Assessment of gamma radiation parameters with different weight fractions of [Na_2O_3-B_2O_3-$Bi_2O_3MoO_3$] glasses; to protect from radiation by using XCOM software and PHY-X software.

Mutaz Aladailah*

Department of Radiology, Federal University, Aljubeiha, Amman, Jordan

Abstract

In this work, the shielding properties of nine examined glasses with the Na_2 -2xB $_4$-4xBixMo0. 05xO_7 - chemical compositions (4x, 0 ≤ x ≤ 0.4 mol%) have been assessed. the ass attenuation coefficient values were theoretically calculated by using XCOM the available online of the XCOM software. Based on the calculated mass attenuation coefficients values and density of these glass samples, linear attenuation coefficient, half value layer and mean free path of penetrating photons have been calculated, listed by their tables, it is found that both half value layer and mean free path increase as gamma ray energy increase. Effective atomic number and effective electron density have been calculated by the available online PHY-X software. Glass shielding properties against the fast neutron has been investigated by calculating, the fast neutron removal cross section. The fast neutron removal cross section values decrease as weight fractions of boron oxides decrease. However, glass samples are good shielding glasses against both of gamma and neutron radiation.

Key words : Attenuation coefficient parameters, Gamma radiation, Neutron, XCOM, Boron oxides, The fast neutron removal cross section, HVL, MAC, LAC.

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Introduction

In recent decades, the use of nuclear applications has been greatly increased. In several areas, such as nuclear science, medicine, industry and agriculture, radioactive isotopes are used. The use of these radioactive isotopes can cause harmful harm to staff and damage to tissues [1]. The mass attenuation coefficient is the most important quantity characterizing the penetration and diffusion of gamma rays in extended media. For technological, biological, agricultural, and medical research, the exact values of gamma rays in many materials are of interest. They are also necessary in solving various radiation physics and radiation dosimetry problems. A large number of measurements, estimates, and compilations of the photon attenuation coefficient have recently been released. Many studies have been studied the measurements of linear and mass attenuation coefficients for differents of pure elements and mixtures of elements, different alloys(monelmetal, bronze aluminium,bronze ordinary),chemical compositions of fatty acids,materials containing hydrogen, carbon,and oxygen,different compounds of ($NaNO_3$,KNO_3,$Sr(NO_3)$, NaCl, $SrCl_2$. $6H_2O$, $BaCl_2$. $2H_2O$, $NaClO_3$, $(NH_4)SO_4$, $MgSO_47H_2O$, and K_2SO_4), In some different of bromides. A range of materials can be used to protect against radiation from gamma rays. The energy of radiation must be taken into account in order to select a suitable type of shielding material. Indeed, interactions between the incident radiation and the atoms of the absorbing medium assess the efficiency of the shielding material. Among the most effective gamma-ray shielding are heavy elements such as lead, tungsten and bismuth. Among the excellent shielding material are steel alloys most often used in the walls of radiology and oncology departments of hospitals and in nuclear power plants. A calculation of the average number of interactions between incident photons and matter occurring in a given mass per unit area thickness of the material under examination is the Mass attenuation coefficient. Mass attenuation coefficient directly proportional to the effective atomic number at the same photon energy, so materials with high atomic numbers such as heavy metals which possess high mass attenuation coefficients are chosen against gamma radiation. Oto et al. measured neutron and gamma radiation shielding properties of ceramics and molybdenum doped ceramics, by using 3_{Ci}^{133Ba} radioactive source emitted photons with 81, 276, 302, 356, 383 KeV and radiation were detected by using Ultra germanium detector. He mentioned that molybdenum increases of gamma radiation shielding properties of the ceramics. The purpose of the present work to determine the interaction of Na_2O-B_2O_3-Bi_2O-MoO glasses against gamma radiation by measuring attenuation parameters for different gamma energies ranged from 0.015 MeV-8 MeV. Glass system has been prepared by the investigation of radiation shielding parameters of the glasses systems have been determined by using the NIST XCOM databases and the available software PHY-X/PSD [2].

Theoritical Background

The gamma radiation mass attenuation coefficient cm ^{2} g^{-1} was calculated theoretically for mentioned mixtures by using NIST XCOM software according to the mixture rule (multi-elements) as seen in relation relation represent the interaction of gamma radiation photons against shielding glasses [3].

Where is the mass shielding coefficient of the element and is the weight fraction of constituent elements of the Na_2O_3-B_2O_3-Bi_2O_3-MoO_3 glasses, and is the density of shielding material. mass attenuation coeficients of the studied glasses were calculated by databases as seen in the linear attenuation coefficients of labeled glasses were calculated based onvalues of those glasses as we seen in, and according to the Lambert-Beer law as follows [4].

Respectively,, referred to intensity of gamma radiation with shielding glasses and without shielding glassesreferred to the thickness of the shielding sample, represents the linear attenuation coefficient. Based on the values of mass attenuation coefficients, the values of both the effective atomic numberand the electron density were calculated. The present study's effective atomic number represents the total atomic cross section devide on the electronic cross-section , and we can evaluate the effective atomic numbers for all shielding glasses based on of the constituent elements of shielding glasses [5]. by using relation relations as follows:

Where, NA represents Avogadro's number. respectively, represent atomic mass, weight fraction,atomic number,and the mass attenuation coefficient of the constituent elements of shielding glasses. The effective electron density (Ne) represents the number of electrons per unit mass of shielding glasses, and it can be evaluated by using relation as follows

The half value layer is an shielding parameter which determined the thickness of glass sample required to reduce the intensity of gamma radiation to half of its initial value, HVL for the glasses samples were calculated by using this relation,as follows:

The Mean Free Path (MFP) is a parameter that defines the distance between two different collisions that photons penetrate inside the shielding material, (MFP)measured by cm, and were calculated by following relation

Additionally, in this work the shielding properties of glass samples aginst the fast neutron have been assessed,by using relation (9) and (10) to calculate the effective removal cross sections values of the fast as follows:

Materials and Methods

The elastic and synthesis properties of were studied by Saddeek. The melt quenching technique was used to prepare the glass samples with the general chemical formula Required quantities of Analar grade Na_2CO_3, H_3BO_3, MoO_3 and Bi_2O_3 were mixed together by repeated grinding of the mixture to obtain a fine powder. In an electrically heated furnace, the mixture was melted in a porcelain crucible under ordinary atmospheric conditions at a temperature of about 1373 K for 2 hours to homogenize the melt [6]. The glass samples presented from the melt quenching into preheated stainless-steel molds were heat treated for 2 hours to eliminate any internal stresses at a temperature of about 20 K below their calorimetric glass transition temperature. The glasses obtained were lapped, and polished on two opposite sides [7]. The two opposite side faces had a non-parallelism of less than 0.01mm. For convenience, the9 glasses selected were labeled 'G0,'G1','G2,' 'G3','G4','G5', 'G6','G7'and 'G8' (Table 1).

Table 1. *Chemical composition (weight fraction%) and elements (weight fraction%) present in the studied glasses, including their density.*

Sample	Chemical composition (wt%)				Chemical composition of elements (wt %)					Density(g cm3)
Образец.										
	Na_2O	B_2O_3	Bi_2O_3	MoO_3	Na	B	Bi	Mo	O	
G0	0.3076971	0.6923029	0	0	0.22826740317 02	0.215009049626 8	0	0	0.556723547202 9	2. 377
G1	0.2536693	0.5531259	0.1476077	0.0455971	0.188186457189 73	0.171784757323 5	0.132402669292 6	0.030392116455 95	0.477233999738	2. 7
G2	0.2088377	0.4553706	0.2565435	0.0792482	0.154927801555 4	0.141424814464 9	0.230117063929 4	0.052821779521 58	0.420708540528 4	3
G3	0.1743912	0.38026	0.3402447	0.1051041	0.129373386214 2	0.118097636178 67	0.305196293012 6	0.070055696978 90	0.377276987615 53	3. 2
G4	0.1470958	0.3207424	0.4065695	0.1255924	0.109124097273 5	0.099613207285 1	0.364688986656 8	0.083711833091 34	0.342861875693 1	3. 52
G5	0.1249341	0.2724187	0.46042	0.1422272	0.092683264357 03	0.084605302173 68	0.412992383325 2	0.094799543517 491	0.314919506626 5	3. 7
G6	0.1071211	0.2285217	0.5075662	0.156791	0.079468563680 56	0.070972169700 79	0.455282076888 3	0.104506850013 0	0.289770339717	3. 93
G7	0.0911355	0.1987211	0.5425467	0.1675967	0.067609585838 09	0.061716961302 036	0.486659200912 1	0.111709251690	0.272305000257 3	4. 12
G8	0.0779548	0.1699805	0.5745744	0.1774903	0.05783135	0.05279097	0.51538777	0.11830369	0.25568620	4. 38

					82437	119924	01156	59376	45037	

Results and Discussion

The effectiveness of usingG0, G1, G2, G3, G4, G5, G6, G7, G8 glasses with a chemical composition of with as a shielding material against gamma and neutron ionizing radiations has been estimated in this work. Table 1 presents the chemical composition, wt percent gram of each element were theoretically evaluated by PHY-X online software, and densities of the glasses samples were represented as we seen in Figure 1. PHY-X is an available online software has been developed to calculate shielding parameters such as, mass attenuation coefficient, linear attenuation coefficient, effective atomic number and the others shielding parameters related to shield the fast neutron such as mass removal cross sections. In the selected energy ranging (0.015 Mev-15 Mev), the software can calculate data on shielding parameters. In order to attain the main purpose,The mass attenuation coefficients (μ/ρ) were calculated for the 9 invistigated glass samples by applying version XCOM software,and plotted against a wide energy range of 0.03 Mev to 6 Mev, As listed in Table 2, the study results were evaluated to be in good agreement Figure. 2 shows the variance of the mass attenuation coefficient values for all glass sample concentrations with respect to photon energy [8]. The XCOM software uses the Hubbell-Seltzer database, which can be used to measure photon cross-sections on the basis of interaction processes (scattering, photoelectric absorption and pair production) and total attenuation coefficients for the element, compound or mixture at high energy levels. It's more clear in Figure 2, that the values of the coefficients of mass attenuation μm started at the maximum values in the low photon energy 0.03 Mev,and these highest values are discussed according to the interact between photon energy and glass sample. However, wide energy 0.03 Mev represents photoelectric cross section σph. σph differed as Z4-5/E3. 5. A sharply decrease in the μm values was observed until 6 Mev; because the energy of the photon interacting with shielding materials increased, followed by an increase in the density and mass of the shielding material,and because both of weight fractions of Bismuth and Molybdenum reached their highest values at photon energy 6 Mev. We were able to determine 5 basic parameters describing the interaction between shielding materials and photon energy from the values of mass attenuation coefficients μm, as linear attenuation coefficients in the function of the variable values of photon energy were theoretically calculated [9]. Figure*ey words: 3 represents that the variation of photon energy with linear attenuation coefficients (μl)displays the same behavior as the μms. μl values started at the maximum values at 0.03 Mev and then began to decrease until the energy of the photon reached 6 Mev; because the energy of the photon interacting with shielding materials increased, followed by an increase in the density and mass of the shielding material [10]. It also shows Figure 3 represents a decrease (linear-inverse) relationship as linear attenuation coefficients gradually begin to decrease as radiation energy increases. The effective atomic number (Zeff) was calculated for the glasses by using the available online PHY-X software. The variety of Zeff for G glasses against gamma photon energy is represented in Figure. 4 [11]. It is noted that Zeff started at the maximum values in the low photon energy 0. 03 Mev due to the cross-section of the photoelectric interaction that happened between photon energy and glass samples σph. σph differed as E-3. 5. In the wide energy ranging between 0. 04 and 1.5 Mev, Zeff decreases sharply as gamma photon energy increases, this decrease due to the Compton scattering cross section σcompton. σcompton varied proportional as E-1 [12]. In the wide photon energy ranging between 1.5to 6.0 Mev, for all glasses increases slowly again with gamma photon energy increases due to pair production cross section σpair. σpair varied as logarithm photon energy log(E),gradual increase in glasses densities, both of weight fractions of Bismuth and Molybdenum reached their highest values at photon energy 6 Mev. as shown in the effective electron density in the function of the variable values of photon energy(Ne) were theoretically calculated for all glass samples [13]. represents that the variation of photon energy with electron density values (Ne)displays the same behavior as the Zeff. Electron Densities were described in we not from [14]. That there is a difference in the number of electrons per gram (Ne) of shielding material with the gradual increase of the energy of photons interacting with the shielding material and this difference between the increase and decrease; so we can describe [15].

As it began to increase and then decreased marginally until it continued between the increase and the decrease. Its known the Half Value Layer (HVL) and Mean Free Path (MFP) values. Half Value Layer (HVL) and Mean Free Path (MFP) parameters are heavily dependent on linear attenuation coefficients and there is a linear inverse relationship between the half value layer and the mean free path and both linear attenuation coefficient and photon energy [16]. We note from that by increasing photon energy the values of both half value layer and mean free path are increasing. show that the values of Half Value Layer(HVL) and Mean Free Path (MFP) started at the minimum values at 0. 03 Mev and then began to increase for all glass samples until the energy of the photon reached 6 Mev; [17] because the energy of the photon interacting with shielding materials increased,followed by an increase in the density and mass of the shielding glass samples;and because both of weight fractions of Bismuth and Molybdenum reached their highest values at photon energy 6 Mev. It also represents the direct proportional relationship between both half value layer and mean free path of interaction photons, the relation gradually begins to increase as radiation energy increases, and as both weight fractions of Bismuth and Molybdenum increase [18]. The fast neutron removal cross section ∑R was calculated as following in relation for all glass samples : this is represented in. It is note that ∑R values for glasses are respectively, 0.101, 0.101, 0.101, 0.098, 0.100, 0.098, 0.097, 0.097 and 0.098 cm-1. Its noted that is no significant decrease in (FNRCS) values in G0, G1, G2 samples respectively; due to these glass samples have the hieghest weight fractions of both boron oxides (B_2O_3) and sodium oxides (Na_2O_3)elements [19]. These have removal cross sections of 0. 101, 0.101, 0.101, 0.100 cm^{-1}. After this,for boron oxides lower than 59.4(% mol), significant decrease was seen for ∑R with boron oxide decrease in G3,G4,G5,G6,G7,G8 [20].

***Table 2**. Mass Attenuation Coefficient µm(cm^2/g) of the studied glasses estimated by XCOM program, with photon energy between 0 03 Mev-6 Mev.*

Mass attenuation coefficient µm (cm^2/g)									
Energy (Mev)	G0	G1	G2	G3	G4	G5	G6	G7	G8
0. 030	0. 4191	5. 378	9. 036	11. 85	14. 07	15. 88	17. 47	18. 64	19. 72
0. 040	0. 2731	2. 602	4. 32	5. 64	6. 686	7. 535	8. 279	8. 83	9. 335
0. 050	0. 2185	1. 506	2. 457	3. 187	3. 765	4. 235	4. 646	4. 951	5. 23
0. 060	0. 192	0. 9836	1. 568	2. 016	2. 372	2. 661	2. 914	3. 101	3. 273
0. 080	0. 1661	0. 5327	0. 8032	1. 011	1. 176	1. 309	1. 427	1. 513	1. 593
0. 200	0. 1207	0. 2453	0. 3373	0. 4079	0. 4639	0. 5094	0. 5492	0. 5787	0. 6058
0. 300	0. 1043	0. 1467	0. 178	0. 2021	0. 2211	0. 2366	0. 2502	0. 2602	0. 2694
0. 400	0. 0932 2	0. 113	0. 1275	0. 1387	0. 1476	0. 1548	0. 1611	0. 1658	0. 1701
0. 500	0. 0850 5	0. 0958 8	0. 1039	0. 11	0. 1149	0. 1188	0. 1223	0. 1249	0. 1272
0. 600	0. 0786 3	0. 0851 8	0. 0900 1	0. 0937 3	0. 0966 8	0. 0990 7	0. 1012	0. 1027	0. 1041
0. 800	0. 0690 3	0. 0718 2	0. 0738 8	0. 0754 7	0. 0767 3	0. 0777 5	0. 0786 4	0. 0793	0. 0799 1
1. 000	0. 0620 6	0. 0633 3	0. 0642 7	0. 0649 9	0. 0655 7	0. 0660 3	0. 0664 4	0. 0667 4	0. 0670 1
1. 500	0. 0505 1	0. 0507 6	0. 0509 4	0. 0510 8	0. 05119	0. 0512 8	0. 0513 6	0. 0514 2	0. 0514 8
2. 000	0. 0434 4	0. 0438 3	0. 0441 3	0. 0443 5	0. 0445 3	0. 0446 8	0. 0448	0. 0449	0. 0449 8
3. 000	0. 0350 5	0. 0361 5	0. 0369 7	0. 0376	0. 0380 9	0. 0385	0. 0388 5	0. 03911	0. 0393 5
4. 000	0. 0302 1	0. 032	0. 0333 1	0. 0343 2	0. 0351 3	0. 0357 8	0. 0363 5	0. 0367 7	0. 0371 6
5. 000	0. 0270 7	0. 0294 5	0. 0312	0. 0325 5	0. 0336 2	0. 0344 8	0. 0352 4	0. 0358	0. 0363 2
6. 000	0. 0248 9	0. 0277 8	0. 0299 1	0. 0315 5	0. 0328 5	0. 0339	0. 0348 2	0. 0355 1	0. 0361 3

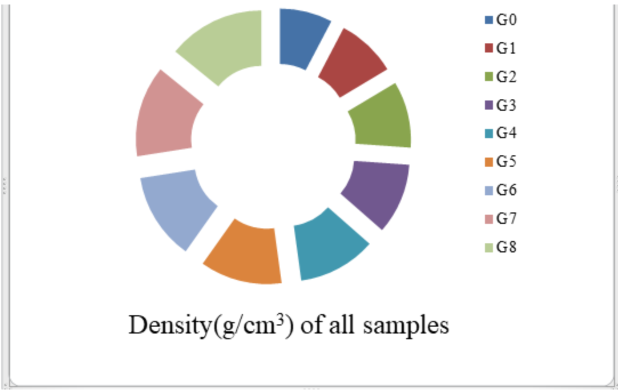

***Figure 1.** Density of the glass samples being examined*

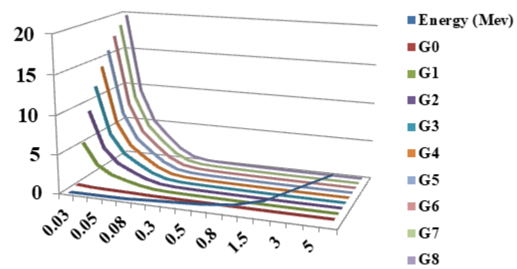

***Figure 2** Mass Attenuation Coefficient of the studied glasses estimated by XCOM program, with photon energy between (0. 03 Mev-6 Mev).*

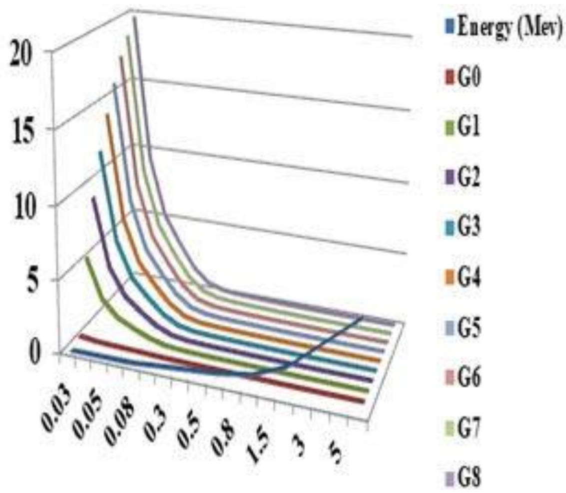

***Figure 3**. Linear attenuation coefficient of the studied glasses,with photon energy between 0.03 Mev-6 Mev.*

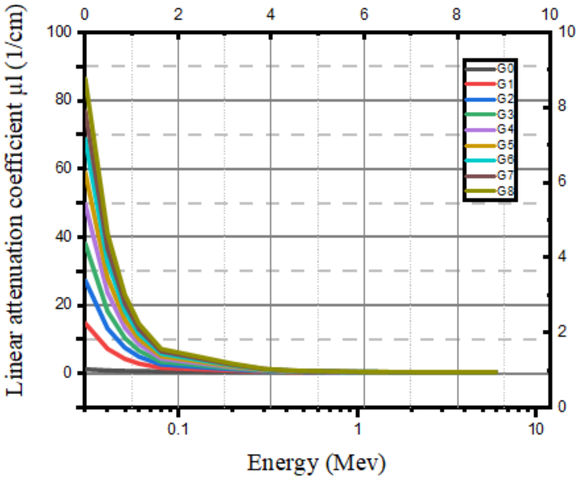

Figure 4. *Effective atomic number (Zeff) values of all samples in range energy between (0. 03-6) Mev.*

Conclusion

In this study,the shielding parameters was estimated for nine glass samples with a Na_2 -2xB_4-4xBixMo0. 05xO7 glasses(4x, 0 ≤ x ≤ 0. 4 mol%) chemical composition,labled G0,G1,G2,G3,G4,G5,G6,G7,G8 have been calculated. The MAC and LAC of Na_2O_3-B_2O_3-Bi_2O_3-MoO_3 glasses was theoretically coputed using the available online XCOM software at gamma ray energy range between 0.03 - 6.0 Mev. Both MAC and LAC reach minimum values for the sample G0 with content (39. 6 mol%)of boron oxide, at gamma ray energy range 6.0 Mev. Moreover, the Zeff, Ne,HVL, MFP shielding parameters were calculated for the glasses. The fast neutron removal cross section values were also computed for glasses: it is observed differ between 0.098 and 0.10 cm^{-1} for G3 and G4 glass samples, respectively.

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***Correspondence to**

Dr. Mutaz Aladailah

Department of Radiology
Federal University

Aljubeiha, Amman

Jordan

E-mail: aladailehmotaz@gmail.com