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Partial and Total Ionization Cross Section of Sodium Atom by Electron Impact

Praveen Bhatt[*1], Ravinder [*2], Nidhi[#3], Umesh Bhardwaj[#4]
[*1] Professor, Deptt. of Applied Science and Humanities, Asia Pacific Institute of Information Technology (APIIT SD INDIA) Panipat, (Kurukshetra University, Kurukshetra, India)
[#.2 &3]Research Scholar, Baba Mast Nath University,Rohtak,(Haryana
[#4]Associate Professor, Department of Chemistry, Hindu College, Sonipat, (MDU University, Kurukshetra, India)

Abstract:- *The Partial scattering cross section of sodium atom have been obtained form 0–2200 eV energy by semi empirical formula. The present cross sections are compared to existing experimental cross sections as well as to theoretical predictions. The correlation between the total electron scattering cross section and the number of target-molecule electrons is discussed.*

Keywords: Ionization cross section, cross section, Electron scattering.

I. INTRODUCTION

The determination of total cross section for electron scattering from atoms and molecules at electron energies 2000 eV. The cross-section measurements at these energies are required to develop theoretical models in understanding the interaction process and in applications in atmospheric physics, astrophysics, plasma physics and chemical physics [1-2]. One of the purposes of this work is to calculate the electron impact ionization cross-sections of the Boron atom by employing the useful features of Semi- empirical model at given energy.

The upper atmosphere is constantly bombarded by the energetic particles and electromagnetic radiations. Particularly during solar flare the sun emits greatly enhanced electromagnetic radiation in X-ray and UV regions, cosmic particles, ions and electron produce photoelectrons and secondary electrons. These electrons then lose their energy through various elastic and inelastic processes and ultimately get thermalized. Thus the energy spectrum of the electrons is a very important parameter for all atmospheric calculations. From the energy spectrum induced by collision processes one gets an idea of chemical composition, density and temperature of constituent elements of atmosphere. The ionic layers in the ionosphere of earth are mainly formed due to the ionization of the neutral constituent of atmosphere by solar radiations leading to production of energetic free electrons and ions. These energetic electrons further excite the neutral particles and these excited states of particles on decay to lower states give rise to fluorescence. This is an important component of day glow. These ionized and excited species also produce the atmospheric emission known as aurora. Hence for the proper understanding of the different phenomena occurring in upper atmosphere, we need a wide knowledge of atomic and molecular Collision processes [3-5].

II. THEORY

Cross sections of many different types of molecules and atoms can be determined by various experimental techniques during the last decades. Electron impact ionization of rare gas ions is an important process in high-energy chemical processes, such as in planetary atmospheres and in plasma physics.

Even though the cross sections for singly and multiply charged ions decline rapidly with increasing stage of ionization, multiple ionization processes are important in fusion plasmas and in other environments with an abundance of energetic electrons.

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Electron impact ionization of a positive ion may occur directly, when one or more electrons are ejected from an outer or from an inner shell or indirectly, via formation of an intermediate auto ionizing state which cans be formed in two ways. Firstly, the incident electron may excite the target ion from an inner shell into short-lived auto ionizing states, which subsequently decay via Auger transitions. Secondly, direct inner shell ionization may be followed by single or multiple auto ionization, either by cascading transitions or by simultaneous ejection of two or more electrons [6-16].

III. FORMULATION

The present calculations are carried out using the modified semi empirical formalism developed by Jain-Khare. In brief, the single differential cross sections in the complete solid angle ($\Omega = 4\pi = \int 2\pi$) is known as a function of secondary electron energy ε corresponding to the production of ith type of ion in the ionization of a molecule by incident electron of energy E is given by

$$Q_i(E,W,^{-}) = \frac{a_0^2 R^2}{E}\left[\int_{k\to 0}^{E-I_i}\left\{\begin{array}{l}\frac{E-W}{E-I_i}\frac{1}{W}df_i(W,K,^{-})\times\ln[1+C_i(E-I_i)]+\\ \frac{E-I_i}{E(\text{£}_0^3+\text{£}^3)}\times S_i\left(\text{£}-\frac{\text{£}^2}{E-\text{£}}+\frac{\text{£}^2}{(E-\text{£})^2}\right)\end{array}\right\}\right]2\text{®}\sin{}^{-}d^{-}\quad ......(I)$$

Where

W (=ε + I_i) is defined as energy loss suffered by the incident electron.

I_i = the ionization threshold for the production of ith type of ion,

a_0= the Bohr radius,

ε_0= energy parameter,

C_i= collision parameter,

S_i= number of ionizable electrons,

R= Rydberg constant and

θ = the scattering angle respectively.

In the present formulation, the dipole oscillator strengths df_i / dw are the key parameters.

The oscillator strength or appearance potential is in direct ratio or directly proportional to the photo ionization cross section. We have used partial photo ionization cross section data set in the energy range provided by Brion using (e, 2e) spectroscopy. The accuracy of the determined oscillator strength scales was estimated to be better.

In the photon energy range, we have used their measured total valence photo absorption oscillator strength data and for higher photon energy range the same were extrapolated by Thomas-Reiche-Kuhn (TRK) sum rule. The total photo absorption cross sections have been distributed into ionic fragments considering the constant ionization efficiency to be above the dipole breakdown limit of 25eV. However, its evaluation is possible quantum mechanically using the suitable wave functions and transition probabilities corresponding to the production of cations.

In case of dissociative ionization of polyatomic molecule, we have no reliable probabilities corresponding to different dissociative ionization processes. The collision parameter and energy parameter ε_0 are evaluated as for other polyatomic molecules. The vertical onsets or the ionization potentials corresponding to the various cations are also given along with the photo ionization measurements. In the present evaluations of cross sections, the estimated uncertainty is more or less the same as for the measurement of photo-ionization cross sections. The double differential cross sections as a function of energy and angle were evaluated by the differentiation of equation of semi empirical formula with respect to the solid angle Ω as follows:

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$$Q_i^t(E,W,^{-}) = \sum_i Q_i(E,W,^{-}).$$

The double differential cross sections are angular dependant in all the scattering geometries and hence the oscillator strength must be angle dependent. In this context, we have used the angular oscillator strengths that were derived in the optical limit (Bethe regime) where angular-momentum-transfer $k \rightarrow 0$,

$$df_i(W,K,^{-}) \rightarrow (1/4®)[1+ \quad P_2(\cos^{-})] \times df_i(W,0)/dW,$$

Where β is an energy dependent asymmetric parameter. Its evaluation is difficult due to the lack of wave functions of molecular ions in ground and excited states. In valence shell ionization of atomic molecules, we have computed β as the ratio of the Bethe spectral transitions $S_i(W)$ to the dipole matrix squared M_i^2 (W). The oscillator strength appeared in equation is simply a derived form in the forward scattering corresponding to $k \rightarrow 0$ and $\theta \rightarrow 0$.

The partial ionization cross section is obtained by the integration of the energy dependent single differential cross sections over the entire energy loss as follows:

$$Q_i(E) = \int Q_i\,(E,W)d$$

and the counting or total electron impact ionization cross section is obtained by

$$Q_i^T(E,W) = \sum_i Q_i\,(E,W)$$

IV. RESULTS & DISCUSSION

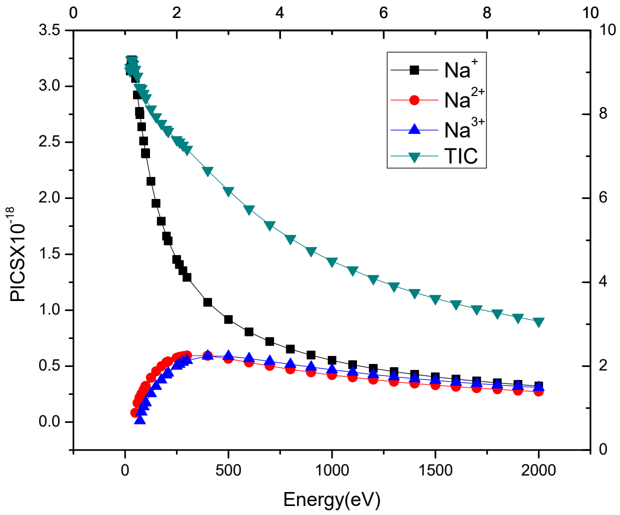
Now we calculate the partial ionization cross section measurements for the Sodium atom from threshold to 2000 eV modified Jain-Khare Semi-empirical model. Table 1 shows the measured partial cross sections for the formation of Na^+, Na^{2+}, $Na^{3+}$and Na (Total).

In figure 1represents the production of Na^+, Na^{2+}, $Na^{3+}$and Na (Total). ionization cross section of Sodium Atom. The present results for partial and total ionization cross sections satisfy the necessary consistency checks to access their consistency and reliability.

24	3.137435			3.137435
25	3.165152			3.165152
30	3.236645			3.236645
35	3.236139			
40	3.197832			3.197832
45	3.138957			3.138957
50	3.070177	0.082254		3.152431
60	2.921714	0.169622		3.091336
70	2.774934	0.214456		2.98939
72	2.746562	0.222424	0.01177	2.980756
80	2.637313	0.252885	0.089733	2.979931
90	2.510877	0.288734	0.138009	2.93762
99	2.406368	0.318787	0.17178	2.896935
100	2.395585	0.322307	0.175324	2.893216
125	2.150106	0.394889	0.253178	2.798173
150	1.954151	0.453127	0.320016	2.727294
175	1.793834	0.497141	0.376823	2.667798

200	1.660841	0.531858	0.422735	2.615434
209	1.617988	0.541135	0.437965	2.597088
250	1.451263	0.573759	0.499045	2.524067
263	1.405958	0.581173	0.515743	2.502874
280	1.351534	0.588591	0.533421	2.473546
300	1.293124	0.593852	0.549914	2.43689
400	1.068715	0.590927	0.58936	2.249002
500	0.915955	0.56493	0.587079	2.067964
600	0.804572	0.532927	0.567829	1.905328
700	0.719393	0.501055	0.542668	1.763116
800	0.651924	0.471336	0.51632	1.63958
900	0.597037	0.44429	0.490709	1.532036
1000	0.551411	0.419879	0.466622	1.437912
1100	0.512832	0.400016	0.446459	1.359307
1200	0.47973	0.3781	0.423755	1.281585
1300	0.450996	0.360192	0.404879	1.216067
1400	0.425793	0.343954	0.387533	1.15728
1500	0.403485	0.329165	0.371598	1.104248
1600	0.383592	0.315663	0.35689	1.056145
1700	0.365725	0.303271	0.343354	1.01235
1800	0.349584	0.291881	0.332253	0.973718
1900	0.334928	0.281349	0.319131	0.935408
2000	0.321548	0.271612	0.308352	0.901512

V. CONCLUSION



The oscillator strengths obtained for the ionic target are observed to be under estimated by the empirical law whereas the latter overestimates the data corresponding to neutral argon. The generalized oscillator strength is deduced from high-energy ionization cross sections.[17-31].

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