ELECTRON-IMPACT IONIZATION CROSS SECTION OF GALLIUM ATOM

[1]Ravinder Sharma, [2]Naveen Kumari
[1&2]Research Schoolar
[1&2]Dept. of Chemistry, Baba Mast Nath University, Rohtak and Deptt. of Biomedical Engineering, DCRUST, Murthal, Sonepat (HR)

Abstract: Total ionization cross section of Gallium atom is determined from threshold to high energy by using modified Jain-Khare semi-empirical approach. In this literature, the total ionization cross section is compared with available experimental and theoretical data. It is found that the present result gives a better account for ionization cross sections up to high energy.

Keywords- Ionization Cross Section, Total Ionization Cross Section, and Electron impact ionization.

I. INTRODUCTION

Gallium has abundant applications in various fields of applied science. It forms the various important semiconductor compounds like gallium nitride, gallium arsenide and indium gallium arsenide phosphide which have optoelectronic properties [5]. Some of these semiconductors are used in lasers, light-emitting diodes, rectifiers, transistors and other solid state devices. All of these interest, the partial and total ionization cross section is calculated.

II. THEORETICAL METHODOLOGY

There are many theoretical methods to determine the ionization cross section [11]. We use a modified Jain-Khare semi-empirical approach for calculating the ionization cross section. This gives ionization cross section for the production of an ith type of ion in the ionization of an atom/molecule by an incident electron of energy E is given by [7, 10].

$$Q_{iE=}\frac{4\pi a_{0^{2}R}}{E}\left[\frac{E}{E-Ii}\left(Mi^{2}-\frac{R}{E}\,Si\right)ln[1+Ci(E-Ii)]\right.$$
$$\left.+\frac{R(E-Ii)}{E}\,Si\,X\int_{0}^{(E-Ii)/2}\frac{1}{\varepsilon^{3}+\varepsilon_{0}^{3}}\left(\varepsilon-\frac{\varepsilon^{2}}{(E-\varepsilon)}+\frac{\varepsilon^{3}}{(E-\varepsilon)^{2}}\right)d\varepsilon\right]$$

----------- Eq. (1)

Where

$$Mi^{2}=\int_{Ii}^{(E+Ii)}\frac{R}{w}\frac{dfi(w,0)}{dw}dw$$

----------- Eq. (2)

$$Si=\int_{Ii}^{(E+Ii)}\frac{dfi(w,0)}{dw}dw$$

----------- Eq. (3)

Where

W= energy loss suffered by the incident electron,

I_i = Ionization Potential,

a_0= Bohr radius,

ε_0= Mixing parameter,

C_i= collision parameter,

S_i= number of ionizable electrons and

R= Rydberg energy respectively.

And df_i/dw is oscillator strength that is the key parameter in this equation. We have not found the experimental values of oscillator strength. The oscillator strength is directly proportional to the photoionization cross section [9].So, we use this relationship to determine the oscillator strength (df_i/dw) at given photon energy[1, 6]by solving the equation (4).

$$df_i/dw = 9.112*10^{16}\, Qp_i\ eV^{-1} \qquad \text{----------- Eq. (4)}$$

Where,

Qp_i is the photoionization cross section (in cm^2)

For calculating the electron impact ionization cross section of Gallium atom, we have used the photoionization data [13] which gives oscillator strengths for this atom. The ionization potential for Gallium atom is 5.99 eV [5].The value of the collision parameter and mixing parameter are (C_i= 0.29887) and (ε_0=45) respectively.

III. RESULTS AND DISCUSSION

In this literature, we have calculated the total ionization cross section of Gallium atom using the modified Jain-Khare semi-empirical approach of Equations (1) with the help of MATLAB programming codes. We calculated the ionization cross sections from 10eV to 3000eV of incident energy which is tabulated in Table 1and presented in graphical form in Fig.1.We have compared the present results with theoretical/ experimental works including Bartlett and Stelboves [2-3], Jha [4]. Jaspreet Kaur [5], and NIST data[12]. Which is shown in Fig.2and data is given in Table 2.This gives abest agreement from 200eV to high energy. But at low incident energy, the present result graph as a slight low Peak while other data have more.

Table 1

Ionization cross-section values for Gallium atom (10^{-16} cm^2)

E (eV)	Present	E (eV)	Present
10	0.70	400	2.62
20	0.83	500	2.35
30	0.94	600	2.10
40	1.05	700	1.97
50	1.20	800	1.73
60	1.40	900	1.59
70	1.61	1000	1.47
80	1.82	1200	1.31
90	2.02	1500	1.15
100	2.19	1800	1.01
150	2.77	2000	0.89

200	2.96	2500	0.74
300	2.88	3000	0.63

Table 2

Ionization cross-section values for Gallium atom ($10^{-16}cm^2$)

E (eV)	Present	NIST(BEB) [12]	Bartlett [2-3]	Kaur et al [5]	Jha [4]
10	0.70	2.39	2.63	1.34	-
20	0.83	5.19	7.00	5.72	5.81
30	0.94	5.71	7.70	6.42	5.61
40	1.05	5.75	7.30	6.17	5.93
50	1.20	5.65	6.72	5.81	6.10
60	1.40	5.48	6.16	5.48	5.83
70	1.61	5.28	5.66	5.20	5.61
80	1.82	5.09	5.24	4.97	5.29
90	2.02	4.89	4.87	4.76	5.16
100	2.19	4.72	4.55	4.58	4.94
150	2.77	3.99	3.46	3.94	4.27
200	2.96	3.47	2.83	3.51	3.53
300	2.88	2.80	2.12	2.95	3.04
400	2.62	2.34	1.72	2.59	2.46
500	2.35	2.03	1.46	2.32	2.09
600	2.10	1.79	1.27	2.11	1.79
700	1.97	1.62	1.15	1.94	1.57
800	1.73	1.47	1.03	1.80	1.44
900	1.59	1.35	0.95	1.70	1.33
1000	1.47	1.25	0.87	1.60	1.23
1500	1.15	0.92	0.64	1.29	0.90
1800	1.01	0.79	0.57	1.16	0.77
2000	0.89	0.73	0.51	1.09	0.71
2500	0.74	0.61	0.42	-	-
3000	0.63	0.53	0.36	-	-

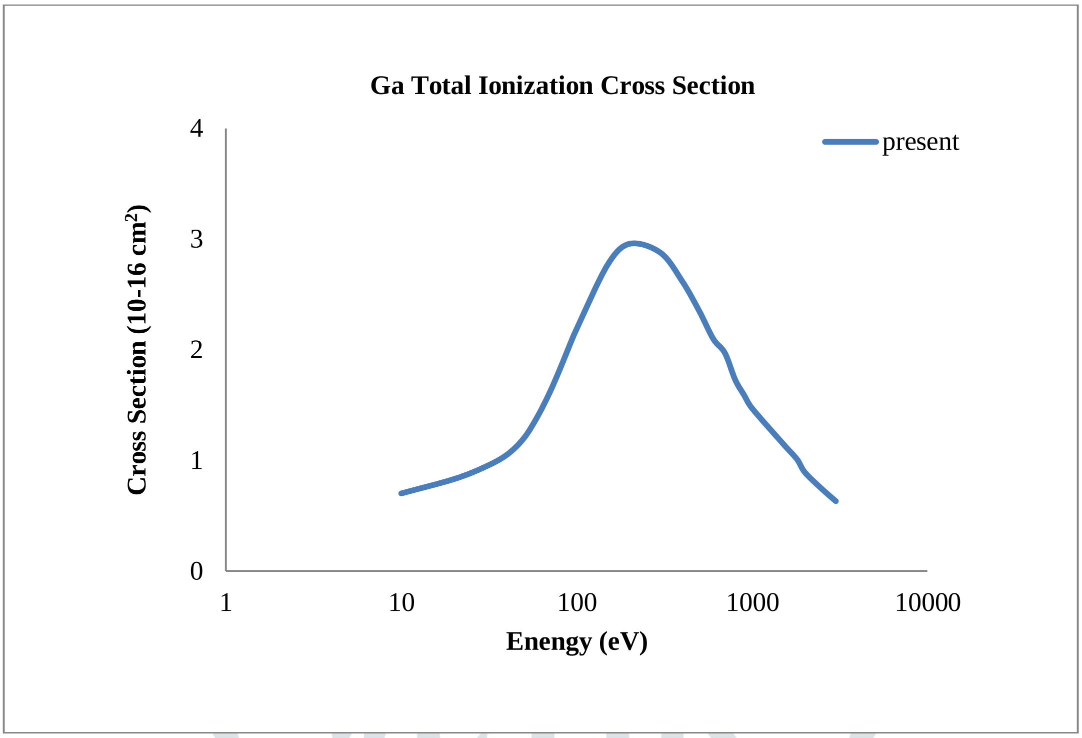

Fig.1: Total Ionization Cross Section at 10 -3000eV energy

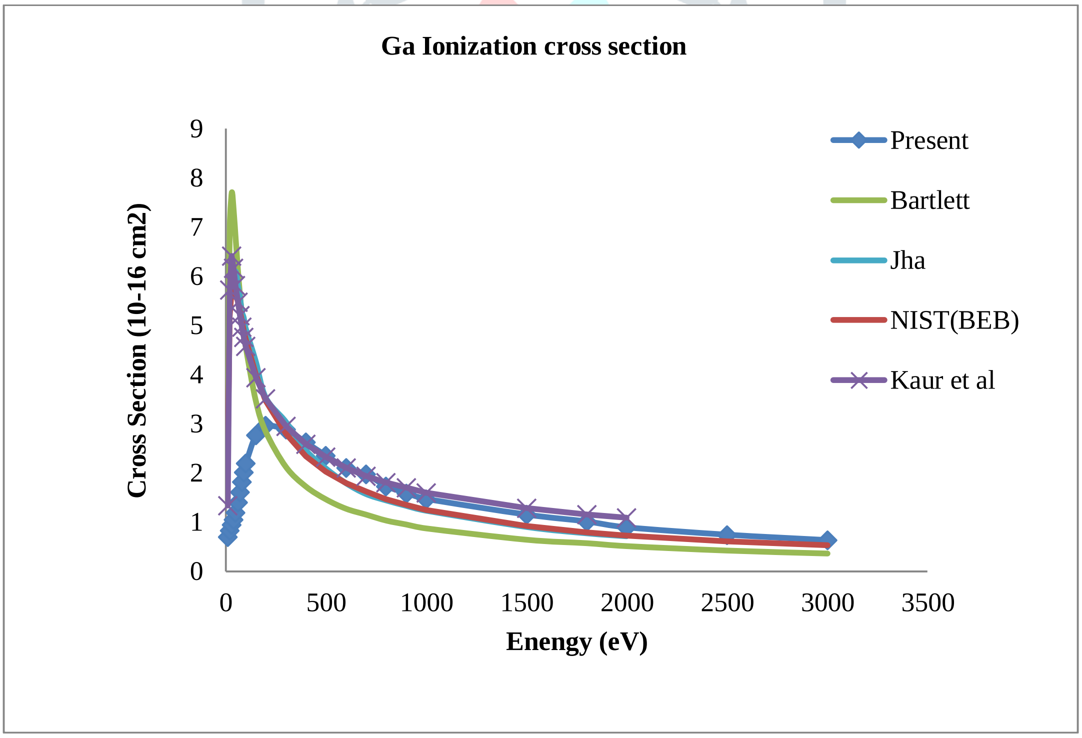

Fig.2.1: Total Ionization Cross Section compared with others [2-5, 12]

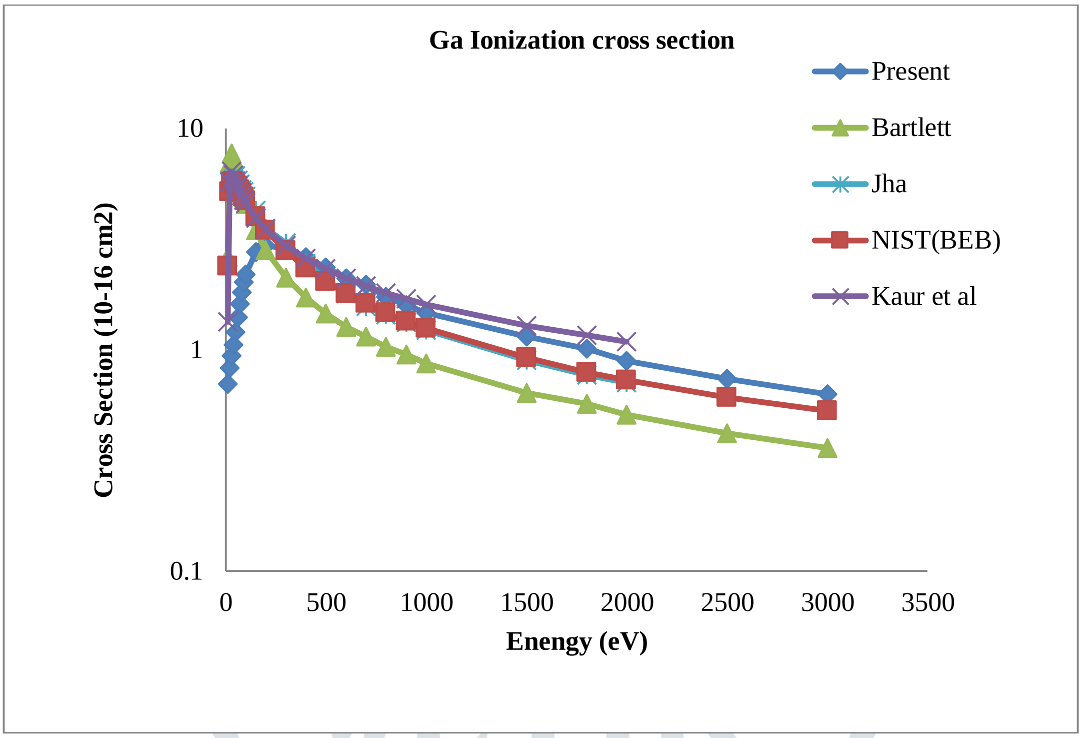

Fig.2.2: As Fig.2.1 but Cross Section in log scale [2-5, 12]

IV. CONCLUSION

Figure 1 and Table 1 shows the calculated present results for Total Ionization Cross Section of Gallium atom by the modified Jain-Khare formalism. Figure 2 and Table 2 shows the compared graph and data which agree with other available data within some experimental error from threshold to 200eV as the photo ionization values are also low at these energies[2-5, 12].The results good agreed from 200eV to high energy. Thus, this semi-empirical method could be applied to determine the cross sections for other atoms also.

V. REFERENCES

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