International Journal of Advance Research in Science and Engineering
Volume No.06, Issue No. 11, November 2017
www.ijarse.com
IJARSE
ISSN: 2319-8354

An analytic review of the different methods for evaluating the Z-effective of the series of glass [$Li_2O – B_2O_3 – SiO_2 – MnO$]

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ABSTRACT

In present paper a comparison has been set up between the calculations made through manual calculations, square root method and direct from the Auto Z-effective over the series of glass [$Li_2O – B_2O_3 – SiO_2 – MnO$] at the given energy levels. In first method Z-effective calculated through manually calculations of Glass mass Attenuation Coefficient, Total cross section and cross section per atom. In Second method Z-effective calculated using square root formula. At last Auto Z-effective software developed by RIMIT used. The results shows good comparison between results except lower(0.01 MeV) and Higher(100 MeV) from the given energy level 0.01, 0.1, 1, 10 & 100 MeV from manual calculation and Auto Z-effective, however the result from the square root method having constant due to non dependence of energy variation only significance at low energy(0.1 MeV) values .

Keywords: Z-Effective, Auto Z-Effective Software, Square Root Formula of Z-Effective, Glass.

I INTRODUCTION

Z – Effective is an important phenomenon for studding the glass structure. It used widely in measurement of the interaction of radiation with matter (Glasses). Z effective calculates the interaction of the radiation with matter, it describe the range of the frequencies of the radiation absorbed by the glasses. Basically it is the screening off the core nucleus by the cluster of the electron cloud around it in given compound of the series of glass. In analysis of the Glasses structure we analyse the interaction of the X-rays and γ- rays with given series[1][2]. The amount of radiation absorbed by the given glass is the measurement corresponds to the Z-effective of the glass[3][4]. Z-Effective is the electron cloud interaction with radiation. It is the effective atomic number per unit mass and provide the packing of the atoms in compound [5][6]. To calculate Z-effective various methods various methods used widely. These methods basically characterised into three main categories.

II Z-EFFECTIVE THROUGH MANUALLY CALCULATION

Compound has been used for evaluation of Z-effective

Compound	$Li_2O – B_2O_3 – SiO_2 – MnO$			
Mole fraction	*(0.1)*	*(0.5)*	*(0.3)*	*(0.1)*

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Initially we have to find out the following basic parameters **A, Z, W, n_i, f_i** & **M** are *Atomic Weight, Atomic Number, Weight Percentage, Formula Units, Fraction, Molecular Weight* of individual atoms respectively. *Fraction* calculated by dividing formula unit of the individual atom by sum of formula units of all atoms[7]

At last *Molecular Weight* evaluated by multiple formula unit of with respective atomic weight e.g Mn(Z = 25) = n× A [8] . Similarly for other atoms the above parameters calculated and drawn the table1

Table no.1: Calculation of formula units and fraction

Elements	A	W	Z	$\sum n_i$	f_i	M
B	10.81	0.16	5	1	0.256	10.8
O	15.99	0.58	8	2.3	0.6	36.8
Li	6.941	0.04	3	0.2	0.05 1	1.4
Si	28.1	0.14	14	0.3	0.07 7	8.43
Mn	54.94	0.07	25	0.1	0.02 6	5.5
Total		1		3.9		62.92

Next step is to evaluate the given values for individual atoms for different energy levels. **μm** Total attenuation with coherent scattering, to evaluate **μm** NIST XCOM database had been used on given **NIST**[9][10]. Then **f(A)m** & **∑f(A/Z)m** is the total weighing factor & weighing factor per atoms in compound respectively calculated using following formulae[2][7][8]

$$\mathbf{f(A)m} = \mathbf{W \times f_i \times \mu m} \quad (1)$$

$$\mathbf{f(A/Z)m} = \frac{\mathbf{f(A)m}}{\textit{Atomic No.}(Z)} \quad (2)$$

Table no. 2: Calculations of f(A)m & ∑f(A/Z)m for Boron(Z=5)

B			
Energy	**μm**	**fAm**	**f(A/Z)m**
1.17	1.26	3.48	0.70

Similarly above these values calculated for rest of atoms

Last step we have to calculate values of **μg, σt , σa, Zeff**. Where **μg** is Glass mass Attenuation Coefficient, **σt** is Total cross section and **σa** is cross section per atom

$$\mathbf{\mu g} = \sum_{all\ atoms}[W \times \mu m] \quad (3)$$

$$\mathbf{\sigma t} = \sum_{all\ atoms}[M \times \mu g] \quad (4)$$

$$\mathbf{\sigma a} = \frac{\mathbf{\sigma t}}{\mathbf{\sum ni}} \quad (5)$$

$$\text{Z-effective} = \frac{\mathbf{\sigma a}}{\mathbf{\sum f(A/Z)m}} \quad (6)$$

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Table no. 3: Table of calculation of Z-effective

Energy (MeV)	∑f(A/Z)m	μg	σt	σa	Z-Eff
0.01	21.5	20.1	1267.4	325	15.1
0.1	0.323	0.17	10.66	2.73	8.47
1	0.127	0.0619	3.89	0.999	7.85
10	0.0412	0.0207	1.31	0.34	8.13
100	0.0353	0.0197	1.24	0.327	8.99

III SQUARE ROOT METHOD

It is widely used for low energy interaction with compounds. In this formula direct atomic numbers of the constituent atoms of the compound and their relative fractions used in compound. This method involves the fractional roots and squares upon the radiation interaction cross sections of compound [11][12][13].

Z-effective = $\sqrt[2.94]{\sum_{i=1}^{n} f_i \times (Z_i)^{2.94}}$ (7)

Where f_i and Z_i are the fraction of total electron associated with i^{th} atom and atom number of i^{th} atom respectively. Z-effective for the chosen compound in this case calculated using above formula is 9.77. This value is the approximation not for any significant energy interaction.

IV AUTO Z-EFFECTIVE SOFTWARE

Auto Z-effective developed using the visual basic for calculating the effective atomic number of individual atoms as well as the compounds. It works over the wide range of the energies from 10 KeV to 10GeV. It can use up to 100 atomic numbers. The predicted variation is of the orders of 1-2% in results[12][13]. Even some researches show fewer variations from real values. At input it requires only the atomic fractions to the corresponding atoms of the compound. This software available freely to the scientific community for research work under copyright to RIMIT university Melbourne(AUS)[15].

Table no. 4: Calculations of Z-effective from Auto Z-effective (RIMIT) software

Energy(MeV)	Z-Effective
0.01	10.67
0.1	8.51
1	7.66
10	7.99
100	8.35

V DATA COMPARISON

Z-effective for the series of glass [Li_2O – B_2O_3 – SiO_2 – MnO] for given energy levels through all three methods compared in table no.5.

Energy(MeV)	Z-Effective (Manual Calculation)	Z-Effective (Square root formula)	Z-Effective (Auto Z-Eff. Software)
0.01	15.1	9.77	10.67
0.1	8.47	9.77	8.51
1	7.85	9.77	7.66
10	8.13	9.77	7.99
100	8.99	9.77	8.35

Since square root method has no significance in terms of the energy variation hence having constant value. It predicted in different studies as well as observed in this comparison has application only at low energy values. Other two methods show good compromise between the results except at very low and very high energy levels. At lower energy levels the difference became about 40-45%. It represents large deviation. At higher energy level deviation competitive small is about 7-8%. All three methods show nearest comparison with minimum deviation at 0.1 MeV.

VI CONCLUSIONS

All three methods show deviations in results. Square root method is suggested to work with minimum error at lower energy levels. Rest two methods good for calculation on medium range of energies. Auto Z software and manual calculation had maximum variation on lowest energy levels. Experimental data comparisons will be significant to evaluate the best out of Auto Z software and manual calculation methods in glasses study.

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