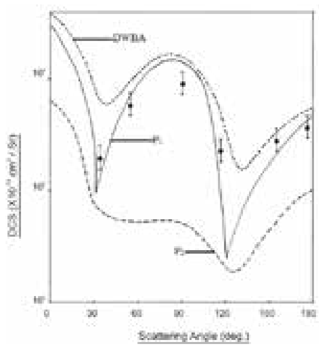

FIGURE [1] : Figure Captions

__________: Present results (P_1) for electron

----------: Present results (P_2) for positron

: DWBA of Brunger [11]

: Experimental results of

Gibson *et al* [12]

TOTAL IONIZATION CROSS SECTION FOR XENON

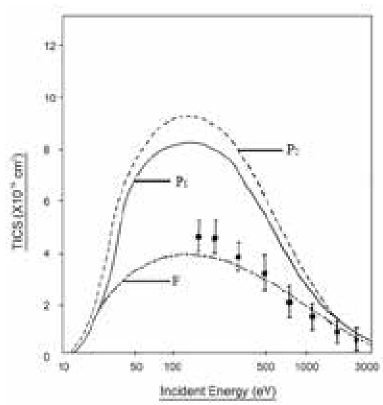

FIGURE [2] : Figure Captions

_________: Present results (P_1) for electron

---------- : Present results (P_2) for positron

: (F) Freund *et al* [14]

: Experimental results of

Sorokin *et al* [13]

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