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GAMMA RAY ATTENUATION COEFFICIENTS IN HIGH Z ELEMENTS NEAR K-ABSORPTION REGION.

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ABSTRACT :

Total gamma ray mass attenuation coefficient and hence photo-electric mass attenuation coefficient for some high Z elements are measured using high resolution detector in the energy region 6.4-22.1 keV. A comparison of measured data with NIST[(3)] values suggest that renewed atoms are needed for compiling accurate experimental mass attenuations of elements especially in the region of absorption edges so that criteria can be worked out for computing data in case of pure metals.

KEYWORDS: Mass attenuation coefficient: HPGe detector; absorption edge.

1. INTRODUCTION

The mass attenuation coefficient values are very important near absorption edges. Total photon interaction comprises three processes, viz. photo electric effect, coherent and incoherent scattering processes. Of these photo electric effect is the most dominating process, especially in the region of absorption edges. Repeated attempts, both theoretical and experimental have been made over 60 years to obtain data with high accuracy. In the last decades, one experimental completions have appeared by viegele[(1)]. Similarly two theoretical completions appeared on the photoelectric cross-section; one by Berger[(3)] and other by scofield[(2)]. There are broadly two methods[5] for the measurement of photoelectric cross-sections. One of the methods is to measure the photoelectron intensity or the X-ray intensity following the photoelectron. The other one is simply to measure the total photon attenuation coefficient by conducting a transmission experiment on 'good geometry' setup and then to subtract the contribution due to the other partial cross-sections which vary from 1 to 15% of the total in the vicinity of absorption edges. Thus the second method is very well applicable at these energies and information can be obtained not only on the total but also on the photoelectric process. After the advent of the high resolution, low background solid state detectors, there is a renewed interest on these measurements. In the present investigation, measurements were made for pure Cu, Cd and Sn foils in the energy region 6.4-22.1 keV using an HPGe detector system.

2. EXPERIMENTAL DETAILS

Total photon attenuation coefficients can be measured on a good geometry[(4)] setup by conducting transmission experiments. In the present investigations, since all the measurements are confined to the lower energy region, i.e. from 6.4 to 22.1 keV, a compact geometrical arrangement is shown in Fig (1). An intrinsic germanium detector 5 mm thick coupled with 16k-multichannal analyzer was used. The shape of each line is fitted with one Gaussian curve. Typically it has a 0.6 keV in the region of interest, which is made by sandwiching collimators of Pb, Cu and Al, always the lowest Z element facing the detector. This is called a graded collimator which reduces the interference of the X-rays produced in the collimators. The collimators are 2" diameter discs of thicknesses ranging from 2mm to 1cm with the central hole diameter ranging from 2mm to 4mm. Suitable combinations were used to achieve the good geometrical conditions.

A thin foils of different thickness of Cu, Cd and Sn are chosen for the present investigations. Gamma-ray sources of ^{57}Co, ^{65}Zn and a variable X-ray source employing ^{241}Am as the primary source were used to perform transmission experiments.

Mass attenuation coefficient of foils are calculated using Beer-Lambert's exponential law as

$$\frac{\mu}{\rho} = \frac{1}{\rho t} \ln\left(\frac{I_0}{I}\right) , \quad cm^2/gram \qquad (1)$$

where I_0 and I are initial and final intensities of gamma rays number of counts and ρt is mass thickness of absorber.

Experiments were carried out at different positions of the foils in different samples and then the errors were evaluated. As such, the present total photon attenuation coefficients are accurate within 2 to 3%. As mentioned, the photoelectric mass absorption coefficients were obtained by subtracting the theoretical contribution(3) due to coherent and incoherent scattering which is no case exceeded 10% of the total but in most of these cases it was less than 3% so, no additional errors are included in the photoelectric absorption coefficients. However, the error in the magnitude of the total photon attenuation coefficient is transferred to the photoelectric absorption coefficient.

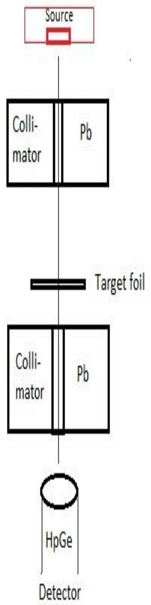

Fig:1 Schematic experimental arragement of attenuation measurement.

3. RESULT AND DISCUSSION

The experimental total photon attenuation coefficients photo-electric coefficient are compared with the theoretical completions of Berger(3) et al.. For comparison, values computed using those in elements are also reported. It can be seen that there are deviations up to 2 to 3% beyond the experimental errors near k-absorption edge. Photoelectric mass absorption coefficients were also deduced from present total coefficients by subtracting the contributions due to the coherent and incoherent scattering (which newer exceeded 15% of the total in any of the present cases) as reported by Berger. For comparison, photoelectric coefficients were also computed using theoretical values of XCOM. These values are also given in Table 1. It can be seen that the agreement between the theory and experiment is reasonably satisfactory within the range of errors. But the present findings suggest that the renewed attempts are needed for experimental completions of attenuation coefficients of elements, is specially in the region of absorption edges so that criteria can be worked out for computing data in case of metal elements.

Table 1. Total mass attenuation coefficient and photo-electric effect for Cu, Cd and Sn at various energies.

Energy keV	Total Photon Attenuation Coefficient ($cm^2/gram$)				Photoelectric, mass absorption coefficients (cm^2/gm)		
	Comparison	Cu	Cd	Sn	Cu	Cd	Sn
6.40	Expt.	98.04	398.54	433.57	91.87	394.65	4.32.25
	Berger	98.82	404.60	443.20	94.41	400.70	441.12
	% err.	0.78	1.49	2.18	2.69	1.50	2.00
7.10	Expt.	71.75	310.50	339.20	68.98	305.57	338.98
	Berger	72.83	308.10	337.50	70.64	304.60	334.71
	% err.	1.89	-0.77	-0.50	2.16	-0.31	-1.27
8.04	Expt.	52.04	224.21	241.07	48.43	221.86	242.98
	Hubb	51.84	222.40	243.50	49.91	219.20	239.60
	% err.	-0.38	-0.80	1.02	2.16	-1.21	-1.41
10.53	Expt.	193.10	108.20	118.17	185.03	106.95	117.43
	Berger	190.20	108.20	117.80	188.80	105.70	116.47
	% err.	-1.52	1.01	1.06	2.01	-1.18	-0.82
14.41	Expt.	81.75	45.20	49.61	82.90	43.82	48.50
	Berger	82.64	46.52	50.01	81.62	44.67	48.89
	% err.	1.43	2.8374	0.81	-1.56	1.90	0.78
17.44	Expt.	50.53	22.90	29.48	47.08	25.76	30.54
	Berger	49.13	27.77	29.48	48.30	26.28	30.05
	% err.	-2.64	-0.46	2.30	2.52	1.97	-1.63
22.10	Expt.	25.90	14.80	14.80	25.48	13.80	1498
	Berger	25.66	14.65	15.21	25.02	13.53	15.31
	% err.	-0.93	-1.02	2.76	-1.83	-1.99	2.09

Expt.: Experimental values, Theo : Berger XCOM values, % err. shown to XCOM values in two decimal digits.

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