CENTRAL ASIAN JOURNAL OF MEDICAL AND NATURAL SCIENCES
https://cajmns.casjournal.org/index.php/CAJMNS
Volume: 07 Issue: 03 | July 2026 ISSN: 2660-4159

Article

Study of Attenuation Properties of Some Materials for X-Ray and Gamma Ray Using x Com Program

Zaid Muzher Nuri[1], Karar Samen Ali[2]

1. Ministry of Education, General Directorate of Salah al Din Education, Amerli Education, Iraq
2. Ministry of Education, General Directorate of Salah al Din Education, Tuz Education, Iraq

* Correspondence: JA230023pep@st.tu.edu.iq, Kl3147460@gmail.com

Abstract: In this research, a number of compounds that can be used as shields against X-rays and gamma rays in various fields, such as hospitals, oncology treatment centres, and research fields such as scientific laboratories and nuclear facilities, were studied. Several attenuation properties (mass and linear attenuation coefficients, half-layer thickness, path rate, molecular, atomic, and electronic cross sections) were studied over the energy range of (0.01-100) MeV using the NIST XCOM database program for each of the compounds (CaWO4_- SnO2_- WO3_- BiOCl-CdWO4_ Ta2O5_ PbO2_ HfO2_ UO2_ and TaC). The results showed that some of these compounds possess good shielding properties, such as (TaC), which has a high attenuation coefficient, especially at low energies where the photoelectric effect dominates. The (SnO2) compound also demonstrated less shielding effectiveness than the other compounds due to its low energy density. Due to its low mass density and relatively medium atomic numbers compared to the rest of the compounds under study, the results also showed that the behaviour of the variables is almost similar, as their values decline quickly - except in cases of the appearance of the Compton edge or the absorption edge - and then a lesser response appears at high energies in which the phenomenon of pair production and triplet production

Keywords: (Atomic, Electronic) cross section, Mass attenuation coefficient, Mean free path. XCOM program

Citation: Nuri, Z. M & Ali, K. S. Study of Attenuation Properties of Some Materials for X-Ray and Gamma Ray Using x Com Program. Central Asian Journal of Medical and Natural Science 2026, 7(3), 204-231

Received: 10th Feb 2026
Revised: 21th Mar 2026
Accepted: 18th Apr 2026
Published: 15th May 2026

Introduction

Calculation of total mass attenuation coefficient and linear attenuation coefficient When a gamma-ray beam traverses an absorber, the intensity of the beam will be attenuated according to the Beer- Lambert's law [1]:

$$I = I_{\circ} e^{-\mu t}$$

Where $I_{\circ}$ and I are the unattenuated and attenuated gamma ray beam intensities, μ (cm^{-1}) is the linear attenuation coefficient.

The mass attenuation coefficient $\mu_t \left(\frac{cm^2}{g}\right)$ offers useful information on materials as radiation attenuators. μ_t does not depend on the particular phase (gas, liquid or solid) of the material. The following equation determines μ_t for compound and mixture as in the table (1) [2]. The linear attenuation coefficient, or narrow - beam attenuation coefficient characterizes how easily a volume of material can be penetrated by a beam of light, sound, particles, or other energy or matter [3]. A coefficient value that is large represents a beam becoming 'attenuated' as it passes through a given medium, while a

small value represents that the medium had little effect on loss [4]. The equation determines μ for compound and mixture as in the table (1).

Half Value Layer (HVL) is the thickness of a shield or an absorber that reduces the radiation level by a factor of 2 that is to half the initial level and is calculated by the following the table (1) [5].

Mean free path (λ) is the average distance between two successive interactions is called the mean free path. It is also called the photon mean free path which is determined by the equation in the table (1) [6]:

The mass attenuation coefficient attenuation coefficients can be used to determine the total molecular cross section σ_m that can be calculated by equation in the table (1) [7].

The total atomic cross section σ_a can be calculated by equation in table (1) [6]. The total electronic cross-section σ_e for the individual element is expressed by the following formula in the table (1) [8][9][10][11][12][13][14][15].

Table 1. The formulas there used in calculated of parameters.

Calculated parameter	Representative equation	Equation identifiers
Mass Attenuation Coefficient μ_t	$\mu_t = \sum_i^n w_i(\mu_t)_i$	**w_i**: weight fraction as $w_i = \frac{n_i A_i}{\sum_i^n n_i A_i}$ **A_i** : atomic weight **n_i** : formula units
Linear Attenuation Coefficient μ	$\mu = \mu_t \times \rho$	ρ: element density
Half Value Layer HVL Effectiveness of gamma – ray shielding as "the thickness of the material that reduces the photon beam intensity to the half of its initial value (I_o)"	$HVL = \frac{\ln 2}{\mu}$	μ: Linear Attenuation Coefficient
Mean Free Path MFP "the average distance between two successive interaction of photons"	$\lambda = \frac{1}{\mu}$	μ: Linear Attenuation Coefficient
Cross Section of Molecular, Atomic and electronic.	$\sigma_m = \frac{M}{N_A}\mu_t$ $\sigma_a = \frac{n_i}{\sum_i n_i}$ $\sigma_e = \frac{1}{N_A}\sum_i \frac{f_i A_i}{Z_i}(\mu_t)_i$	$M = \sum_i^n n_i A_i$ is the molecular weight **N_A**: Avogadro number Effective atomic cross- section **σ_a** Total electronic cross-section **σ_e** **Fractional abundance**: $\sum_i^n f_i = 1$ **Z_i**: atomic number

A number of compounds were used that can be used as shielding materials, as shown in Table 2.

Table 2. The compounds under study with their densities and molar masses.

Chemical formula	Density (g/cm^3)	Molecular weight (g/mol)	Features of use
$CaWO_4$	6.06	287.93	Popular in radiography screens
SnO_2	6.95	150.71	Test
WO_3	7.16	231.84	Used in x-ray tubes
BiOCl	7.72	260.43	Non-toxic alternative to lead in equipment
$CdWO_4$	7.9	360.25	Radiological detector in medical imaging
Ta_2O_5	8.2	441.89	Test
PbO_2	9.38	239.20	It is used in inexpensive body armor
HfO_2	9.68	210.49	Test
UO_2	10.97	270.03	Highly efficient but radioactive (for nuclear applications)
TaC	14.5	192.96	Heat and radiation resistant.

Materials and Methods

The methodology of this study was based on evaluating the attenuation and shielding properties of selected compounds against X-ray and gamma-ray radiation using the XCOM program developed by the National Institute of Standards and Technology (NIST). Ten compounds with different densities and molecular compositions, namely CaWO4, SnO2, WO3, BiOCl, CdWO4, Ta2O5, PbO2, HfO2, UO2, and TaC, were selected because of their potential applications in radiation shielding for medical, industrial, and nuclear purposes. The photon energy range considered in this work extended from 0.01 MeV to 100 MeV in order to investigate the shielding behavior of the compounds under low, intermediate, and high-energy radiation conditions. Theoretical calculations were carried out using Beer–Lambert's law to determine the attenuation characteristics of each material. The mass attenuation coefficient and linear attenuation coefficient were obtained from the XCOM database, while other shielding parameters such as half value layer (HVL), mean free path (MFP), molecular cross section, atomic cross section, and electronic cross section were calculated using standard radiation interaction equations. The densities and molecular weights of the compounds were incorporated into the calculations to ensure accurate comparison among the selected materials. The obtained data were analyzed by plotting the attenuation parameters as a function of photon energy to evaluate the variation in shielding effectiveness. Comparative analysis was then performed to identify the most efficient shielding compound by examining the relationship between attenuation behavior, density, and atomic composition over the investigated energy range.

Results and Discussion

The table (3) shows the highest and lowest values for mass attenuation coefficient $\mu_t \left(\frac{\mathrm{cm}^2}{\mathrm{g}}\right)$ was the highest value for the compound (TaC) and was equal to $\left(236.2 \frac{\mathrm{cm}^2}{\mathrm{g}}\right)$ at energy $(0.01168\ \mathrm{MeV})$ due to its high density compared to the rest of the compounds under study , while the lowest value was for the compound (SnO_2) at energy (6 MeV) and was equal to $\left(0.034 \frac{\mathrm{cm}^2}{\mathrm{g}}\right)$. We also note the rapid decrease of (μ_t) with the rapid increase in the energy of the incident photons, as the photoelectric phenomenon dominates at significantly lower energies as shown in the figure (1).

As the table (4) shows the maximum and minimum values of the linear attenuation coefficient μ (cm^{-1}), we note that the highest value was for the compound (TaC) and equaled ($3424.9\ cm^{-1}$) at energy (0.01168 MeV), while the lowest value was for the compound ($CaWO_4$) at energy (6 MeV) which equaled ($0.223\ cm^{-1}$), and (μ) decreases rapidly with increasing energy of the incident photons, which means a decrease in the number of photons penetrating the shielding material as shown in the figure (2).

As the table (5) shows the maximum and minimum values of the half-thickness layer HVL (cm), we notice that the lowest value was for the compound (TaC) and equals (0.0002 cm) at energy (0.01168 MeV) due to the inverse proportion between (HVL (cm)) and μ (cm^{-1}), and this result gives a good impression for using this material as a shielding material. The highest value was for the compound ($CaWO_4$) at energy (6 MeV) which equals (3.11 cm) due to the low density of this compound compared to the rest of the compounds under study, and HVL (cm) behaves in the same way as the previous two variables because it depends on them directly as shown in the Figure 3.

As the table (6) shows the maximum and minimum values of the mean free path λ (cm), we note that the lowest value was for the compound (TaC) and equals (0.0003 cm) at energy (0.01168 MeV) due to the inverse proportionality between (HVL (cm)) and λ (cm) and this represents the average distance between each two successive interactions of the photon with the target material, while the highest value was for the compound ($CaWO_4$) at energy (6 MeV) which equals (4.49 cm) and (HVL (cm)) decreases quickly with increasing energy as in Figure (4).

As the table (7) shows the highest and lowest values of the total molecular cross section $\sigma_m\left(\frac{\text{barn}}{\text{molecule}}\right)$, which represents the potential area that a photon sees when it falls on the molecule, we note that the highest value was for the compound (Ta_2O_5) and equals $\left(151723.15\frac{\text{barn}}{\text{molecule}}\right)$ at energy (0.01168 MeV) due to its large molecular weight, while the lowest value was for the compound (SnO_2) at energy (6 MeV) and equals $\left(8.42\frac{\text{barn}}{\text{molecule}}\right)$, and σ_m decreases rapidly with increasing energy, as in Figure (5).

As the table (8) shows the highest and lowest values of the total atomic cross section $\sigma_a\left(\frac{\text{barn}}{\text{atom}}\right)$ which represents the probabilistic area that a photon sees when it falls on an atom, we notice that the highest value was for the compound (TaC) and equals $\left(37835.9\frac{\text{barn}}{\text{atom}}\right)$ at energy (0.01168 MeV) due to the small number of atoms in this molecule, while the lowest value was for the compound (SnO_2) at energy (6 MeV) which equals $\left(2.806\frac{\text{barn}}{\text{atom}}\right)$ and σ_a which depends on the number of atoms decreases quickly with increasing energy as in the figure (6).

As the table (9) shows the highest and lowest values of the total electron cross section $\sigma_e\left(\frac{\text{barn}}{\text{electron}}\right)$, which represents the probability area that a photon sees when it falls on an electron, we note that the highest value was for the compound (TaC) and equals $\left(87.86\frac{\text{barn}}{\text{electron}}\right)$ at energy (0.01168 MeV), while the lowest value was for the compound (SnO_2) at energy (6 MeV) which equals $\left(0.012\frac{\text{barn}}{\text{electron}}\right)$, and σ_e decreases rapidly with increasing energy, as in Figure (7).

Table 3. Mass attenuation coefficient against energy photon.

E(MeV)	$CaWO_4$	E(MeV)	SnO_2	E(MeV)	WO_3	E(MeV)	BiOCl	E(MeV)	$CdWO_4$
0.01	76.2	0.01	110.3	0.01	78.07	0.01	117.3	0.01	89.33
0.01021	72.27	0.015	37.13	0.01021	74.11	0.01342	55.58	0.01021	84.67
0.01021	162.5	0.02	17.09	0.01021	186.2	0.01342	128.7	0.01021	156.8
0.01085	138.1	0.0292	6.196	0.01085	158.4	0.015	95.59	0.01085	133.2
0.01154	117.4	0.0292	34.41	0.01154	134.7	0.01571	84.62	0.01154	113.2
0.01154	157.2	0.03	32.54	0.01154	184.1	0.01571	115.9	0.01154	145

0.01182	148.5	0.04	15.36	0.01182	174	0.01605	110.2	0.01182	136.9
0.0121	140.2	0.05	8.473	0.0121	164.5	0.01639	104.9	0.0121	129.2
0.0121	160.5	0.06	5.212	0.0121	189.6	0.01639	120.5	0.0121	145.3
0.015	93.24	0.08	2.421	0.015	110.5	0.02	72.94	0.015	84.24
0.02	43.97	0.1	1.354	0.02	52.29	0.03	25.64	0.02	39.68
0.03	15.16	0.15	0.5087	0.03	18.1	0.04	12.17	0.02671	18.53
0.04	7.125	0.2	0.283	0.04	8.514	0.05	6.824	0.02671	31.58
0.05	3.989	0.3	0.1518	0.05	4.762	0.06	4.271	0.03	23.41
0.06	2.505	0.4	0.1114	0.06	2.984	0.08	2.071	0.04	11.04
0.06953	1.735	0.5	0.09237	0.06953	2.06	0.09053	1.531	0.05	6.125
0.06953	7.279	0.6	0.08104	0.06953	8.945	0.09053	5.962	0.06	3.794
0.08	5.074	0.8	0.06752	0.08	6.227	0.1	4.641	0.06953	2.586
0.1	2.903	1	0.05922	0.1	3.55	0.15	1.699	0.06953	7.017
0.15	1.063	1.022	0.05846	0.15	1.282	0.2	0.854	0.08	4.873
0.2	0.5475	1.25	0.05222	0.2	0.6477	0.3	0.3551	0.1	2.767
0.3	0.2461	1.5	0.04755	0.3	0.2789	0.4	0.2104	0.15	1.006
0.4	0.1578	2	0.04186	0.4	0.1724	0.5	0.1497	0.2	0.5171
0.5	0.1197	2.044	0.0415	0.5	0.1273	0.6	0.118	0.3	0.2333
0.6	0.09907	3	0.03667	0.6	0.1034	0.8	0.08616	0.4	0.1504
0.8	0.07717	4	0.03463	0.8	0.07864	1	0.07014	0.5	0.1147
1	0.06531	5	0.03384	1	0.06567	1.022	0.06884	0.6	0.09528
1.022	0.06429	6	0.03364	1.022	0.06457	1.25	0.05873	0.8	0.07457
1.25	0.05622	7	0.0338	1.25	0.05601	1.5	0.05239	1	0.06327
1.5	0.0507	8	0.03413	1.5	0.05038	2	0.04602	1.022	0.0623
2	0.04452	9	0.03459	2	0.04438	2.044	0.04566	1.25	0.05458
2.044	0.04415	10	0.03512	2.044	0.04404	3	0.04143	1.5	0.04931
3	0.03928	11	0.03568	3	0.03976	4	0.04028	2	0.04346
4	0.0374	12	0.03626	4	0.03843	5	0.04036	2.044	0.04312
5	0.03679	13	0.03684	5	0.03829	6	0.04099	3	0.03872
6	0.03678	14	0.03741	6	0.03867	7	0.04188	4	0.03722
7	0.0371	15	0.03795	7	0.03934	8	0.04289	5	0.03691
8	0.03761	16	0.03848	8	0.04015	9	0.04397	6	0.03714
9	0.03823	18	0.03951	9	0.04104	10	0.04508	7	0.03767
10	0.03891	20	0.04048	10	0.04197	11	0.0462	8	0.03836
11	0.03961	22	0.04141	11	0.04291	12	0.0473	9	0.03914
12	0.04035	24	0.04228	12	0.04387	13	0.04839	10	0.03996
13	0.04107	26	0.0431	13	0.04479	14	0.04945	11	0.0408
14	0.0418	28	0.04387	14	0.04571	15	0.05045	12	0.04165
15	0.04248	30	0.0446	15	0.04656	16	0.05143	13	0.04248
16	0.04317	40	0.04767	16	0.04742	18	0.05323	14	0.0433
18	0.04442	50	0.05007	18	0.04896	20	0.05488	15	0.04406
20	0.0456	60	0.05204	20	0.05039	22	0.05643	16	0.04483
22	0.04672	80	0.05499	22	0.05175	24	0.05788	18	0.04622
24	0.04778	100	0.05719	24	0.05301	26	0.05922	20	0.04753
26	0.04875			26	0.05417	28	0.06047	22	0.04877
28	0.04968			28	0.05528	30	0.06163	24	0.04992
30	0.05053			30	0.05629	40	0.06652	26	0.05099
40	0.05421			40	0.06061	50	0.07029	28	0.052

50	0.05707			50	0.06395	60	0.07327	30	0.05293
60	0.05935			60	0.0666	80	0.07773	40	0.0569
80	0.06282			80	0.0706	100	0.08094	50	0.05998
100	0.06532			100	0.07347			60	0.06242
								80	0.06614
								100	0.06881

Table 3. Mass attenuation coefficient against energy photon. Continued.

E(MeV)	Ta_2O_5	E(MeV)	PbO_2	E(MeV)	HfO_2	E(MeV)	UO_2	E(MeV)	TaC
0.01	195.9	0.01	114	0.01	196	0.01	158.6	0.01	223.2
0.01114	147.4	0.01304	58.41	0.01074	161.4	0.015	57.75	0.01114	168
0.01114	201.4	0.01304	140.8	0.01074	220.3	0.01717	41.25	0.01114	229.8
0.01141	190.1	0.015	96.89	0.011	207.9	0.01717	94.44	0.01141	216.9
0.01168	179.4	0.0152	93.59	0.01127	196.1	0.02	62.75	0.01168	204.8
0.01168	206.8	0.0152	128.9	0.01127	226.2	0.02095	55.63	0.01168	236.2
0.015	110.1	0.01553	122.6	0.015	109.6	0.02095	77.99	0.015	125.7
0.02	52.03	0.01586	116.6	0.02	51.75	0.02135	74.32	0.02	59.43
0.03	17.98	0.01586	134.3	0.03	17.85	0.02176	70.82	0.03	20.53
0.04	8.445	0.02	74.93	0.04	8.372	0.02176	81.36	0.04	9.629
0.05	4.721	0.03	26.31	0.05	4.678	0.03	36.44	0.05	5.374
0.06	2.957	0.04	12.47	0.06	2.929	0.04	17.51	0.06	3.358
0.06742	2.205	0.05	6.994	0.06535	2.361	0.05	9.908	0.06742	2.498
0.06742	9.696	0.06	4.374	0.06535	10.51	0.06	6.223	0.06742	11.08
0.08	6.244	0.08	2.118	0.08	6.259	0.08	3.013	0.08	7.125
0.1	3.55	0.088	1.676	0.1	3.545	0.1	1.741	0.1	4.042
0.15	1.278	0.088	6.678	0.15	1.273	0.1156	1.232	0.15	1.444
0.2	0.6447	0.1	4.828	0.2	0.641	0.1156	4.331	0.2	0.7203
0.3	0.2773	0.15	1.763	0.3	0.2753	0.15	2.3	0.3	0.302
0.4	0.1713	0.2	0.8816	0.4	0.17	0.2	1.159	0.4	0.1823
0.5	0.1266	0.3	0.3636	0.5	0.1256	0.3	0.4704	0.5	0.1323
0.6	0.1027	0.4	0.214	0.6	0.102	0.4	0.2689	0.6	0.1059
0.8	0.07819	0.5	0.1514	0.8	0.07759	0.5	0.1845	0.8	0.07925
1	0.06531	0.6	0.1189	1	0.06482	0.6	0.1409	1	0.06554
1.022	0.06424	0.8	0.08631	1.022	0.06375	0.8	0.09796	1.022	0.06441
1.25	0.05573	1	0.07004	1.25	0.05534	1	0.07715	1.25	0.05554
1.5	0.05015	1.022	0.06874	1.5	0.0498	1.022	0.0755	1.5	0.0499
2	0.04422	1.25	0.05851	2	0.04398	1.25	0.0629	2	0.04415
2.044	0.04388	1.5	0.05217	2.044	0.04365	1.5	0.05539	2.044	0.04384
3	0.03974	2	0.04587	3	0.03964	2	0.04828	3	0.04027
4	0.03852	2.044	0.04554	4	0.03854	2.044	0.04789	4	0.03958
5	0.03846	3	0.04149	5	0.03858	3	0.04346	5	0.03997
6	0.03892	4	0.04051	6	0.03911	4	0.04239	6	0.04081
7	0.03964	5	0.04072	7	0.0399	5	0.04264	7	0.04187
8	0.04051	6	0.04145	8	0.04083	6	0.04343	8	0.04303
9	0.04145	7	0.04242	9	0.04182	7	0.0445	9	0.04424
10	0.04241	8	0.04352	10	0.04284	8	0.04569	10	0.04545
11	0.0434	9	0.04468	11	0.04386	9	0.04698	11	0.04668
12	0.04438	10	0.04586	12	0.04489	10	0.04827	12	0.04787

13	0.04535	11	0.04703	13	0.0459	11	0.04958	13	0.04903
14	0.04631	12	0.0482	14	0.04687	12	0.05084	14	0.05017
15	0.04719	13	0.04934	15	0.04779	13	0.05208	15	0.05123
16	0.04805	14	0.05045	16	0.04867	14	0.05329	16	0.05224
18	0.04966	15	0.0515	18	0.05031	15	0.05446	18	0.05414
20	0.05113	16	0.05251	20	0.05184	16	0.05556	20	0.05586
22	0.05251	18	0.05439	22	0.05327	18	0.05761	22	0.05746
24	0.05379	20	0.05612	24	0.05458	20	0.0595	24	0.05895
26	0.055	22	0.05772	26	0.05582	22	0.06126	26	0.06034
28	0.05614	24	0.05922	28	0.05697	24	0.0629	28	0.06165
30	0.05718	26	0.0606	30	0.05806	26	0.06444	30	0.06285
40	0.06162	28	0.0619	40	0.06257	28	0.06584	40	0.06793
50	0.06502	30	0.06311	50	0.06606	30	0.06717	50	0.0718
60	0.06774	40	0.06819	60	0.06883	40	0.07268	60	0.07489
80	0.0718	50	0.07206	80	0.073	50	0.07689	80	0.07946
100	0.07474	60	0.07514	100	0.07599	60	0.08023	100	0.08277
		80	0.07974			80	0.08521		
		100	0.08304			100	0.08879		

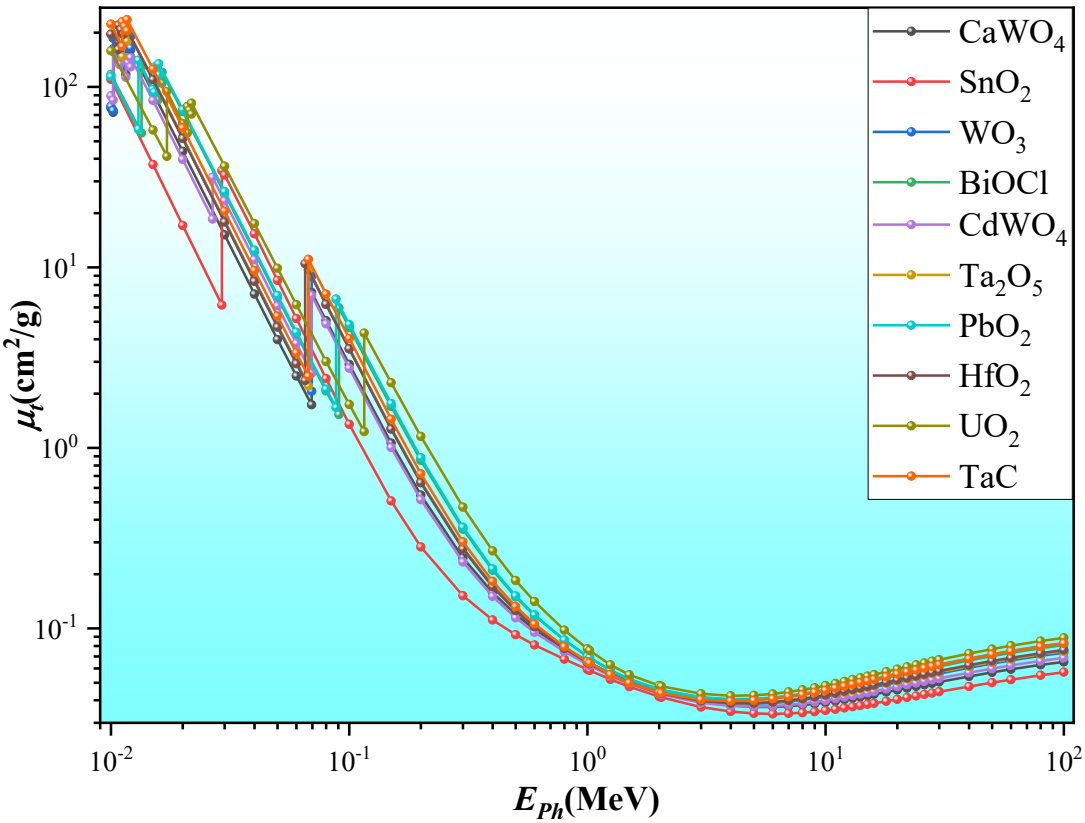

Figure 1. Mass attenuation coefficient versus photon energy.

Table 4. Linear attenuation coefficient against energy photon.

E(MeV)	$CaWO_4$	E(MeV)	SnO_2	E(MeV)	WO_3	E(MeV)	BiOCl	E(MeV)	$CdWO_4$
0.01	461.772	0.01	766.585	0.01	558.9812	0.01	905.556	0.01	705.707
0.01021	437.9562	0.015	258.0535	0.01021	530.6276	0.01342	429.0776	0.01021	668.893
0.01021	984.75	0.02	118.7755	0.01021	1333.192	0.01342	993.564	0.01021	1238.72
0.01085	836.886	0.0292	43.0622	0.01085	1134.144	0.015	737.9548	0.01085	1052.28

0.01154	711.444	0.0292	239.1495	0.01154	964.452	0.01571	653.2664	0.01154	894.28
0.01154	952.632	0.03	226.153	0.01154	1318.156	0.01571	894.748	0.01154	1145.5
0.01182	899.91	0.04	106.752	0.01182	1245.84	0.01605	850.744	0.01182	1081.51
0.0121	849.612	0.05	58.88735	0.0121	1177.82	0.01639	809.828	0.0121	1020.68
0.0121	972.63	0.06	36.2234	0.0121	1357.536	0.01639	930.26	0.0121	1147.87
0.015	565.0344	0.08	16.82595	0.015	791.18	0.02	563.0968	0.015	665.496
0.02	266.4582	0.1	9.4103	0.02	374.3964	0.03	197.9408	0.02	313.472
0.03	91.8696	0.15	3.53546	0.03	129.596	0.04	93.9524	0.02671	146.387
0.04	43.1775	0.2	1.96685	0.04	60.96024	0.05	52.68128	0.02671	249.482
0.05	24.17334	0.3	1.05501	0.05	34.09592	0.06	32.97212	0.03	184.939
0.06	15.1803	0.4	0.77423	0.06	21.36544	0.08	15.98812	0.04	87.216
0.06953	10.5141	0.5	0.64197	0.06953	14.7496	0.09053	11.81932	0.05	48.3875
0.06953	44.11074	0.6	0.56323	0.06953	64.0462	0.09053	46.02664	0.06	29.9726
0.08	30.74844	0.8	0.46926	0.08	44.58532	0.1	35.82852	0.06953	20.4294
0.1	17.59218	1	0.41158	0.1	25.418	0.15	13.11628	0.06953	55.4343
0.15	6.44178	1.022	0.4063	0.15	9.17912	0.2	6.59288	0.08	38.4967
0.2	3.31785	1.25	0.36293	0.2	4.63753	0.3	2.74137	0.1	21.8593
0.3	1.49137	1.5	0.33047	0.3	1.99692	0.4	1.62429	0.15	7.9474
0.4	0.95627	2	0.29093	0.4	1.23438	0.5	1.15568	0.2	4.08509
0.5	0.72538	2.044	0.28843	0.5	0.91147	0.6	0.91096	0.3	1.84307
0.6	0.60036	3	0.25486	0.6	0.74034	0.8	0.66516	0.4	1.18816
0.8	0.46765	4	0.24068	0.8	0.56306	1	0.54148	0.5	0.90613
1	0.39578	5	0.23519	1	0.4702	1.022	0.53144	0.6	0.75271
1.022	0.3896	6	0.2338	1.022	0.46232	1.25	0.4534	0.8	0.5891
1.25	0.34069	7	0.23491	1.25	0.40103	1.5	0.40445	1	0.49983
1.5	0.30724	8	0.2372	1.5	0.36072	2	0.35527	1.022	0.49217
2	0.26979	9	0.2404	2	0.31776	2.044	0.3525	1.25	0.43118
2.044	0.26755	10	0.24408	2.044	0.31533	3	0.31984	1.5	0.38955
3	0.23804	11	0.24798	3	0.28468	4	0.31096	2	0.34333
4	0.22664	12	0.25201	4	0.27516	5	0.31158	2.044	0.34065
5	0.22295	13	0.25604	5	0.27416	6	0.31644	3	0.30589
6	0.22289	14	0.26	6	0.27688	7	0.32331	4	0.29404
7	0.22483	15	0.26375	7	0.28167	8	0.33111	5	0.29159
8	0.22792	16	0.26744	8	0.28747	9	0.33945	6	0.29341
9	0.23167	18	0.27459	9	0.29385	10	0.34802	7	0.29759
10	0.23579	20	0.28134	10	0.30051	11	0.35666	8	0.30304
11	0.24004	22	0.2878	11	0.30724	12	0.36516	9	0.30921
12	0.24452	24	0.29385	12	0.31411	13	0.37357	10	0.31568
13	0.24888	26	0.29955	13	0.3207	14	0.38175	11	0.32232
14	0.25331	28	0.3049	14	0.32728	15	0.38947	12	0.32904
15	0.25743	30	0.30997	15	0.33337	16	0.39704	13	0.33559
16	0.26161	40	0.33131	16	0.33953	18	0.41094	14	0.34207
18	0.26919	50	0.34799	18	0.35055	20	0.42367	15	0.34807
20	0.27634	60	0.36168	20	0.36079	22	0.43564	16	0.35416
22	0.28312	80	0.38218	22	0.37053	24	0.44683	18	0.36514
24	0.28955	100	0.39747	24	0.37955	26	0.45718	20	0.37549
26	0.29542			26	0.38786	28	0.46683	22	0.38528
28	0.30106			28	0.3958	30	0.47578	24	0.39437

30	0.30621			30	0.40304	40	0.51353	26	0.40282
40	0.32851			40	0.43397	50	0.54264	28	0.4108
50	0.34584			50	0.45788	60	0.56564	30	0.41815
60	0.35966			60	0.47686	80	0.60008	40	0.44951
80	0.38069			80	0.5055	100	0.62486	50	0.47384
100	0.39584			100	0.52605			60	0.49312
								80	0.52251
								100	0.5436

Table 4. Linear attenuation coefficient against energy photon. Continued.

E(MeV)	Ta2O5	E(MeV)	PbO2	E(MeV)	HfO2	E(MeV)	UO2	E(MeV)	TaC
0.01	1606.38	0.01	1069.32	0.01	1897.28	0.01	1739.842	0.01	3236.4
0.01114	1208.68	0.01304	547.8858	0.01074	1562.352	0.015	633.5175	0.01114	2436
0.01114	1651.48	0.01304	1320.704	0.01074	2132.504	0.01717	452.5125	0.01114	3332.1
0.01141	1558.82	0.015	908.8282	0.011	2012.472	0.01717	1036.007	0.01141	3145.05
0.01168	1471.08	0.0152	877.8742	0.01127	1898.248	0.02	688.3675	0.01168	2969.6
0.01168	1695.76	0.0152	1209.082	0.01127	2189.616	0.02095	610.2611	0.01168	3424.9
0.015	902.82	0.01553	1149.988	0.015	1060.928	0.02095	855.5503	0.015	1822.65
0.02	426.646	0.01586	1093.708	0.02	500.94	0.02135	815.2904	0.02	861.735
0.03	147.436	0.01586	1259.734	0.03	172.788	0.02176	776.8954	0.03	297.685
0.04	69.249	0.02	702.8434	0.04	81.04096	0.02176	892.5192	0.04	139.6205
0.05	38.7122	0.03	246.7878	0.05	45.28304	0.03	399.7468	0.05	77.923
0.06	24.2474	0.04	116.9686	0.06	28.35272	0.04	192.0847	0.06	48.691
0.06742	18.081	0.05	65.60372	0.06535	22.85448	0.05	108.6908	0.06742	36.221
0.06742	79.5072	0.06	41.02812	0.06535	101.7368	0.06	68.26631	0.06742	160.66
0.08	51.2008	0.08	19.86684	0.08	60.58712	0.08	33.05261	0.08	103.3125
0.1	29.11	0.088	15.72088	0.1	34.3156	0.1	19.09877	0.1	58.609
0.15	10.4796	0.088	62.63964	0.15	12.32264	0.1156	13.51504	0.15	20.938
0.2	5.28654	0.1	45.28664	0.2	6.20488	0.1156	47.51107	0.2	10.44435
0.3	2.27386	0.15	16.53694	0.3	2.6649	0.15	25.231	0.3	4.379
0.4	1.40466	0.2	8.26941	0.4	1.6456	0.2	12.71423	0.4	2.64335
0.5	1.03812	0.3	3.41057	0.5	1.21581	0.3	5.16029	0.5	1.91835
0.6	0.84214	0.4	2.00732	0.6	0.98736	0.4	2.94983	0.6	1.53555
0.8	0.64116	0.5	1.42013	0.8	0.75107	0.5	2.02397	0.8	1.14913
1	0.53554	0.6	1.11528	1	0.62746	0.6	1.54567	1	0.95033
1.022	0.52677	0.8	0.80959	1.022	0.6171	0.8	1.07462	1.022	0.93394
1.25	0.45699	1	0.65698	1.25	0.53569	1	0.84634	1.25	0.80533
1.5	0.41123	1.022	0.64478	1.5	0.48206	1.022	0.82824	1.5	0.72355
2	0.3626	1.25	0.54882	2	0.42573	1.25	0.69001	2	0.64018
2.044	0.35982	1.5	0.48935	2.044	0.42253	1.5	0.60763	2.044	0.63568
3	0.32587	2	0.43026	3	0.38372	2	0.52963	3	0.58391
4	0.31586	2.044	0.42717	4	0.37307	2.044	0.52535	4	0.57391
5	0.31537	3	0.38918	5	0.37345	3	0.47676	5	0.57957
6	0.31914	4	0.37998	6	0.37858	4	0.46502	6	0.59175
7	0.32505	5	0.38195	7	0.38623	5	0.46776	7	0.60712
8	0.33218	6	0.3888	8	0.39523	6	0.47643	8	0.62394
9	0.33989	7	0.3979	9	0.40482	7	0.48817	9	0.64148

10	0.34776	8	0.40822	10	0.41469	8	0.50122	10	0.65902
11	0.35588	9	0.4191	11	0.42456	9	0.51537	11	0.67686
12	0.36392	10	0.43017	12	0.43454	10	0.52952	12	0.69411
13	0.37187	11	0.44114	13	0.44431	11	0.54389	13	0.71094
14	0.37974	12	0.45212	14	0.4537	12	0.55771	14	0.72747
15	0.38696	13	0.46281	15	0.46261	13	0.57132	15	0.74284
16	0.39401	14	0.47322	16	0.47113	14	0.58459	16	0.75748
18	0.40721	15	0.48307	18	0.487	15	0.59743	18	0.78503
20	0.41927	16	0.49254	20	0.50181	16	0.60949	20	0.80997
22	0.43058	18	0.51018	22	0.51565	18	0.63198	22	0.83317
24	0.44108	20	0.52641	24	0.52833	20	0.65272	24	0.85477
26	0.451	22	0.54141	26	0.54034	22	0.67202	26	0.87493
28	0.46035	24	0.55548	28	0.55147	24	0.69001	28	0.89393
30	0.46888	26	0.56843	30	0.56202	26	0.70691	30	0.91133
40	0.50528	28	0.58062	40	0.60568	28	0.72226	40	0.98499
50	0.53316	30	0.59197	50	0.63946	30	0.73685	50	1.0411
60	0.55547	40	0.63962	60	0.66627	40	0.7973	60	1.0859
80	0.58876	50	0.67592	80	0.70664	50	0.84348	80	1.15217
100	0.61287	60	0.70481	100	0.73558	60	0.88012	100	1.20016
		80	0.74796			80	0.93475		
		100	0.77892			100	0.97403		

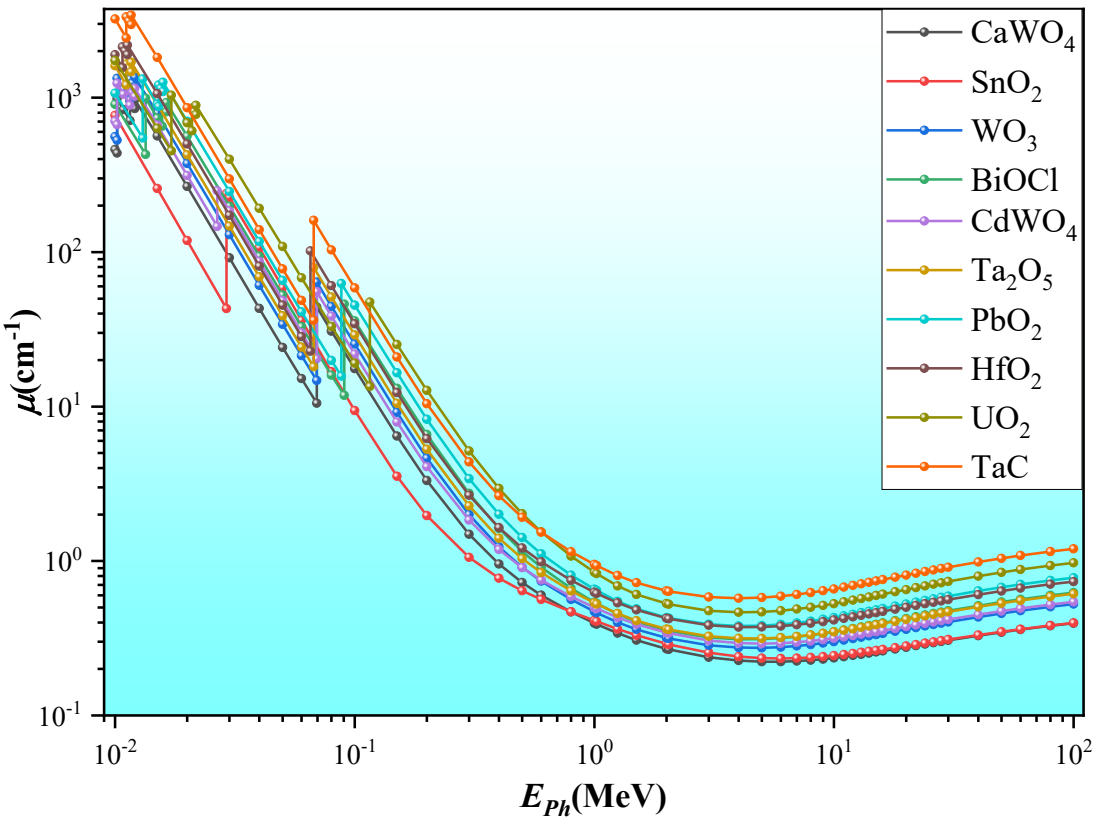

Figure 2. Linear attenuation coefficient versus photon energy.

Table 5. Half value layer against energy photon.

E(MeV)	$CaWO_4$	E(MeV)	SnO_2	E(MeV)	WO_3	E(MeV)	BiOCl	E(MeV)	$CdWO_4$
0.01	0.0015	0.01	9.04E-04	0.01	0.00124	0.01	7.65E-04	0.01	9.82E-04
0.01021	0.00158	0.015	0.00269	0.01021	0.00131	0.01342	0.00162	0.01021	0.00104
0.01021	7.04E-04	0.02	0.00584	0.01021	5.20E-04	0.01342	6.98E-04	0.01021	5.60E-04
0.01085	8.28E-04	0.0292	0.0161	0.01085	6.11E-04	0.015	9.39E-04	0.01085	6.59E-04
0.01154	9.74E-04	0.0292	0.0029	0.01154	7.19E-04	0.01571	0.00106	0.01154	7.75E-04
0.01154	7.28E-04	0.03	0.00306	0.01154	5.26E-04	0.01571	7.75E-04	0.01154	6.05E-04
0.01182	7.70E-04	0.04	0.00649	0.01182	5.56E-04	0.01605	8.15E-04	0.01182	6.41E-04
0.0121	8.16E-04	0.05	0.01177	0.0121	5.89E-04	0.01639	8.56E-04	0.0121	6.79E-04
0.0121	7.13E-04	0.06	0.01914	0.0121	5.11E-04	0.01639	7.45E-04	0.0121	6.04E-04
0.015	0.00123	0.08	0.0412	0.015	8.76E-04	0.02	0.00123	0.015	0.00104
0.02	0.0026	0.1	0.07366	0.02	0.00185	0.03	0.0035	0.02	0.00221
0.03	0.00754	0.15	0.19606	0.03	0.00535	0.04	0.00738	0.02671	0.00474
0.04	0.01605	0.2	0.35241	0.04	0.01137	0.05	0.01316	0.02671	0.00278
0.05	0.02867	0.3	0.65701	0.05	0.02033	0.06	0.02102	0.03	0.00375
0.06	0.04566	0.4	0.89527	0.06	0.03244	0.08	0.04335	0.04	0.00795
0.06953	0.06593	0.5	1.07972	0.06953	0.04699	0.09053	0.05865	0.05	0.01432
0.06953	0.01571	0.6	1.23067	0.06953	0.01082	0.09053	0.01506	0.06	0.02313
0.08	0.02254	0.8	1.47709	0.08	0.01555	0.1	0.01935	0.06953	0.03393
0.1	0.0394	1	1.68412	0.1	0.02727	0.15	0.05285	0.06953	0.0125
0.15	0.1076	1.022	1.70601	0.15	0.07551	0.2	0.10514	0.08	0.01801
0.2	0.20891	1.25	1.90987	0.2	0.14946	0.3	0.25285	0.1	0.03171
0.3	0.46477	1.5	2.09744	0.3	0.34711	0.4	0.42674	0.15	0.08722
0.4	0.72485	2	2.38255	0.4	0.56153	0.5	0.59977	0.2	0.16968
0.5	0.95556	2.044	2.40321	0.5	0.76047	0.6	0.7609	0.3	0.37608
0.6	1.15454	3	2.71975	0.6	0.93625	0.8	1.04208	0.4	0.58338
0.8	1.48219	4	2.87997	0.8	1.23103	1	1.2801	0.5	0.76495
1	1.75135	5	2.9472	1	1.47416	1.022	1.30427	0.6	0.92087
1.022	1.77914	6	2.96473	1.022	1.49928	1.25	1.52879	0.8	1.17661
1.25	2.03452	7	2.95069	1.25	1.72841	1.5	1.7138	1	1.38676
1.5	2.25603	8	2.92216	1.5	1.92156	2	1.95102	1.022	1.40835
2	2.5692	9	2.8833	2	2.18135	2.044	1.9664	1.25	1.60755
2.044	2.59073	10	2.83979	2.044	2.19819	3	2.16717	1.5	1.77936
3	2.91193	11	2.79522	3	2.43482	4	2.22904	2	2.01887
4	3.05831	12	2.75051	4	2.51908	5	2.22463	2.044	2.03479
5	3.10902	13	2.7072	5	2.52829	6	2.19043	3	2.26602
6	3.10986	14	2.66596	6	2.50345	7	2.14389	4	2.35734
7	3.08304	15	2.62802	7	2.46081	8	2.0934	5	2.37714
8	3.04123	16	2.59182	8	2.41116	9	2.04198	6	2.36242
9	2.99191	18	2.52426	9	2.35888	10	1.9917	7	2.32918
10	2.93962	20	2.46377	10	2.30661	11	1.94342	8	2.28728
11	2.88767	22	2.40844	11	2.25608	12	1.89822	9	2.2417
12	2.83471	24	2.35888	12	2.20671	13	1.85546	10	2.1957
13	2.78502	26	2.314	13	2.16138	14	1.81569	11	2.15049
14	2.73638	28	2.27339	14	2.11788	15	1.7797	12	2.10661
15	2.69258	30	2.23618	15	2.07922	16	1.74579	13	2.06545
16	2.64954	40	2.09216	16	2.04151	18	1.68675	14	2.02633

18	2.57498	50	1.99188	18	1.97729	20	1.63604	15	1.99138
20	2.50835	60	1.91648	20	1.92118	22	1.5911	16	1.95717
22	2.44822	80	1.81366	22	1.87069	24	1.55124	18	1.89832
24	2.3939	100	1.7439	24	1.82623	26	1.51614	20	1.846
26	2.34627			26	1.78712	28	1.4848	22	1.79906
28	2.30235			28	1.75123	30	1.45685	24	1.75762
30	2.26362			30	1.71981	40	1.34976	26	1.72073
40	2.10996			40	1.59723	50	1.27736	28	1.68731
50	2.00422			50	1.51381	60	1.22541	30	1.65766
60	1.92722			60	1.45358	80	1.1551	40	1.54201
80	1.82077			80	1.37122	100	1.10929	50	1.46282
100	1.75108			100	1.31766			60	1.40564
								80	1.32658
								100	1.27511

Table 5. Half value layer against energy photon. Continued.

E(MeV)	Ta2O5	E(MeV)	PbO2	E(MeV)	HfO2	E(MeV)	UO2	E(MeV)	TaC
0.01	4.31E-04	0.01	6.48E-04	0.01	3.65E-04	0.01	3.98E-04	0.01	2.14E-04
0.01114	5.73E-04	0.01304	0.00127	0.01074	4.44E-04	0.015	0.00109	0.01114	2.85E-04
0.01114	4.20E-04	0.01304	5.25E-04	0.01074	3.25E-04	0.01717	0.00153	0.01114	2.08E-04
0.01141	4.45E-04	0.015	7.63E-04	0.011	3.44E-04	0.01717	6.69E-04	0.01141	2.20E-04
0.01168	4.71E-04	0.0152	7.90E-04	0.01127	3.65E-04	0.02	0.00101	0.01168	2.33E-04
0.01168	4.09E-04	0.0152	5.73E-04	0.01127	3.17E-04	0.02095	0.00114	0.01168	2.02E-04
0.015	7.68E-04	0.01553	6.03E-04	0.015	6.53E-04	0.02095	8.10E-04	0.015	3.80E-04
0.02	0.00162	0.01586	6.34E-04	0.02	0.00138	0.02135	8.50E-04	0.02	8.04E-04
0.03	0.0047	0.01586	5.50E-04	0.03	0.00401	0.02176	8.92E-04	0.03	0.00233
0.04	0.01001	0.02	9.86E-04	0.04	0.00855	0.02176	7.77E-04	0.04	0.00496
0.05	0.01791	0.03	0.00281	0.05	0.01531	0.03	0.00173	0.05	0.0089
0.06	0.02859	0.04	0.00593	0.06	0.02445	0.04	0.00361	0.06	0.01424
0.06742	0.03834	0.05	0.01057	0.06535	0.03033	0.05	0.00638	0.06742	0.01914
0.06742	0.00872	0.06	0.01689	0.06535	0.00681	0.06	0.01015	0.06742	0.00431
0.08	0.01354	0.08	0.03489	0.08	0.01144	0.08	0.02097	0.08	0.00671
0.1	0.02381	0.088	0.04409	0.1	0.0202	0.1	0.03629	0.1	0.01183
0.15	0.06614	0.088	0.01107	0.15	0.05625	0.1156	0.05129	0.15	0.0331
0.2	0.13112	0.1	0.01531	0.2	0.11171	0.1156	0.01459	0.2	0.06637
0.3	0.30483	0.15	0.04192	0.3	0.2601	0.15	0.02747	0.3	0.15829
0.4	0.49346	0.2	0.08382	0.4	0.42121	0.2	0.05452	0.4	0.26222
0.5	0.66769	0.3	0.20324	0.5	0.57011	0.3	0.13432	0.5	0.36132
0.6	0.82308	0.4	0.34531	0.6	0.70202	0.4	0.23498	0.6	0.4514
0.8	1.08109	0.5	0.48809	0.8	0.92288	0.5	0.34247	0.8	0.6032
1	1.29429	0.6	0.6215	1	1.10469	0.6	0.44844	1	0.72938
1.022	1.31585	0.8	0.85617	1.022	1.12323	0.8	0.64502	1.022	0.74217
1.25	1.51678	1	1.05506	1.25	1.29393	1	0.819	1.25	0.8607
1.5	1.68555	1.022	1.07501	1.5	1.43787	1.022	0.8369	1.5	0.95798
2	1.91158	1.25	1.26297	2	1.62815	1.25	1.00454	2	1.08275
2.044	1.92639	1.5	1.41645	2.044	1.64046	1.5	1.14074	2.044	1.0904
3	2.12708	2	1.61099	3	1.80641	2	1.30873	3	1.18707
4	2.19445	2.044	1.62267	4	1.85797	2.044	1.31939	4	1.20776

5	2.19787	3	1.78106	5	1.85604	3	1.45388	5	1.19598
6	2.17189	4	1.82415	6	1.83089	4	1.49058	6	1.17136
7	2.13245	5	1.81474	7	1.79464	5	1.48184	7	1.14171
8	2.08665	6	1.78278	8	1.75376	6	1.45489	8	1.11093
9	2.03933	7	1.74202	9	1.71225	7	1.4199	9	1.08054
10	1.99317	8	1.69798	10	1.67148	8	1.38292	10	1.05178
11	1.9477	9	1.6539	11	1.63261	9	1.34495	11	1.02406
12	1.90469	10	1.61135	12	1.59515	10	1.30901	12	0.99861
13	1.86395	11	1.57126	13	1.56005	11	1.27442	13	0.97498
14	1.82531	12	1.53312	14	1.52776	12	1.24283	14	0.95283
15	1.79127	13	1.4977	15	1.49835	13	1.21324	15	0.93311
16	1.75921	14	1.46474	16	1.47126	14	1.1857	16	0.91507
18	1.70218	15	1.43488	18	1.4233	15	1.16022	18	0.88296
20	1.65324	16	1.40728	20	1.38129	16	1.13725	20	0.85577
22	1.60979	18	1.35864	22	1.34421	18	1.09678	22	0.83194
24	1.57148	20	1.31675	24	1.31195	20	1.06194	24	0.81091
26	1.53691	22	1.28025	26	1.2828	22	1.03143	26	0.79223
28	1.5057	24	1.24783	28	1.25691	24	1.00454	28	0.7754
30	1.47832	26	1.21941	30	1.23331	26	0.98054	30	0.76059
40	1.3718	28	1.1938	40	1.14442	28	0.95969	40	0.70371
50	1.30006	30	1.17091	50	1.08396	30	0.94068	50	0.66578
60	1.24786	40	1.08368	60	1.04033	40	0.86937	60	0.63831
80	1.1773	50	1.02548	80	0.98091	50	0.82177	80	0.6016
100	1.13099	60	0.98345	100	0.94231	60	0.78756	100	0.57754
		80	0.92672			80	0.74153		
		100	0.88989			100	0.71163		

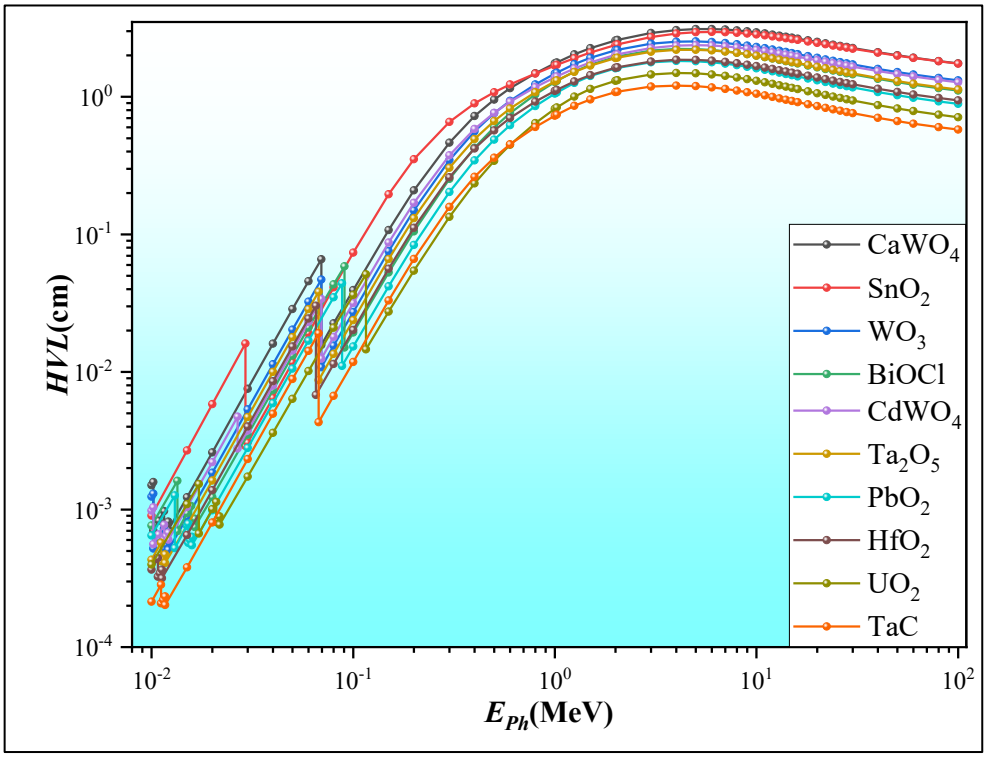

Figure 3. Half value layer versus photon energy.

Table 6. Mean free path against energy photon.

E(MeV)	$CaWO_4$	E(MeV)	SnO_2	E(MeV)	WO_3	E(MeV)	BiOCl	E(MeV)	$CdWO_4$
0.01	0.00217	0.01	0.0013	0.01	0.00179	0.01	0.0011	0.01	0.00142
0.01021	0.00228	0.015	0.00388	0.01021	0.00188	0.01342	0.00233	0.01021	0.0015
0.01021	0.00102	0.02	0.00842	0.01021	7.50E-04	0.01342	0.00101	0.01021	8.07E-04
0.01085	0.00119	0.0292	0.02322	0.01085	8.82E-04	0.015	0.00136	0.01085	9.50E-04
0.01154	0.00141	0.0292	0.00418	0.01154	0.00104	0.01571	0.00153	0.01154	0.00112
0.01154	0.00105	0.03	0.00442	0.01154	7.59E-04	0.01571	0.00112	0.01154	8.73E-04
0.01182	0.00111	0.04	0.00937	0.01182	8.03E-04	0.01605	0.00118	0.01182	9.25E-04
0.0121	0.00118	0.05	0.01698	0.0121	8.49E-04	0.01639	0.00123	0.0121	9.80E-04
0.0121	0.00103	0.06	0.02761	0.0121	7.37E-04	0.01639	0.00107	0.0121	8.71E-04
0.015	0.00177	0.08	0.05943	0.015	0.00126	0.02	0.00178	0.015	0.0015
0.02	0.00375	0.1	0.10627	0.02	0.00267	0.03	0.00505	0.02	0.00319
0.03	0.01088	0.15	0.28285	0.03	0.00772	0.04	0.01064	0.02671	0.00683
0.04	0.02316	0.2	0.50843	0.04	0.0164	0.05	0.01898	0.02671	0.00401
0.05	0.04137	0.3	0.94786	0.05	0.02933	0.06	0.03033	0.03	0.00541
0.06	0.06587	0.4	1.29161	0.06	0.0468	0.08	0.06255	0.04	0.01147
0.06953	0.09511	0.5	1.5577	0.06953	0.0678	0.09053	0.08461	0.05	0.02067
0.06953	0.02267	0.6	1.77548	0.06953	0.01561	0.09053	0.02173	0.06	0.03336
0.08	0.03252	0.8	2.131	0.08	0.02243	0.1	0.02791	0.06953	0.04895
0.1	0.05684	1	2.42967	0.1	0.03934	0.15	0.07624	0.06953	0.01804
0.15	0.15524	1.022	2.46125	0.15	0.10894	0.2	0.15168	0.08	0.02598
0.2	0.3014	1.25	2.75536	0.2	0.21563	0.3	0.36478	0.1	0.04575
0.3	0.67053	1.5	3.02597	0.3	0.50077	0.4	0.61565	0.15	0.12583
0.4	1.04573	2	3.43729	0.4	0.81012	0.5	0.86529	0.2	0.24479
0.5	1.37858	2.044	3.46711	0.5	1.09713	0.6	1.09774	0.3	0.54257
0.6	1.66566	3	3.92378	0.6	1.35072	0.8	1.50341	0.4	0.84164
0.8	2.13835	4	4.15492	0.8	1.776	1	1.84679	0.5	1.10359
1	2.52667	5	4.25192	1	2.12677	1.022	1.88166	0.6	1.32853
1.022	2.56675	6	4.2772	1.022	2.163	1.25	2.20558	0.8	1.6975
1.25	2.93519	7	4.25695	1.25	2.49357	1.5	2.47249	1	2.00067
1.5	3.25476	8	4.21579	1.5	2.77223	2	2.81473	1.022	2.03182
2	3.70657	9	4.15973	2	3.14702	2.044	2.83692	1.25	2.31921
2.044	3.73763	10	4.09695	2.044	3.17132	3	3.12657	1.5	2.56707
3	4.20103	11	4.03265	3	3.5127	4	3.21583	2	2.91262
4	4.41221	12	3.96814	4	3.63427	5	3.20946	2.044	2.93558
5	4.48536	13	3.90567	5	3.64755	6	3.16013	3	3.26917
6	4.48658	14	3.84616	6	3.61171	7	3.09297	4	3.40092
7	4.44788	15	3.79143	7	3.5502	8	3.02014	5	3.42948
8	4.38757	16	3.73921	8	3.47858	9	2.94596	6	3.40825
9	4.31641	18	3.64173	9	3.40314	10	2.87342	7	3.36029
10	4.24098	20	3.55447	10	3.32773	11	2.80376	8	3.29985
11	4.16603	22	3.47464	11	3.25483	12	2.73856	9	3.23409
12	4.08963	24	3.40314	12	3.18361	13	2.67687	10	3.16772
13	4.01793	26	3.3384	13	3.11821	14	2.61949	11	3.10251
14	3.94776	28	3.2798	14	3.05545	15	2.56757	12	3.03919
15	3.88457	30	3.22612	15	2.99967	16	2.51864	13	2.97981
16	3.82248	40	3.01835	16	2.94527	18	2.43347	14	2.92338

18	3.71491	50	2.87367	18	2.85263	20	2.36031	15	2.87295
20	3.61878	60	2.76489	20	2.77168	22	2.29548	16	2.82361
22	3.53203	80	2.61656	22	2.69884	24	2.23797	18	2.73869
24	3.45367	100	2.51591	24	2.63469	26	2.18733	20	2.66321
26	3.38495			26	2.57827	28	2.14211	22	2.59549
28	3.32159			28	2.5265	30	2.1018	24	2.5357
30	3.26571			30	2.48117	40	1.94729	26	2.48249
40	3.04402			40	2.30432	50	1.84285	28	2.43427
50	2.89148			50	2.18397	60	1.7679	30	2.3915
60	2.7804			60	2.09707	80	1.66646	40	2.22464
80	2.62681			80	1.97826	100	1.60037	50	2.11041
100	2.52628			100	1.90098			60	2.02791
								80	1.91385
								100	1.83959

Table 6. Mean free path against energy photon. Continued.

E(MeV)	Ta2O5	E(MeV)	PbO2	E(MeV)	HfO2	E(MeV)	UO2	E(MeV)	TaC
0.01	6.23E-04	0.01	9.35E-04	0.01	5.27E-04	0.01	5.75E-04	0.01	3.09E-04
0.01114	8.27E-04	0.01304	0.00183	0.01074	6.40E-04	0.015	0.00158	0.01114	4.11E-04
0.01114	6.06E-04	0.01304	7.57E-04	0.01074	4.69E-04	0.01717	0.00221	0.01114	3.00E-04
0.01141	6.42E-04	0.015	0.0011	0.011	4.97E-04	0.01717	9.65E-04	0.01141	3.18E-04
0.01168	6.80E-04	0.0152	0.00114	0.01127	5.27E-04	0.02	0.00145	0.01168	3.37E-04
0.01168	5.90E-04	0.0152	8.27E-04	0.01127	4.57E-04	0.02095	0.00164	0.01168	2.92E-04
0.015	0.00111	0.01553	8.70E-04	0.015	9.43E-04	0.02095	0.00117	0.015	5.49E-04
0.02	0.00234	0.01586	9.14E-04	0.02	0.002	0.02135	0.00123	0.02	0.00116
0.03	0.00678	0.01586	7.94E-04	0.03	0.00579	0.02176	0.00129	0.03	0.00336
0.04	0.01444	0.02	0.00142	0.04	0.01234	0.02176	0.00112	0.04	0.00716
0.05	0.02583	0.03	0.00405	0.05	0.02208	0.03	0.0025	0.05	0.01283
0.06	0.04124	0.04	0.00855	0.06	0.03527	0.04	0.00521	0.06	0.02054
0.06742	0.05531	0.05	0.01524	0.06535	0.04376	0.05	0.0092	0.06742	0.02761
0.06742	0.01258	0.06	0.02437	0.06535	0.00983	0.06	0.01465	0.06742	0.00622
0.08	0.01953	0.08	0.05034	0.08	0.01651	0.08	0.03025	0.08	0.00968
0.1	0.03435	0.088	0.06361	0.1	0.02914	0.1	0.05236	0.1	0.01706
0.15	0.09542	0.088	0.01596	0.15	0.08115	0.1156	0.07399	0.15	0.04776
0.2	0.18916	0.1	0.02208	0.2	0.16116	0.1156	0.02105	0.2	0.09575
0.3	0.43978	0.15	0.06047	0.3	0.37525	0.15	0.03963	0.3	0.22836
0.4	0.71192	0.2	0.12093	0.4	0.60768	0.2	0.07865	0.4	0.37831
0.5	0.96328	0.3	0.29321	0.5	0.8225	0.3	0.19379	0.5	0.52128
0.6	1.18745	0.4	0.49818	0.6	1.0128	0.4	0.339	0.6	0.65123
0.8	1.55968	0.5	0.70416	0.8	1.33143	0.5	0.49408	0.8	0.87023
1	1.86727	0.6	0.89663	1	1.59373	0.6	0.64697	1	1.05227
1.022	1.89837	0.8	1.2352	1.022	1.62048	0.8	0.93056	1.022	1.07073
1.25	2.18825	1	1.52213	1.25	1.86675	1	1.18156	1.25	1.24173
1.5	2.43173	1.022	1.55091	1.5	2.07441	1.022	1.20739	1.5	1.38207
2	2.75783	1.25	1.82208	2	2.34893	1.25	1.44925	2	1.56207
2.044	2.7792	1.5	2.04351	2.044	2.36668	1.5	1.64574	2.044	1.57312
3	3.06873	2	2.32417	3	2.6061	2	1.8881	3	1.71258
4	3.16592	2.044	2.34101	4	2.68048	2.044	1.90348	4	1.74243

5	3.17086	3	2.56953	5	2.6777	3	2.09751	5	1.72543
6	3.13338	4	2.63169	6	2.64142	4	2.15045	6	1.68992
7	3.07647	5	2.61812	7	2.58912	5	2.13784	7	1.64713
8	3.0104	6	2.57201	8	2.53014	6	2.09896	8	1.60273
9	2.94213	7	2.5132	9	2.47025	7	2.04849	9	1.5589
10	2.87553	8	2.44967	10	2.41143	8	1.99513	10	1.51739
11	2.80994	9	2.38607	11	2.35535	9	1.94035	11	1.47741
12	2.74789	10	2.32468	12	2.30131	10	1.8885	12	1.44068
13	2.68911	11	2.26685	13	2.25067	11	1.8386	13	1.4066
14	2.63337	12	2.21182	14	2.20409	12	1.79303	14	1.37464
15	2.58426	13	2.16072	15	2.16166	13	1.75034	15	1.34619
16	2.53801	14	2.11318	16	2.12258	14	1.7106	16	1.32017
18	2.45572	15	2.07009	18	2.05338	15	1.67385	18	1.27384
20	2.38512	16	2.03028	20	1.99278	16	1.64071	20	1.23461
22	2.32244	18	1.9601	22	1.93929	18	1.58232	22	1.20024
24	2.26717	20	1.89968	24	1.89274	20	1.53206	24	1.1699
26	2.21729	22	1.84702	26	1.85069	22	1.48805	26	1.14295
28	2.17227	24	1.80023	28	1.81334	24	1.44925	28	1.11866
30	2.13276	26	1.75924	30	1.77929	26	1.41461	30	1.0973
40	1.97909	28	1.72229	40	1.65104	28	1.38453	40	1.01524
50	1.8756	30	1.68927	50	1.56382	30	1.35712	50	0.96052
60	1.80028	40	1.56342	60	1.50088	40	1.25423	60	0.92089
80	1.69848	50	1.47946	80	1.41515	50	1.18556	80	0.86793
100	1.63167	60	1.41882	100	1.35947	60	1.1362	100	0.83322
		80	1.33697			80	1.0698		
		100	1.28384			100	1.02667		

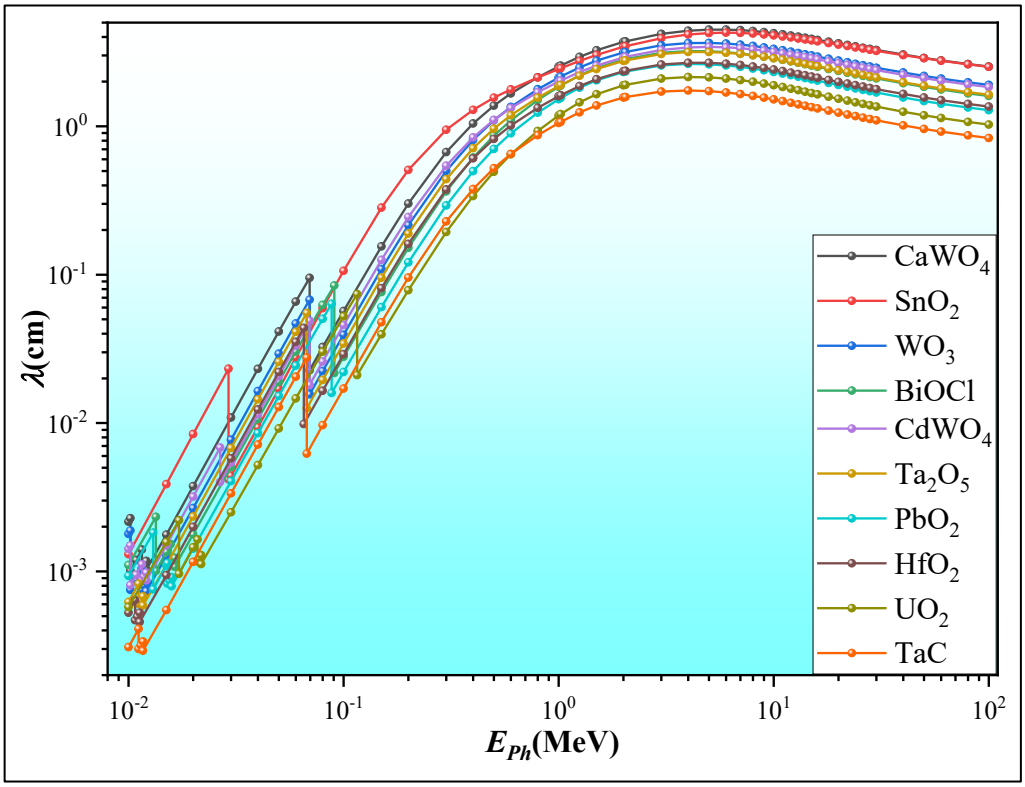

Figure 4. Mean free path versus photon energy.

Table 7. Molecular cross section against energy photon.

E(MeV)	$CaWO_4$	E(MeV)	SnO_2	E(MeV)	WO_3	E(MeV)	BiOCl	E(MeV)	$CdWO_4$
0.01	36427.47	0.01	27599.72	0.01	30051.05	0.01	50719.64	0.01	53430.4
0.01021	34548.73	0.015	9290.822	0.01021	28526.75	0.01342	24032.37	0.01021	50643.15
0.01021	77683.26	0.02	4276.331	0.01021	71672.93	0.01342	55648.91	0.01021	93785.82
0.01085	66018.82	0.0292	1550.389	0.01085	60972.03	0.015	41332.4	0.01085	79670.1
0.01154	56123.16	0.0292	8610.213	0.01154	51849.32	0.01571	36589.05	0.01154	67707.62
0.01154	75149.59	0.03	8142.294	0.01154	70864.59	0.01571	50114.29	0.01154	86727.96
0.01182	70990.54	0.04	3843.443	0.01182	66976.86	0.01605	47649.65	0.01182	81883.16
0.0121	67022.72	0.05	2120.149	0.0121	63320.07	0.01639	45357.97	0.0121	77277.6
0.0121	76727.15	0.06	1304.168	0.0121	72981.68	0.01639	52103.3	0.0121	86907.4
0.015	44573.46	0.08	605.7926	0.015	42534.15	0.02	31538.71	0.015	50385.95
0.02	21019.89	0.1	338.8035	0.02	20127.7	0.03	11086.54	0.02	23733.55
0.03	7247.25	0.15	127.289	0.03	6967.133	0.04	5262.217	0.02671	11083.24
0.04	3406.112	0.2	70.81343	0.04	3277.247	0.05	2950.646	0.02671	18888.75
0.05	1906.945	0.3	37.98402	0.05	1833.01	0.06	1846.748	0.03	14002.08
0.06	1197.517	0.4	27.87497	0.06	1148.615	0.08	895.4849	0.04	6603.287
0.06953	829.4182	0.5	23.1132	0.06953	792.9444	0.09053	661.9929	0.05	3663.509
0.06953	3479.732	0.6	20.27816	0.06953	3443.149	0.09053	2577.924	0.06	2269.282
0.08	2425.63	0.8	16.89513	0.08	2396.925	0.1	2006.734	0.06953	1546.748
0.1	1387.781	1	14.81827	0.1	1366.482	0.15	734.6349	0.06953	4197.035
0.15	508.168	1.022	14.6281	0.15	493.4732	0.2	369.2632	0.08	2914.658
0.2	261.7328	1.25	13.0667	0.2	249.3156	0.3	153.5426	0.1	1655.009
0.3	117.6483	1.5	11.89816	0.3	107.3554	0.4	90.97538	0.15	601.7126
0.4	75.43642	2	10.47438	0.4	66.36098	0.5	64.72916	0.2	309.2899
0.5	57.22268	2.044	10.3843	0.5	49.00088	0.6	51.02231	0.3	139.5423
0.6	47.36049	3	9.17572	0.6	39.80119	0.8	37.25494	0.4	89.95783
0.8	36.89118	4	8.66526	0.8	30.27046	1	30.32801	0.5	68.60481
1	31.2215	5	8.46758	1	25.27799	1.022	29.7659	0.6	56.98924
1.022	30.73389	6	8.41754	1.022	24.85457	1.25	25.39441	0.8	44.6021
1.25	26.87602	7	8.45758	1.25	21.55962	1.5	22.65304	1	37.8433
1.5	24.23718	8	8.54015	1.5	19.39249	2	19.8987	1.022	37.26312
2	21.28282	9	8.65525	2	17.08295	2.044	19.74304	1.25	32.6456
2.044	21.10594	10	8.78787	2.044	16.95207	3	17.91402	1.5	29.49349
3	18.77784	11	8.928	3	15.3046	4	17.41677	2	25.99446
4	17.8791	12	9.07313	4	14.79265	5	17.45136	2.044	25.7911
5	17.58749	13	9.21826	5	14.73876	6	17.72377	3	23.15936
6	17.58271	14	9.36089	6	14.88503	7	18.1086	4	22.26217
7	17.73568	15	9.49601	7	15.14293	8	18.54531	5	22.07675
8	17.97949	16	9.62862	8	15.45472	9	19.0123	6	22.21432
9	18.27588	18	9.88636	9	15.7973	10	19.49225	7	22.53133
10	18.60096	20	10.12907	10	16.15528	11	19.97653	8	22.94403
11	18.93559	22	10.36178	11	16.51711	12	20.45217	9	23.41057
12	19.28935	24	10.57948	12	16.88664	13	20.92347	10	23.90103
13	19.63355	26	10.78466	13	17.24077	14	21.38181	11	24.40345
14	19.98252	28	10.97733	14	17.5949	15	21.8142	12	24.91186
15	20.3076	30	11.16	15	17.92208	16	22.23795	13	25.4083
16	20.63745	40	11.92818	16	18.25312	18	23.01625	14	25.89876

18	21.23502	50	12.52872	18	18.8459	20	23.7297	15	26.35334
20	21.79912	60	13.02166	20	19.39634	22	24.39991	16	26.81389
22	22.33453	80	13.75983	22	19.91984	24	25.02688	18	27.64528
24	22.84127	100	14.31032	24	20.40485	26	25.60628	20	28.42883
26	23.30498			26	20.85136	28	26.14677	22	29.1705
28	23.74956			28	21.27862	30	26.64835	24	29.85834
30	24.15591			30	21.6674	40	28.76275	26	30.49834
40	25.91513			40	23.33027	50	30.39287	28	31.10244
50	27.28236			50	24.61592	60	31.6814	30	31.6587
60	28.37232			60	25.63597	80	33.60987	40	34.03325
80	30.03115			80	27.17567	100	34.99785	50	35.87547
100	31.22628			100	28.2804			60	37.33489
								80	39.55991
								100	41.1569

Table 7. Molecular cross section against energy photon. Continued.

E(MeV)	Ta2O5	E(MeV)	PbO2	E(MeV)	HfO2	E(MeV)	UO2	E(MeV)	TaC
0.01	143726.1	0.01	45274.45	0.01	68497.49	0.01	71105.36	0.01	71507.01
0.01114	108143.1	0.01304	23197.2	0.01074	56405.59	0.015	25891.14	0.01114	53822.48
0.01114	147761.3	0.01304	55917.91	0.01074	76989.78	0.01717	18493.67	0.01114	73621.46
0.01141	139470.8	0.015	38479.31	0.011	72656.27	0.01717	42340.42	0.01141	69488.67
0.01168	131620.6	0.0152	37168.73	0.01127	68532.44	0.02	28132.8	0.01168	65612.17
0.01168	151723.1	0.0152	51191.9	0.01127	79051.7	0.02095	24940.68	0.01168	75671.84
0.015	80777.17	0.01553	48689.89	0.015	38302.68	0.02095	34965.37	0.015	40270.75
0.02	38172.9	0.01586	46307.02	0.02	18085.44	0.02135	33319.99	0.02	19039.7
0.03	13191.4	0.01586	53336.48	0.03	6238.165	0.02176	31750.83	0.03	6577.235
0.04	6195.851	0.02	29758.02	0.04	2925.821	0.02176	36476.24	0.04	3084.861
0.05	3463.66	0.03	10448.87	0.05	1634.853	0.03	16337.2	0.05	1721.679
0.06	2169.465	0.04	4952.389	0.06	1023.618	0.04	7850.283	0.06	1075.809
0.06742	1617.744	0.05	2777.627	0.06535	825.1152	0.05	4442.067	0.06742	800.289
0.06742	7113.673	0.06	1737.109	0.06535	3673.003	0.06	2789.966	0.06742	3549.721
0.08	4581.041	0.08	841.1516	0.08	2187.377	0.08	1350.823	0.08	2282.65
0.1	2604.532	0.088	665.6138	0.1	1238.896	0.1	780.545	0.1	1294.943
0.15	937.6315	0.088	2652.13	0.15	444.8842	0.1156	552.3443	0.15	462.617
0.2	472.9977	0.1	1917.413	0.2	224.0148	0.1156	1941.723	0.2	230.7639
0.3	203.447	0.15	700.1654	0.3	96.21102	0.15	1031.162	0.3	96.75232
0.4	125.6778	0.2	350.1224	0.4	59.41109	0.2	519.6161	0.4	58.4038
0.5	92.88274	0.3	144.4017	0.5	43.89431	0.3	210.8951	0.5	42.3852
0.6	75.348	0.4	84.98888	0.6	35.64665	0.4	120.5563	0.6	33.92739
0.8	57.36573	0.5	60.12764	0.8	27.11592	0.5	82.71714	0.8	25.38947
1	47.91605	0.6	47.22045	1	22.6531	0.6	63.16989	1	20.99717
1.022	47.13102	0.8	34.27752	1.022	22.27916	0.8	43.91854	1.022	20.63515
1.25	40.88748	1	27.81599	1.25	19.34006	1	34.58877	1.25	17.79346
1.5	36.7936	1.022	27.2997	1.5	17.40395	1.022	33.84902	1.5	15.98656
2	32.44293	1.25	23.23691	2	15.37	1.25	28.20004	2	14.14442
2.044	32.19348	1.5	20.71902	2.044	15.25467	1.5	24.83308	2.044	14.0451
3	29.15608	2	18.21701	3	13.85327	2	21.64544	3	12.90138
4	28.261	2.044	18.08595	4	13.46884	2.044	21.47059	4	12.68032

5	28.21698	3	16.47752	5	13.48282	3	19.48448	5	12.80527
6	28.55447	4	16.08831	6	13.66805	4	19.00477	6	13.07438
7	29.08272	5	16.17172	7	13.94413	5	19.11685	7	13.41397
8	29.72101	6	16.46163	8	14.26915	6	19.47103	8	13.7856
9	30.41066	7	16.84686	9	14.61513	7	19.95075	9	14.17325
10	31.11498	8	17.28372	10	14.97159	8	20.48426	10	14.5609
11	31.84132	9	17.74441	11	15.32806	9	21.06261	11	14.95496
12	32.56032	10	18.21304	12	15.68802	10	21.64096	12	15.3362
13	33.27198	11	18.6777	13	16.04099	11	22.22827	13	15.70783
14	33.9763	12	19.14235	14	16.37999	12	22.79317	14	16.07306
15	34.62193	13	19.5951	15	16.70151	13	23.3491	15	16.41265
16	35.25289	14	20.03593	16	17.00905	14	23.89158	16	16.73623
18	36.4341	15	20.45293	18	17.58219	15	24.41613	18	17.34494
20	37.51259	16	20.85405	20	18.11689	16	24.90929	20	17.89597
22	38.52506	18	21.60068	22	18.61664	18	25.82837	22	18.40857
24	39.46416	20	22.28774	24	19.07445	20	26.67572	24	18.88592
26	40.3519	22	22.92317	26	19.50781	22	27.46478	26	19.33124
28	41.18829	24	23.51888	28	19.9097	24	28.20004	28	19.75093
30	41.9513	26	24.06694	30	20.29063	26	28.89048	30	20.13537
40	45.2088	28	24.58323	40	21.86678	28	29.51814	40	21.76286
50	47.70328	30	25.06378	50	23.08645	30	30.11442	50	23.0027
60	49.69887	40	27.08127	60	24.0545	40	32.58473	60	23.99265
80	52.67757	50	28.61822	80	25.51182	50	34.4722	80	25.45675
100	54.83457	60	29.84142	100	26.55676	60	35.96963	100	26.51718
		80	31.66828			80	38.20232		
		100	32.97886			100	39.80734		

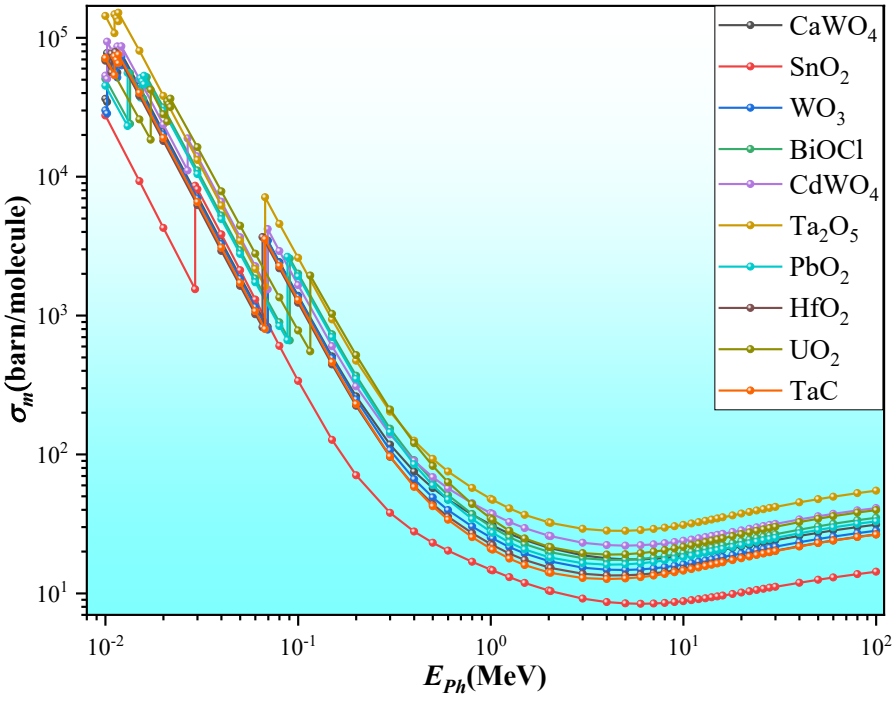

Figure 5. Molecular cross section versus photon energy.

Table 8. Atomic cross section against energy photon.

E(MeV)	$CaWO_4$	E(MeV)	SnO_2	E(MeV)	WO_3	E(MeV)	BiOCl	E(MeV)	$CdWO_4$
0.01	6071.245	0.01	9199.908	0.01	7512.763	0.01	16906.55	0.01	8905.067
0.01021	5758.122	0.015	3096.941	0.01021	7131.688	0.01342	8010.792	0.01021	8440.525
0.01021	12947.21	0.02	1425.444	0.01021	17918.23	0.01342	18549.64	0.01021	15630.97
0.01085	11003.14	0.0292	516.7963	0.01085	15243.01	0.015	13777.47	0.01085	13278.35
0.01154	9353.861	0.0292	2870.071	0.01154	12962.33	0.01571	12196.35	0.01154	11284.6
0.01154	12524.93	0.03	2714.098	0.01154	17716.15	0.01571	16704.76	0.01154	14454.66
0.01182	11831.76	0.04	1281.148	0.01182	16744.21	0.01605	15883.22	0.01182	13647.19
0.0121	11170.45	0.05	706.7164	0.0121	15830.02	0.01639	15119.32	0.0121	12879.6
0.0121	12787.86	0.06	434.7227	0.0121	18245.42	0.01639	17367.77	0.0121	14484.57
0.015	7428.91	0.08	201.9309	0.015	10633.54	0.02	10512.9	0.015	8397.659
0.02	3503.316	0.1	112.9345	0.02	5031.925	0.03	3695.515	0.02	3955.592
0.03	1207.875	0.15	42.42967	0.03	1741.783	0.04	1754.072	0.02671	1847.206
0.04	567.6853	0.2	23.60448	0.04	819.3117	0.05	983.5488	0.02671	3148.125
0.05	317.8241	0.3	12.66134	0.05	458.2526	0.06	615.5828	0.03	2333.68
0.06	199.5862	0.4	9.29166	0.06	287.1536	0.08	298.495	0.04	1100.548
0.06953	138.2364	0.5	7.7044	0.06953	198.2361	0.09053	220.6643	0.05	610.5848
0.06953	579.9553	0.6	6.75939	0.06953	860.7873	0.09053	859.308	0.06	378.2137
0.08	404.2716	0.8	5.63171	0.08	599.2312	0.1	668.9112	0.06953	257.7914
0.1	231.2969	1	4.93942	0.1	341.6205	0.15	244.8783	0.06953	699.5059
0.15	84.69467	1.022	4.87603	0.15	123.3683	0.2	123.0877	0.08	485.7763
0.2	43.62214	1.25	4.35557	0.2	62.32889	0.3	51.18086	0.1	275.8348
0.3	19.60805	1.5	3.96605	0.3	26.83886	0.4	30.32513	0.15	100.2854
0.4	12.57274	2	3.49146	0.4	16.59024	0.5	21.57639	0.2	51.54831
0.5	9.53711	2.044	3.46143	0.5	12.25022	0.6	17.00744	0.3	23.25705
0.6	7.89342	3	3.05857	0.6	9.9503	0.8	12.41831	0.4	14.99297
0.8	6.14853	4	2.88842	0.8	7.56761	1	10.10934	0.5	11.43413
1	5.20358	5	2.82253	1	6.3195	1.022	9.92197	0.6	9.49821
1.022	5.12231	6	2.80585	1.022	6.21364	1.25	8.4648	0.8	7.43368
1.25	4.47934	7	2.81919	1.25	5.3899	1.5	7.55101	1	6.30722
1.5	4.03953	8	2.84672	1.5	4.84812	2	6.6329	1.022	6.21052
2	3.54714	9	2.88508	2	4.27074	2.044	6.58101	1.25	5.44093
2.044	3.51766	10	2.92929	2.044	4.23802	3	5.97134	1.5	4.91558
3	3.12964	11	2.976	3	3.82615	4	5.80559	2	4.33241
4	2.97985	12	3.02438	4	3.69816	5	5.81712	2.044	4.29852
5	2.93125	13	3.07275	5	3.68469	6	5.90792	3	3.85989
6	2.93045	14	3.1203	6	3.72126	7	6.0362	4	3.71036
7	2.95595	15	3.16534	7	3.78573	8	6.18177	5	3.67946
8	2.99658	16	3.20954	8	3.86368	9	6.33743	6	3.70239
9	3.04598	18	3.29545	9	3.94932	10	6.49742	7	3.75522
10	3.10016	20	3.37636	10	4.03882	11	6.65884	8	3.82401
11	3.15593	22	3.45393	11	4.12928	12	6.81739	9	3.90176
12	3.21489	24	3.52649	12	4.22166	13	6.97449	10	3.9835
13	3.27226	26	3.59489	13	4.31019	14	7.12727	11	4.06724
14	3.33042	28	3.65911	14	4.39872	15	7.2714	12	4.15198
15	3.3846	30	3.72	15	4.48052	16	7.41265	13	4.23472
16	3.43958	40	3.97606	16	4.56328	18	7.67208	14	4.31646

18	3.53917	50	4.17624	18	4.71148	20	7.9099	15	4.39222
20	3.63319	60	4.34055	20	4.84909	22	8.1333	16	4.46898
22	3.72242	80	4.58661	22	4.97996	24	8.34229	18	4.60755
24	3.80688	100	4.77011	24	5.10121	26	8.53543	20	4.73814
26	3.88416			26	5.21284	28	8.71559	22	4.86175
28	3.95826			28	5.31966	30	8.88278	24	4.97639
30	4.02598			30	5.41685	40	9.58758	26	5.08306
40	4.31919			40	5.83257	50	10.13096	28	5.18374
50	4.54706			50	6.15398	60	10.56047	30	5.27645
60	4.72872			60	6.40899	80	11.20329	40	5.67221
80	5.00519			80	6.79392	100	11.66595	50	5.97924
100	5.20438			100	7.0701			60	6.22248
								80	6.59332
								100	6.85948

Table 8. Atomic cross section against energy photon. Continued.

E(MeV)	Ta2O5	E(MeV)	PbO2	E(MeV)	HfO2	E(MeV)	UO2	E(MeV)	TaC
0.01	20532.3	0.01	15091.48	0.01	22832.5	0.01	23701.79	0.01	35753.5
0.01114	15449.01	0.01304	7732.399	0.01074	18801.86	0.015	8630.379	0.01114	26911.24
0.01114	21108.76	0.01304	18639.3	0.01074	25663.26	0.01717	6164.557	0.01114	36810.73
0.01141	19924.41	0.015	12826.44	0.011	24218.76	0.01717	14113.47	0.01141	34744.33
0.01168	18802.94	0.0152	12389.58	0.01127	22844.15	0.02	9377.598	0.01168	32806.08
0.01168	21674.74	0.0152	17063.97	0.01127	26350.57	0.02095	8313.559	0.01168	37835.92
0.015	11539.6	0.01553	16229.96	0.015	12767.56	0.02095	11655.12	0.015	20135.37
0.02	5453.271	0.01586	15435.67	0.02	6028.478	0.02135	11106.66	0.02	9519.851
0.03	1884.486	0.01586	17778.83	0.03	2079.388	0.02176	10583.61	0.03	3288.618
0.04	885.1216	0.02	9919.34	0.04	975.2738	0.02176	12158.75	0.04	1542.431
0.05	494.8086	0.03	3482.955	0.05	544.9511	0.03	5445.732	0.05	860.8393
0.06	309.9236	0.04	1650.796	0.06	341.2061	0.04	2616.761	0.06	537.9044
0.06742	231.1063	0.05	925.8757	0.06535	275.0384	0.05	1480.689	0.06742	400.1445
0.06742	1016.239	0.06	579.0364	0.06535	1224.334	0.06	929.9888	0.06742	1774.86
0.08	654.4345	0.08	280.3839	0.08	729.1255	0.08	450.2742	0.08	1141.325
0.1	372.076	0.088	221.8713	0.1	412.9653	0.1	260.1817	0.1	647.4716
0.15	133.9474	0.088	884.0432	0.15	148.2947	0.1156	184.1148	0.15	231.3085
0.2	67.57109	0.1	639.1375	0.2	74.67159	0.1156	647.2411	0.2	115.3819
0.3	29.06385	0.15	233.3885	0.3	32.07034	0.15	343.7207	0.3	48.37616
0.4	17.95398	0.2	116.7075	0.4	19.8037	0.2	173.2054	0.4	29.2019
0.5	13.26896	0.3	48.13389	0.5	14.63144	0.3	70.29836	0.5	21.1926
0.6	10.764	0.4	28.32963	0.6	11.88222	0.4	40.18544	0.6	16.96369
0.8	8.1951	0.5	20.04255	0.8	9.03864	0.5	27.57238	0.8	12.69474
1	6.84515	0.6	15.74015	1	7.55103	0.6	21.05663	1	10.49859
1.022	6.733	0.8	11.42584	1.022	7.42639	0.8	14.63951	1.022	10.31758
1.25	5.84107	1	9.272	1.25	6.44669	1	11.52959	1.25	8.89673
1.5	5.25623	1.022	9.0999	1.5	5.80132	1.022	11.28301	1.5	7.99328
2	4.6347	1.25	7.74564	2	5.12333	1.25	9.40001	2	7.07221
2.044	4.59907	1.5	6.90634	2.044	5.08489	1.5	8.27769	2.044	7.02255
3	4.16515	2	6.07234	3	4.61776	2	7.21515	3	6.45069
4	4.03729	2.044	6.02865	4	4.48961	2.044	7.15686	4	6.34016

5	4.031	3	5.49251	5	4.49427	3	6.49483	5	6.40263
6	4.07921	4	5.36277	6	4.55602	4	6.33492	6	6.53719
7	4.15467	5	5.39057	7	4.64804	5	6.37228	7	6.70699
8	4.24586	6	5.48721	8	4.75638	6	6.49034	8	6.8928
9	4.34438	7	5.61562	9	4.87171	7	6.65025	9	7.08663
10	4.445	8	5.76124	10	4.99053	8	6.82809	10	7.28045
11	4.54876	9	5.9148	11	5.10935	9	7.02087	11	7.47748
12	4.65147	10	6.07101	12	5.22934	10	7.21365	12	7.6681
13	4.75314	11	6.2259	13	5.347	11	7.40942	13	7.85392
14	4.85376	12	6.38078	14	5.46	12	7.59772	14	8.03653
15	4.94599	13	6.5317	15	5.56717	13	7.78303	15	8.20633
16	5.03613	14	6.67864	16	5.66968	14	7.96386	16	8.36811
18	5.20487	15	6.81764	18	5.86073	15	8.13871	18	8.67247
20	5.35894	16	6.95135	20	6.03896	16	8.3031	20	8.94799
22	5.50358	18	7.20023	22	6.20555	18	8.60946	22	9.20428
24	5.63774	20	7.42925	24	6.35815	20	8.89191	24	9.44296
26	5.76456	22	7.64106	26	6.5026	22	9.15493	26	9.66562
28	5.88404	24	7.83963	28	6.63657	24	9.40001	28	9.87546
30	5.99304	26	8.02231	30	6.76354	26	9.63016	30	10.06769
40	6.4584	28	8.19441	40	7.28893	28	9.83938	40	10.88143
50	6.81475	30	8.35459	50	7.69548	30	10.03814	50	11.50135
60	7.09984	40	9.02709	60	8.01817	40	10.86158	60	11.99633
80	7.52537	50	9.53941	80	8.50394	50	11.49073	80	12.72838
100	7.83351	60	9.94714	100	8.85225	60	11.98988	100	13.25859
		80	10.55609			80	12.73411		
		100	10.99295			100	13.26911		

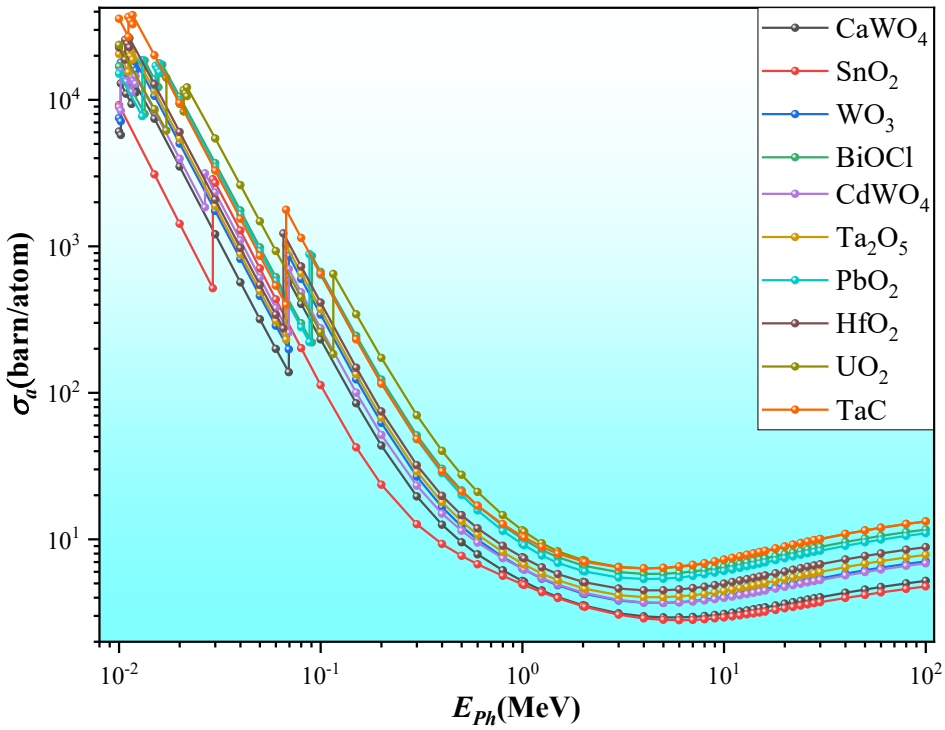

Figure 6. Atomic cross section versus photon energy.

Table 9. Electronic cross section against energy photon.

E(MeV)	$CaWO_4$	E(MeV)	SnO_2	E(MeV)	WO_3	E(MeV)	BiOCl	E(MeV)	$CdWO_4$
0.01	26.33183	0.01	38.90961	0.01	27.49268	0.01	42.86677	0.01	31.70456
0.01021	24.97378	0.015	13.09804	0.01021	26.09815	0.01342	20.31147	0.01021	30.05066
0.01021	56.15385	0.02	6.0287	0.01021	65.57111	0.01342	47.03285	0.01021	55.65068
0.01085	47.72213	0.0292	2.18571	0.01085	55.78123	0.015	34.93294	0.01085	47.27468
0.01154	40.56899	0.0292	12.13853	0.01154	47.43517	0.01571	30.92401	0.01154	40.17638
0.01154	54.32237	0.03	11.47886	0.01154	64.83159	0.01571	42.35515	0.01154	51.46268
0.01182	51.31598	0.04	5.41842	0.01182	61.27483	0.01605	40.27211	0.01182	48.58787
0.0121	48.44781	0.05	2.98895	0.0121	57.92937	0.01639	38.33524	0.0121	45.85502
0.0121	55.46272	0.06	1.83859	0.0121	66.76844	0.01639	44.03619	0.0121	51.56916
0.015	32.22021	0.08	0.85404	0.015	38.91304	0.02	26.6556	0.015	29.89804
0.02	15.19437	0.1	0.47764	0.02	18.41414	0.03	9.37003	0.02	14.08303
0.03	5.23872	0.15	0.17945	0.03	6.37399	0.04	4.44747	0.02671	6.57658
0.04	2.46213	0.2	0.09983	0.04	2.99824	0.05	2.4938	0.02671	11.20822
0.05	1.37845	0.3	0.05355	0.05	1.67696	0.06	1.56082	0.03	8.30856
0.06	0.86563	0.4	0.0393	0.06	1.05083	0.08	0.75684	0.04	3.91826
0.06953	0.59955	0.5	0.03258	0.06953	0.72544	0.09053	0.5595	0.05	2.17385
0.06953	2.51535	0.6	0.02859	0.06953	3.15002	0.09053	2.17879	0.06	1.34655
0.08	1.75338	0.8	0.02382	0.08	2.19286	0.1	1.69603	0.06953	0.91781
0.1	1.00317	1	0.02089	0.1	1.25015	0.15	0.62089	0.06953	2.49044
0.15	0.36733	1.022	0.02062	0.15	0.45146	0.2	0.31209	0.08	1.7295
0.2	0.1892	1.25	0.01842	0.2	0.22809	0.3	0.12977	0.1	0.98205
0.3	0.08504	1.5	0.01677	0.3	0.09822	0.4	0.07689	0.15	0.35704
0.4	0.05453	2	0.01477	0.4	0.06071	0.5	0.05471	0.2	0.18353
0.5	0.04136	2.044	0.01464	0.5	0.04483	0.6	0.04312	0.3	0.0828
0.6	0.03423	3	0.01294	0.6	0.03641	0.8	0.03149	0.4	0.05338
0.8	0.02667	4	0.01222	0.8	0.02769	1	0.02563	0.5	0.04071
1	0.02257	5	0.01194	1	0.02313	1.022	0.02516	0.6	0.03382
1.022	0.02222	6	0.01187	1.022	0.02274	1.25	0.02146	0.8	0.02647
1.25	0.01943	7	0.01192	1.25	0.01972	1.5	0.01915	1	0.02246
1.5	0.01752	8	0.01204	1.5	0.01774	2	0.01682	1.022	0.02211
2	0.01538	9	0.0122	2	0.01563	2.044	0.01669	1.25	0.01937
2.044	0.01526	10	0.01239	2.044	0.01551	3	0.01514	1.5	0.0175
3	0.01357	11	0.01259	3	0.014	4	0.01472	2	0.01542
4	0.01292	12	0.01279	4	0.01353	5	0.01475	2.044	0.0153
5	0.01271	13	0.013	5	0.01348	6	0.01498	3	0.01374
6	0.01271	14	0.0132	6	0.01362	7	0.0153	4	0.01321
7	0.01282	15	0.01339	7	0.01385	8	0.01567	5	0.0131
8	0.013	16	0.01357	8	0.01414	9	0.01607	6	0.01318
9	0.01321	18	0.01394	9	0.01445	10	0.01647	7	0.01337
10	0.01345	20	0.01428	10	0.01478	11	0.01688	8	0.01361
11	0.01369	22	0.01461	11	0.01511	12	0.01729	9	0.01389
12	0.01394	24	0.01491	12	0.01545	13	0.01768	10	0.01418
13	0.01419	26	0.0152	13	0.01577	14	0.01807	11	0.01448
14	0.01444	28	0.01548	14	0.0161	15	0.01844	12	0.01478
15	0.01468	30	0.01573	15	0.0164	16	0.01879	13	0.01508
16	0.01492	40	0.01682	16	0.0167	18	0.01945	14	0.01537

18	0.01535	50	0.01766	18	0.01724	20	0.02006	15	0.01564
20	0.01576	60	0.01836	20	0.01775	22	0.02062	16	0.01591
22	0.01614	80	0.0194	22	0.01822	24	0.02115	18	0.0164
24	0.01651	100	0.02017	24	0.01867	26	0.02164	20	0.01687
26	0.01685			26	0.01908	28	0.0221	22	0.01731
28	0.01717			28	0.01947	30	0.02252	24	0.01772
30	0.01746			30	0.01982	40	0.02431	26	0.0181
40	0.01873			40	0.02134	50	0.02569	28	0.01846
50	0.01972			50	0.02252	60	0.02678	30	0.01879
60	0.02051			60	0.02345	80	0.02841	40	0.02019
80	0.02171			80	0.02486	100	0.02958	50	0.02129
100	0.02257			100	0.02587			60	0.02215
								80	0.02347
								100	0.02442

Table 9. Electronic cross section against energy photon. Continued.

E(MeV)	Ta_2O5	E(MeV)	PbO_2	E(MeV)	HfO_2	E(MeV)	UO2	E(MeV)	TaC
0.01	69.49779	0.01	41.17779	0.01	70.27838	0.01	57.81822	0.01	83.01946
0.01114	52.29185	0.01304	21.0982	0.01074	57.87209	0.015	21.05298	0.01114	62.48777
0.01114	71.44898	0.01304	50.85818	0.01074	78.99146	0.01717	15.03784	0.01114	85.47434
0.01141	67.44017	0.015	34.99751	0.011	74.54528	0.01717	34.42845	0.01141	80.67617
0.01168	63.64422	0.0152	33.80552	0.01127	70.31424	0.02	22.87574	0.01168	76.17556
0.01168	73.36469	0.0152	46.5598	0.01127	81.10699	0.02095	20.28012	0.01168	87.85483
0.015	39.05925	0.01553	44.28418	0.015	39.29852	0.02095	28.43154	0.015	46.75424
0.02	18.45824	0.01586	42.11693	0.02	18.55564	0.02135	27.09363	0.02	22.10505
0.03	6.37861	0.01586	48.51032	0.03	6.40035	0.02176	25.81769	0.03	7.63615
0.04	2.99596	0.02	27.06536	0.04	3.00189	0.02176	29.66009	0.04	3.58152
0.05	1.67483	0.03	9.5034	0.05	1.67736	0.03	13.28434	0.05	1.99886
0.06	1.04903	0.04	4.50427	0.06	1.05023	0.04	6.38334	0.06	1.24901
0.06742	0.78225	0.05	2.52629	0.06535	0.84657	0.05	3.612	0.06742	0.92913
0.06742	3.43977	0.06	1.57993	0.06535	3.7685	0.06	2.26862	0.06742	4.12122
0.08	2.21513	0.08	0.76504	0.08	2.24425	0.08	1.0984	0.08	2.65015
0.1	1.2594	0.088	0.60539	0.1	1.27111	0.1	0.63469	0.1	1.50343
0.15	0.45339	0.088	2.41215	0.15	0.45645	0.1156	0.44913	0.15	0.5371
0.2	0.22871	0.1	1.74392	0.2	0.22984	0.1156	1.57888	0.2	0.26792
0.3	0.09838	0.15	0.63681	0.3	0.09871	0.15	0.83847	0.3	0.11233
0.4	0.06077	0.2	0.31844	0.4	0.06096	0.2	0.42252	0.4	0.06781
0.5	0.04491	0.3	0.13134	0.5	0.04504	0.3	0.17149	0.5	0.04921
0.6	0.03643	0.4	0.0773	0.6	0.03657	0.4	0.09803	0.6	0.03939
0.8	0.02774	0.5	0.05469	0.8	0.02782	0.5	0.06726	0.8	0.02948
1	0.02317	0.6	0.04295	1	0.02324	0.6	0.05137	1	0.02438
1.022	0.02279	0.8	0.03118	1.022	0.02286	0.8	0.03571	1.022	0.02396
1.25	0.01977	1	0.0253	1.25	0.01984	1	0.02813	1.25	0.02066
1.5	0.01779	1.022	0.02483	1.5	0.01786	1.022	0.02752	1.5	0.01856
2	0.01569	1.25	0.02113	2	0.01577	1.25	0.02293	2	0.01642
2.044	0.01557	1.5	0.01884	2.044	0.01565	1.5	0.02019	2.044	0.01631
3	0.0141	2	0.01657	3	0.01421	2	0.0176	3	0.01498
4	0.01367	2.044	0.01645	4	0.01382	2.044	0.01746	4	0.01472

5	0.01364	3	0.01499	5	0.01383	3	0.01584	5	0.01487
6	0.01381	4	0.01463	6	0.01402	4	0.01545	6	0.01518
7	0.01406	5	0.01471	7	0.01431	5	0.01554	7	0.01557
8	0.01437	6	0.01497	8	0.01464	6	0.01583	8	0.01601
9	0.0147	7	0.01532	9	0.015	7	0.01622	9	0.01646
10	0.01505	8	0.01572	10	0.01536	8	0.01666	10	0.01691
11	0.0154	9	0.01614	11	0.01573	9	0.01713	11	0.01736
12	0.01574	10	0.01657	12	0.0161	10	0.0176	12	0.01781
13	0.01609	11	0.01699	13	0.01646	11	0.01807	13	0.01824
14	0.01643	12	0.01741	14	0.01681	12	0.01853	14	0.01866
15	0.01674	13	0.01782	15	0.01714	13	0.01899	15	0.01906
16	0.01705	14	0.01822	16	0.01745	14	0.01943	16	0.01943
18	0.01762	15	0.0186	18	0.01804	15	0.01985	18	0.02014
20	0.01814	16	0.01897	20	0.01859	16	0.02025	20	0.02078
22	0.01863	18	0.01965	22	0.0191	18	0.021	22	0.02137
24	0.01908	20	0.02027	24	0.01957	20	0.02169	24	0.02193
26	0.01951	22	0.02085	26	0.02001	22	0.02233	26	0.02244
28	0.01992	24	0.02139	28	0.02043	24	0.02293	28	0.02293
30	0.02029	26	0.02189	30	0.02082	26	0.02349	30	0.02338
40	0.02186	28	0.02236	40	0.02244	28	0.024	40	0.02527
50	0.02307	30	0.0228	50	0.02369	30	0.02449	50	0.02671
60	0.02403	40	0.02463	60	0.02468	40	0.0265	60	0.02786
80	0.02547	50	0.02603	80	0.02618	50	0.02803	80	0.02956
100	0.02651	60	0.02714	100	0.02725	60	0.02925	100	0.03079
		80	0.0288			80	0.03106		
		100	0.02999			100	0.03237		

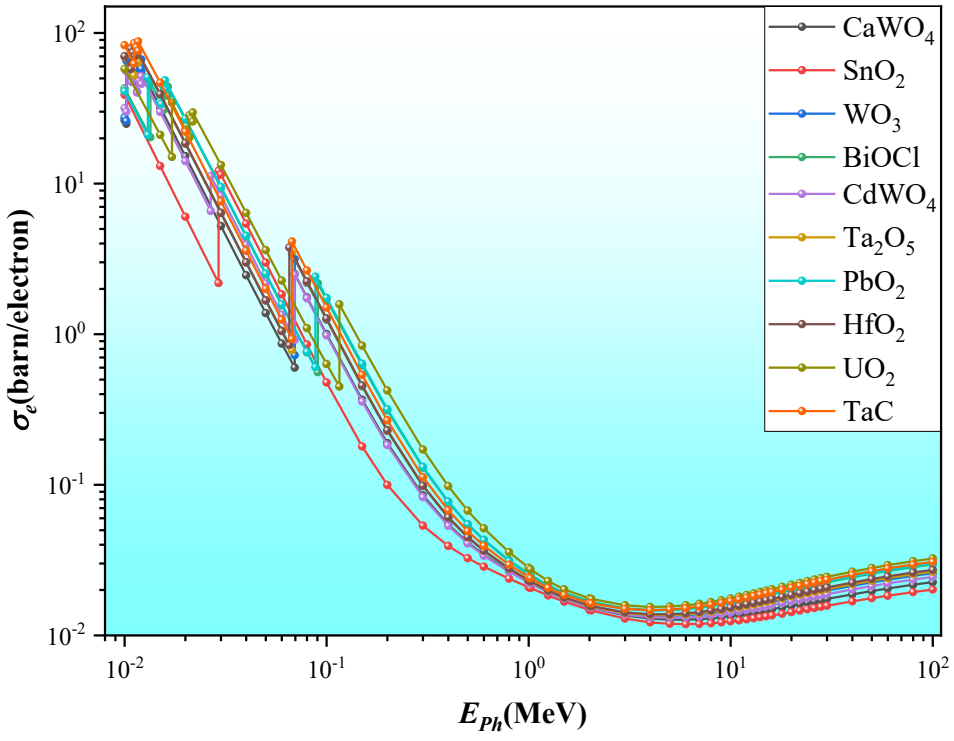

Figure 7. Electronic cross section versus photon energy.

Table 10. Represents the highest and lowest values for tables (3-9).

Representative equation	Value	E	$CaWO_4$	E	SnO_2	E	WO3	E	BiOCl	E	CdWO4
$\mu_t\left(\frac{cm^2}{g}\right)$	MIN	6	0.037	6	0.034	5	0.0381	4	0.0401	5	0.037
	MAX	0.01021	162.5	0.01	110.3	0.0121	189.6	0.01342	128.7	0.01021	156.8
$\mu(cm^{-1})$	MIN	6	0.223	6	0.234	5	0.2742	4	0.311	5	0.292
	MAX	0.01021	984.75	0.01	766.6	0.0121	1357.5	0.0134	993.6	0.01021	1238.72
HVL (cm)	MIN	0.01021	0.0007	0.01	0.0009	0.0121	0.00051	0.01342	0.0007	0.01021	0.00056
	MAX	6	3.11	6	2.97	5	2.528	4	2.23	5	2.377
λ (cm)	MIN	0.01021	0.001	0.01	0.0013	0.0121	0.00074	0.01	0.0010	0.01021	0.0008
	MAX	6	4.49	6	4.28	5	3.65	4	3.216	5	3.43
$\sigma_m\left(\frac{barn}{molecule}\right)$	MIN	6	17.58	6	8.42	5	14.74	4	17.42	5	22.08
	MAX	0.01021	77683.26	0.01	27599.7	0.0121	72981.68	0.01342	55648.9	0.01021	93785.82
$\sigma_a\left(\frac{barn}{atom}\right)$	MIN	6	2.93	6	2.806	5	3.685	4	5.806	5	3.68
	MAX	0.01021	12947.21	0.01	9199.91	0.0121	18245.42	0.01342	18549.6	0.01021	15630.97
$\sigma_e\left(\frac{barn}{electron}\right)$	MIN	6	0.013	6	0.012	5	0.0135	4	0.015	5	0.0131
	MAX	0.01021	56.15	0.01	38.91	0.0121	66.77	0.01342	47.033	0.01021	55.651

Table 10. Represents the highest and lowest values for tables (3-9) Continued.

Representative equation	Value	E	Ta2O5	E	PbO2	E	HfO2	E	UO2	E	TaC
$\mu_t\left(\frac{cm^2}{g}\right)$	MIN	5	0.03846	4	0.04051	4	0.03854	4	0.04239	4	0.03958
	MAX	0.01168	206.8	0.01304	140.8	0.01127	226.2	0.01	158.6	0.01168	236.2
$\mu(cm^{-1})$	MIN	5	0.3154	4	0.38	4	0.3731	4	0.465	4	0.574
	MAX	0.01168	1695.76	0.01304	1320.704	0.01127	2189.62	0.01	1739.84	0.01168	3424.9
HVL (cm)	MIN	0.01168	0.00041	0.01304	0.00052	0.01127	0.00032	0.01	0.0004	0.01168	0.0002
	MAX	5	2.198	4	1.8242	4	1.86	4	1.491	4	1.21
λ (cm)	MIN	0.01168	0.00059	0.01304	0.00076	0.01127	0.00045	0.01	0.00057	0.01168	0.0003
	MAX	5	3.171	5	2.632	4	2.68	4	2.1505	4	1.74
$\sigma_m\left(\frac{barn}{molecu}\right)$	MIN	5	28.23	4	16.09	4	13.47	4	19.005	4	12.68
	MAX	0.01168	151723.15	0.01304	55917.92	0.01127	79051.7	0.01	71105.4	0.01168	75671.85
$\sigma_a\left(\frac{barn}{atom}\right)$	MIN	5	4.031	4	5.363	4	4.49	4	6.33492	4	6.34
	MAX	0.01168	21674.74	0.01304	18639.31	0.01127	26350.6	0.01	23701.8	0.01168	37835.9
$\sigma_e\left(\frac{barn}{electron}\right)$	MIN	5	0.01364	4	0.01463	4	0.0138	4	0.0155	4	0.015

	MAX	0.01168	73.365	0.01304	50.86	0.01127	81.107	0.01	57.82	0.01168	87.86

Conclusion

Our results show that some of these compounds have good shielding properties, such as (TaC), while the compound (SnO2) showed less shielding effectiveness due to its low mass density and relatively medium atomic numbers compared to the rest of the compounds under study. The behaviour of the variables is almost similar, as they decrease rapidly and then show a lesser response at high energies. Some of them can be used as protective shields against X-rays and gamma rays of different energy ranges in many fields such as health centres, scientific research fields, and various nuclear facilities.

REFERENCES

[1] Y. Elmahroug, B. Tellili, and C. Souga, "Calculation of gamma and neutron shielding parameters for some polyethylene-based materials," International Journal of Physics and Research, vol. 3, pp. 33–40, 2013.

[2] H. O. Tekin, E. Kavaz, A. Papachristodoulou, M. Kamislioglu, O. Agar, E. E. Altunsoy Guclu, O. Kilicoglu, and M. I. Sayyed, "Characterization of SiO2-PbO-CdO-Ga2O3 glasses for comprehensive nuclear shielding performance: Alpha, proton, gamma, neutron radiation," Ceramics International, vol. 45, pp. 19206–19222, 2019.

[3] CIE, International Lighting Vocabulary, 4th ed. Vienna, Austria: International Commission on Illumination (CIE), 1987. ISBN: 978-3-900734-07-7.

[4] G. K. Pal and P. Pal, "Chapter 52," in Textbook of Practical Physiology, 1st ed. Chennai, India: Orient Blackswan, 2001, p. 387.

[5] M. Sayyed, A. Kumar, H. Tekin, R. Kaur, M. Singh, O. Agar, and M. U. Khandaker, "Evaluation of gamma-ray and neutron shielding features of heavy metals doped Bi2O3-BaO-Na2O-MgO-B2O3 glass systems," Progress in Nuclear Energy, vol. 118, p. 103118, 2020.

[6] N. Prabhu, V. Hegde, M. Sayyed, O. Agar, and S. D. Kamath, "Investigations on structural and radiation shielding properties of Er3+ doped zinc bismuth borate glasses," Materials Chemistry and Physics, vol. 230, pp. 267–276, 2019.

[7] K. Singh and L. Gerward, "Summary of existing information on gamma-ray and X-ray attenuation coefficients of solutions," Indian Journal of Pure and Applied Physics, vol. 40, no. 9, pp. 643–649, 2002.

[8] S. S. Obaid, M. Sayyed, D. Gaikwad, and P. Pawar, "Attenuation coefficients and exposure buildup factor of some rocks for gamma ray shielding applications," Radiation Physics and Chemistry, vol. 148, pp. 86–94, 2018.

[9] K. Singh, N. Singh, K. J. Singh, and H. Singh, "Comparative study of lead borate and bismuth lead borate glass systems as gamma-radiation shielding materials," Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms, vol. 225, no. 3, pp. 305–309, 2004. [Online]. Available: https://doi.org/10.1016/j.nimb.2004.05.016

[10] V. P. Singh and N. M. Badiger, "Shielding efficiency of lead borate and nickel borate glasses for gamma rays and neutrons," Glass Physics and Chemistry, vol. 41, no. 3, pp. 276–283, 2015. [Online]. Available: https://doi.org/10.1134/S1087659615030177

[11] Y. B. Saddeek, K. A. Aly, and M. S. Shaaban, "Physical, optical, structural and gamma-ray shielding properties of lead sodium borate glasses," Journal of Physics and Chemistry of Solids, vol. 72, no. 4, pp. 245–251, 2011. [Online]. Available: https://doi.org/10.1016/j.jpcs.2011.01.007

[12] P. Kaur, K. J. Singh, S. Thakur, P. Singh, and B. S. Bajwa, "Investigation of bismuth borate glass system modified with barium for structural and gamma-ray shielding properties," Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy, vol. 206, pp. 367–377, 2019. [Online]. Available: https://doi.org/10.1016/j.saa.2018.08.038

[13] Y. S. Rammah, H. O. Tekin, C. Sriwunkum, I. Olarinoye, A. Alalawi, M. S. Al-Buriahi, T. Nutaro, and B. T. Tonguc, "Investigations on borate glasses within SBC-Bx system for gamma-ray shielding applications," Nuclear Engineering and Technology, vol. 53, no. 1, pp. 282–293, 2021. [Online]. Available: https://doi.org/10.1016/j.net.2020.06.034

[14] A. Aboalatta, J. Asad, M. Humaid, H. Musleh, S. K. K. Shaat, K. Ramadan, M. I. Sayyed, Y. Alajerami, and N. Aldahoudi, "Experimental investigation of zinc sodium borate glass systems containing barium oxide for gamma

radiation shielding applications," Nuclear Engineering and Technology, vol. 53, no. 9, pp. 3058–3067, 2021. [Online]. Available: https://doi.org/10.1016/j.net.2021.04.002
[15] M. S. Al-Buriahi, "Gamma attenuation parameters of some borate glasses," arXiv preprint arXiv:2012.12315, 2020. [Online]. Available: https://arxiv.org/abs/2012.12315