Calculation of Gamma-ray Mass Absorption Coefficients for some Geological Compounds for Energy of 10–150 keV

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Abstract— Information about gamma-ray mass absorption coefficients in different geological compounds with different percentage to their rations is vital for accurate gamma-ray spectroscopy analysis. In this paper, gamma-ray absorption coefficients for energy (10-150 keV) were calculated for Corundum (AL_2O_3), Quartz (SiO_2), Calcite ($CaCO_3$), Hematite (Fe_2O_3), and Magnetite (Fe_3O_4) compounds with their % mixtures.

Keywords — Mass Absorption Coefficients; Gamma-Ray Spectroscopy; Geology; Mixtures.

1. Introduction

The most important description of the amount of radiation penetration into the material is the Linear Attenuation Coefficient, which is a quantity that depends on the energy of the incident photon and the atomic number of the material. This quantity represents a fraction of the energy lost from the incident photon for every 1cm penetrated through the material. The unit of linear absorption coefficient μ is cm^{-1}. According to Lambert - Beer's law [1-6], when a narrow photon beam of single-energy $h\upsilon_0$ and a flux density N_0 (the number of photons per unit area and time) falls on a homogeneous medium and penetrates it a distance (x), the flux density of the transmitted photon beam from this medium is N and is given as:

$$N(X) = N_0 e^{-\mu x}$$

(1)

This law shows that the transmitted photons decrease exponentially with the thickness of the absorbent material. It can be stated that, when photon energies are greater than electron binding energies, μ is directly proportional to the physical density of the absorbent material [5, 7]. Therefore, equation (1) can be rewritten as follows:

$$N = N_0 e^{-\left[\frac{\mu}{\rho}\right]x\rho}$$

(2)

Where (μ/ρ) is the mass absorption coefficient (cm^2/g). This quantity (μ/ρ) is related to the probability (or cross-section) that the beam will interact with matter and contribute in some way. Each interaction somehow contributes to the loss of a number of photons from the incident photon ray even though the scattering of the photon does not lead to its absorption from the photon beam. This probability gives a measure of the mass absorption of the photons that pass through the medium and since there are three basic interactions that occur when

the photon interacts with the material, and these interactions are the phenomenon of photoelectric absorption (ph), Compton scattering (C) and Rayleigh scattering (R), the mass absorption coefficient It can be written as follows:

$$\left(\frac{\mu}{\rho}\right) = \left(\frac{\mu}{\rho}\right)_{ph} + \left(\frac{\mu}{\rho}\right)_C + \left(\frac{\mu}{\rho}\right)_R$$

(3)

2. Mass Absorption Coefficient of Mixtures

When the absorbent material is a homogeneous mixture of different types of elements (chemical compound) or a mixture, the mass attenuation coefficient is given as [6]

$$\mu / \rho = \sum_j w_j \mu_j / \rho_j$$

(4)

Where w_j represents the weight of the component j, μ_j represents the element's linear attenuation coefficient for element j and ρ_j is the density of element j.

3. Calculation of the Mass Absorption Coefficient of some Geological Components

The mass absorption coefficients for Corundum (AL_2O_3), Quartz (SiO_2), Calcite ($CaCO_3$), Hematite (Fe_2O_3), and Magnetite (Fe_3O_4) compounds with their % mixtures were calculated as a function of incident photon energies (10 – 150 keV). Table1 shows the mass absorption coefficient of a mixture in terms of the energy of the incident photon.

Figure1 shows the calculated mass absorption coefficients for AL_2O_3, SiO_2 and Fe_3O_4 as a function of incident photon energies. It can be seen from figure1, that Haematite (density 5.3 gm./cm^3) has higher mass absorption coefficients than Corundum (density 4.02

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gm./cm^3) and Quartz (density 2.65 gm./cm^3) due to differences in density.

Table1: The calculated mass absorption coefficients for different compounds as a function of incident photon energies

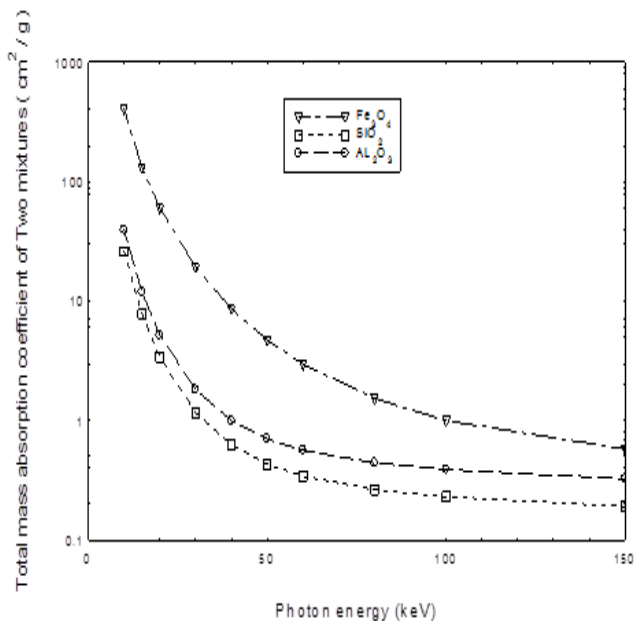| Energy (keV)	Corundum AL$_2$O$_3$	Quartz SiO$_2$	Calcite CaCO$_3$	Hematite Fe$_2$O$_3$	Magnetite Fe$_3$O$_4$
	Total mass absorption coefficient (cm^2/g)				
10	39.53	25.98	61.25	272.38	407.93
15	11.89	7.80	19.11	87.97	131.77
20	05.20	3.39	8.28	40.26	60.30
30	01.82	1.17	2.65	12.88	19.28
40	00.99	0.63	1.26	5.79	8.66
50	00.70	0.43	0.77	3.16	4.72
60	00.56	0.34	0.54	1.99	2.97
80	00.44	0.26	0.36	1.03	1.53
100	00.38	0.23	0.28	0.67	1.00
150	00.32	0.19	0.21	0.39	0.57

Fig.1: shows mass absorption coefficients for AL$_2$O$_3$, SiO$_2$ and Fe$_3$O$_4$ in the energy range (10 – 150 keV).

Table2 shows the calculations of the mass absorption coefficients of two mixtures in fixed proportions in terms of the energy of the incident photon.

Figure2 shows the mass absorption coefficients of two mixtures with 50% proportions in the photon energy range (10 – 150 keV). As shown in figure2 that the two curves for the mass absorption coefficients of two mixtures

(CaCO3 50 %; AL2O3 50 %) and (SiO2 50 %; AL2O3 50 %) are very close to each other due to the fact that (CaCO3 and SiO2) have almost the same density values.

Table2: Calculations of the mass absorption coefficients of two mixtures in terms of the energy of the incident photon

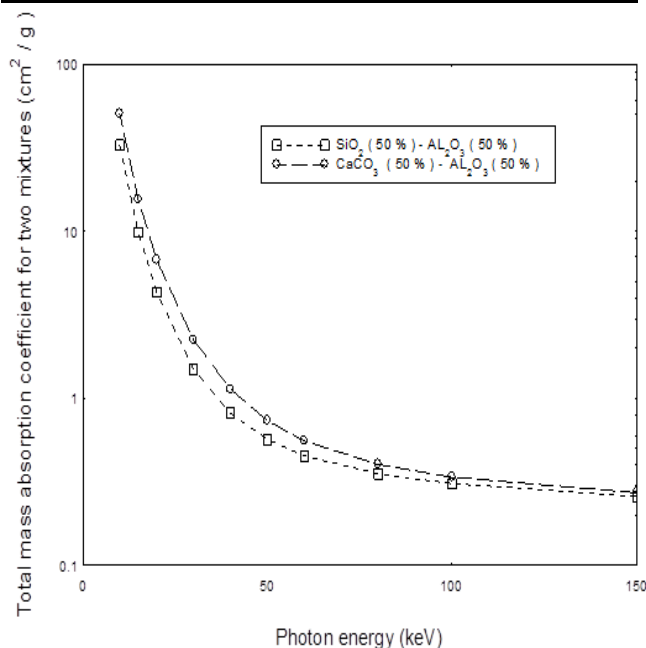| Energy (keV)	CaCO$_3$ 50 % AL$_2$O$_3$ 50 %	SiO$_2$ 50 % AL$_2$O$_3$ 50 %
	Mass absorption coefficients (cm2/g)	
10	50.39	32.75
15	15.50	9.85
20	6.74	4.29
30	2.23	1.49
40	1.13	0.81
50	0.73	0.56
60	0.55	0.45
80	0.40	0.35
100	0.33	0.30
150	0.27	0.25

Fig.2: The mass absorption coefficient of two mixtures in the photon energy range (10 – 150 keV)

Table3 shows the mass absorption coefficient of three compounds with different ratios in terms of the energy of the incident photon.

Figure3 shows the projection of the calculated mass absorption coefficients of three compounds (SiO2 20 %, CaCO3 60 % and AL2O3 20 %) as a function of incident

photon energies. This curve shows higher values of mass absorption coefficients for the mixture which made up of light and relatively higher atomic numbers.

Table3: Calculated mass absorption coefficient of three compounds with different ratios as a function of incident photon energies

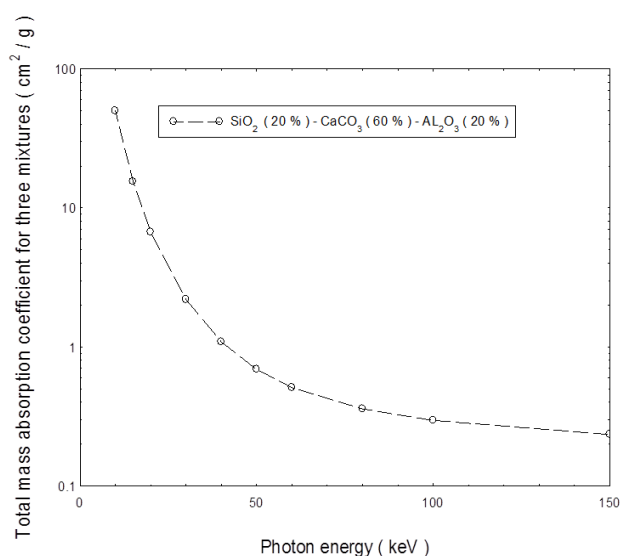| Energy (keV)	SiO$_2$ 20 % CaCO$_3$ 60 % AL$_2$O$_3$ 20 %
	Mass absorption coefficients of three mixtures (cm2/g)
10	49.85748552
15	15.41015454
20	6.689505311
30	2.192178901
40	1.085724707
50	0.689576363
60	0.510042313
80	0.358827563
100	0.296490347
150	0.234766092

Fig.3: shows the curve of mass absorption coefficient of three compounds with different proportions as a function of incident photon energies (10-150 keV).

5. Conclusion

In x-ray and gamma- ray spectroscopy analysis, it is always required appropriate correction for data matrix of geological materials. However, there are many corrections to be taken into account. Such corrections depend on the type of analysis required. One such important correction is mass absorption coefficients. Since the mass absorption coefficients for materials cannot be measured experimentally due to the fact that there are many different scattering processes involved. Therefore, seeking a theoretical method for calculation of mass absorption coefficients of materials appears to be the only method that is available. This paper deals with estimation of mass absorption coefficients for some geological compounds and their mixtures for incident photon energies (10 -150 keV). As seen from the above figures, the mass absorption coefficients curves show exponential decrease as a function of increasing photon energy. This last point has many theoretical and practical applications in different research desplines.

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