DCS and TICS for Ionization of Noble gas Atom

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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 noble gas atom i.e. Krypton by impact of electron (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] for noble gas series (Ne, Ar, Kr and Xe), but here we are presenting only for Krypton 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.*

INTODUCTION

The collision physics gave new ideas about internal structure of atom. The ionization of noble gases by impact of charged particles continuously attracts a deep interest in collision physics for several reasons. The study of electron as well as positron impact ionization of Krypton 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. The collision of electron (positron) with Krypton, play a dynamic role in many fields, e.g. in the initiation of plasma from neutral gas and medical field etc. Due to characteristics properties of Krypton, it is used in lighting, photography and high powered gas lasers. On the practical side, reliable knowledge of ionization cross sections for above processes is very important for applications in plasma and discharge physics. In recent years, much progress has been made in the theoretical as well as experimental treatment ionization processes. The convergent close coupled methodology of Bray and Stelbovics [3] has provided the best correlation of scattering theory with experimental results. Also the close coupling approximation is the successful non - perturbative approach which used to computational treatment of ionization process.

Most of the theoretical work on positron impact ionization of atoms is based on the distorted wave formalism. Measurements of doubly differential single and multiple ionization of atomic Krypton have been performed by Santos et al [4] for 750eV positron and electron impact and also for 240eV and 500eV electron impact by de Lucio et al [5]. Using this approximation Moxom et al [6] and Kara et al [7] measured the cross sections for Krypton by impact of positron. Marler et al [8] studied positron impact ionization cross sections for inert gases by using a qualitatively different method. McEachran and Stauffer [9] have been investigated positron impact ionization cross sections by applying relativistic complex optical – potential method. Recently, Montanari and Miraglia [10] have been reported the results of electron impact ionization of rare gases.

THEORY

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

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

Where σ is the ionization cross section, $d\Omega$ and $d\Omega_K$ 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), k' is the scattered electron momentum, K is the ejected electron momentum and q=k- k' is momentum transfer.

The matrix element is given by

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

Where φ_{nlm} is the target orbital wave function and $\psi_K^{(-)}$ 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.

Using equation (5.1), the DCS is given as

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

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

Where N_{nl} is the number of electrons in the nl 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 Krypton 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 Krypton

Using equation (6), we have obtained DCS for electron and

positron impact ionization of noble gas atoms at 100eV impact energy. The computed DCS of Krypton by electron as well as positron impact are shown in figure [1] at 100eV impact energy. Here we have compared the present results with other theoretical results (U) Guo et al [11] using unitrized first order many body theory (UFOMBT). The only experimental data of Guo et al [11] has also been plotted in this figure. The present results P_1 and experimental data both are in a good agreement. The other theoretical results (U) give higher cross section and show unmatched with experimental data as well as present results P_1. However the appeared dip is same in all the results in the angular range 80^0 to 100^0.

TICS for Ionization of Krypton

Using equation (7), we have obtained TICS for electron (positron) impact ionization of noble gas atoms. Figure [2] depicts present results P_1 and P_2 for total ionization cross section of Krypton. The theoretical results of Moores [12] and experimental results of Sorokin et al [13] are also plotted. The variation of TICS for Krypton is in a good agreement with experimental data.

ACKNOWLEDGEMENT

TOTAL IONIZATION CROSS SECTION FOR KRYPTON

FIGURE [2] :   Figure Captions

----- : Present results (P_1) for electron

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

–•–•– : (M) Moores [12]

� : Experimental results of Sorokin et al [13]

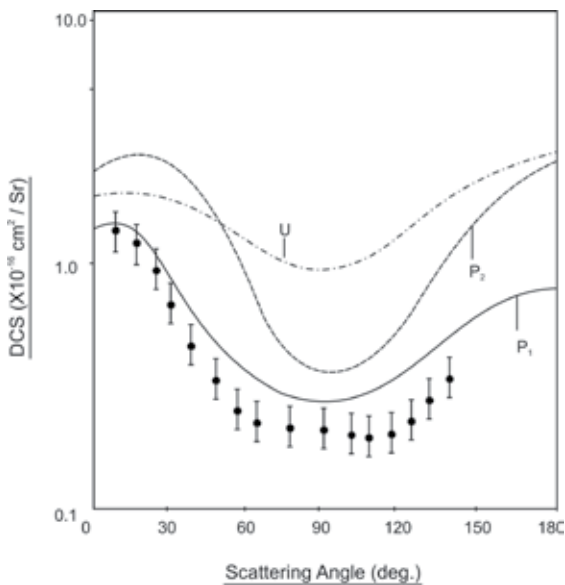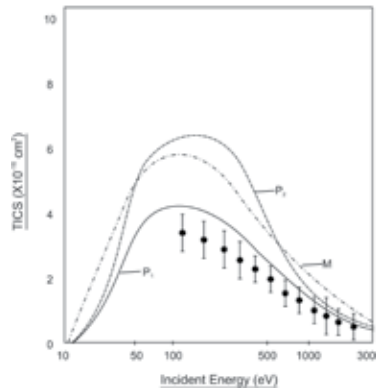### DIFFERENTIAL CROSS SECTION FOR KRYPTON AT 100eV

FIGURE [1] :   Figure Captions

----- : Present results (P_1) for electron

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

–•–•– : (U) Guo et al (UFOMBT) [11]

⎸ : Experimental results of Guo et al [11]

REFERENCES   [1] Kumar, K. and Saxena, S. (2010), "Acta Ciencia Indica", Int. J. Phy. Sc., Vol. XXXVI P, No.4, 437. | [2] Sharma, Kamlesh K. and Saxena, S. (2011), "Proceeding of 3rd International Conference on Current Developments in Atomic, Molecular, Optical and Nano Physics (CDAMOP-2011)" held at Delhi University, Delhi, 156. | [3] Bray, I. and Stelbovics, A. T. (1995), "Adv. At. Mol., Opt. Phys." 35, 209. | [4] Santos, A. C. F., Hasan, A. and Dubois, R.D. (2004), "Phys. Rev. A" 69, 032706. | [5] de Lucio, O.G., Gavin, J. and Dubois, R.D. (2007), "Phys. Rev. A" 75, 052709. | [6] Moxom, J., Ashley, P. and Laricchia, G. (1996), "Can. J. Phys." 74, 367. | [7] Kara, V., Paludan, K., Moxom, J., Ashley, P and Laricchia, G. (1997), "J. Phys. B" 30, 3933. | [8] Marler, J. P., Sullivan, J. P. Sukro, C. M. (2005), "Phys. Rev. A" 71, 022701. | [9] McEachran, R. P. and Stauffer, A. D. (2010), "J. Phys. B" 43, 215209. | [10] Montanari, C. C. and Miraglia, J. E. (2012), "J. Phys. B" 45, 105201. | [11] Guo, X., Mathewst, D. F., Mikaelian, G., Khakoo, M. A., Crowe, A., Kanik, I., Trajmar, S., Zeman, V., Bartschat, K. and Fontes, C.J. (2000), "J. Phys. B" 33, 1895. | [12] Moores, D. L. (2001), "Nucl. Instrum. Methods Phys. Res. B" 179, 316. | [13] Sorokin, A. A., Shmaenok, L. A., Bobashev, S. V., Mobus, B., Richter, M. and Ulm, G. (2000), "Phys. Rev. A" 61, 022723.