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Research Article

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Photoelectric cross sections deduced from the measured total photon interaction cross sections for five elements (24< z < 82) at 360 keV

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ABSTRACT

The total photon interaction cross sections for five elements (Mg,Ni,Zn,Ag,Au,Pb) in the range 12< z < 82 at photon energy 360 keV have been measured. The photoelectric cross sections at this photon energy have been deduced by subtracting the scattering cross sections from the measured values of total interaction cross sections. The results have been compared with corresponding theoretical values available in the literature.

Keywords: Photoelectric cross sections, total photon interaction cross sections, scattering cross sections.

INTRODUCTION

Mass attenuation and energy absorption coefficients are widely used in the study of interaction of γ-rays with matter. The photoelectric effect, Compton scattering and pair production processes are the predominant interactions between the photons and atoms apart from other types over a wide range of energies. By irradiating the material with γ-rays, ionization of the material takes place and the stored energy of the material increases [1]. Extensive studies have been carried out to determine γ-ray attenuation coefficients for various elements and photon energy [2-4].

Accurate values of photoelectric cross sections for photon radiation in several materials are needed in solving various problems in radiation physics and radiation dosimetry.It is important to note that much of the data is based on theoretical work and only few experimental results are available for comparison. Such comparison is necessary to ensure that the theoretically predicted values do indeed agree with experimental results [5].Although a number of experimental measurements are reported in the literature [6,7], the work therein actually carried out is limited to a few energy points and materials. Further, the experimental techniques used by different workers are not identical and hence it is difficult to intercompare the experimental results. It is, therefore, necessary to carry out accurate measurements of photon attenuation data. Therefore, in the present work accurate photon transmission measurements have been carried out under a narrow beam counting geometry employing high resolution NaI(Tl) as a photon detector. The attenuation data has been used to obtain the photoelectric cross sections. Photoelectric cross sections are determined either by counting the photoelectrons emitted during photoelectric absorption or by detecting those photons which have not undergone any interaction within the material [8, 9]. In the earlier work, the photoelectrons were detected by organic scintillators and total-absorption-proportional counters. The accuracy of the final results was limited by the poor efficiency of either of these detectors. A good photon detector with high-energy-resolution characteristics as used in the present measurements is an essential requirement for higher accuracy. Solid-state detectors have the high-energy resolution characteristics necessary for such measurements to be performed accurately. In view of these facts, it was considered worthwhile to carry out accurate and systematic measurement of total photon cross sections, which form the basic input data for the calculation of photoelectric cross sections. Hence, in the present investigation, systematic measurements on the total photon cross sections at the energy point 360keV, using a high resolution photon detector is made and results are employed to extract photoelectric cross sections.

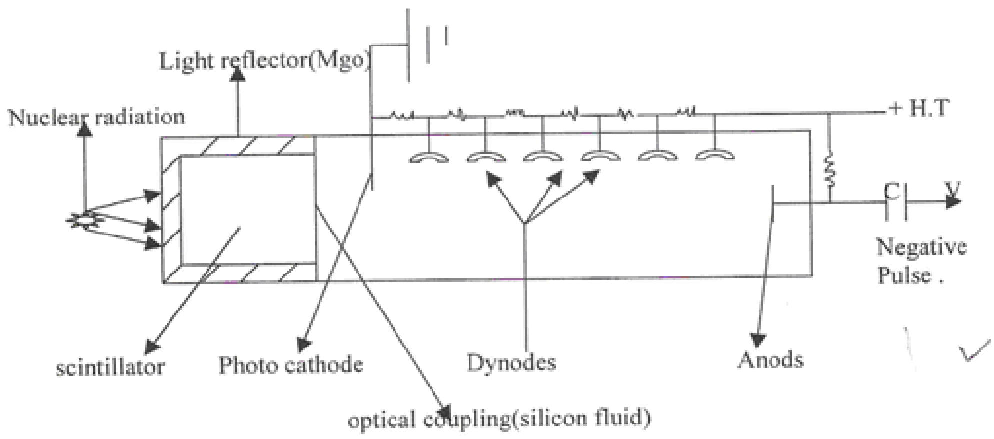

Figure1. Schematic construction of a Scintillation detector

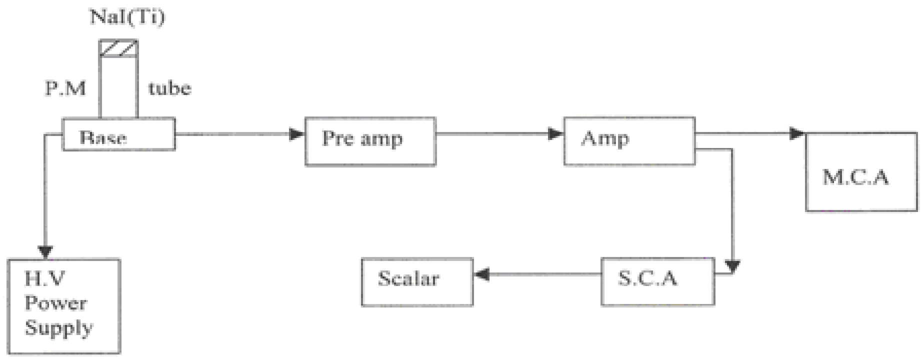

Figure. 2 Block diagram of photon counting system.

EXPERIMENTAL SECTION

In the present work the photoelectric-cross-section values for 360 keV photons are determined in five elemental solids of atomic numbers ranging from 12 to 82 through photon transmission measurements. The monoenergetic photon radiation required for these measurements was derived from Ba^{133} radionuclide .The source was procured as a sealed source from BARC, Trombay, Mumbai. The photon transmission measurements were done under a narrow beam counting geometry employing high resolution NaI(Tl) solid state detector. The NaI (Tl) detector utilized in the present work is of 30.3 cc active volume and was obtained from Nucleonix systems Hyderabad India.. The detector was operated at liquid nitrogen temperature and had a good stability of the order of 0.01 % over the entire range of photon energy. The energy resolution of the detector at 360 keV from Ba^{133} was about 3.3% with full width at half maxima (FWHM) being 3.9 keV.The experimental set up used in the present work as shown in figure1. The experimental system consists mainly of two aluminum collimators of about 12 cm long, having internal and external diameters of 10 and 60 mm, respectively. These collimators were internally lined with 4 mmthick perspex so as to provide a scatter-free collimated photon beam 2mm in diameter. With the present experimental system, it was established from the photon spectrum that the energy of transmitted photons did not change appreciably due to scatter or fluorescent radiation from the collimators. A provision was made midway between the collimators to introduce absorbers which were in the form of thin foils. The entire system was arranged vertically over the NaI(Tl) detector, ensuring that the central axis of the collimators coincided with the central axis of the detector. Radioactive source of Ba^{133} had thin beryllium windows for the exit of photon radiations. The source was kept in a lead container which was provided with an aperture for the exit of photons. The source container assembly was then kept over the collimator so as to allow a narrow, well collimated photon beam from the collimator incident normally on the absorbers. The source and the detector were well aligned with the collimators. The incident energy of photon radiations from the source was known accurately from the photon spectrum. The chosen absorbers include thin and uniform foils of high purity of chromium, nickel, copper, silver and lead. These foils were weighed accurately using a digital balance, and from their measured area the thickness proportional to the areal density in g cm-2 was determined. The absorbers had varying thicknesses of a few mg cm-2and higher thicknesses were obtained by stacking the foils together. The presently used absorbers are uniform sheets of Mg,Ni,Zn,Ag,Au,Pb. These sheets/foils were weight accurately and from their measured area, the thickness (t) in gm/cm2 was determined in each case. The absorbers had varying thicknesses of a few mg/cm2. The higher values of thickness were obtained by stacking required number of foils together. The absorbers used were of nuclear grade of specified purity of the order of 99.95%. No further attempts were made to ascertain the purity of these absorbers.

RESULTS AND DISCUSSION

The physical characteristics of the absorber including atomic number Z, density g/cm3 and purity are given in Table 1.

Table I. Purities and atomic weights of the absorbers used.

Element	Atomic Number Z	Density g/cm3	Purity
Mg	12	1.74	99.99%
Ni	28	8.91	99.99%
Zn	30	7.13	99.99%
Ag	47	10.48	99.99%
Au	79	19.32	99.99%
Pb	82	11.34	99.99%

The target foils used were circular in shape (1.6 cm diameter) and each foil was of uniform thickness. The maximum thickness t for each foil was chosen such that the condition $\mu t<1$ is satisfied. [10]The individual thicknesses varied from element to element and the purity of the target materials was higher than 99.7%.The total photon absorption cross sections were calculated by using expressions

μ=-ln (I/I0)/t

and

σ_{tot}= μ/ρ (A/N) x 1024,

Where I and I_0 are the photon intensities with and without foil, t is the thickness of the foil expressed in g/cm2, μ is the mass attenuation coefficient, A is the atomic weight, N is

Avogadro's number, and σ_{tot} is the total photon interaction cross section in b/atom. The photoelectric cross sections were obtained by subtracting the scattering (coherent plus incoherent) cross sections as interpolated from the compilation work of E.B.Saloman [11]

Table II. Total photon absorption cross sections (b/atom) at 360 keV.

Mg	Ni	Zn	Ag	Au	Pb
1.99 a	4.65 a	5.18 a	10.45 a	38.03 a	42.89 a
1.98 b	4.70b	5.20 b	10.50b	38.05 b	42.88 b

a Experimental results   b J.H.Hubble (Ref.12)

Table III. Interpolated theoretical values of coherent (first row) and incoherent (second row) scattering cross sections as taken from b J.H.Hubble (Ref.12)

Mg	Ni	Zn	Ag	Au	Pb
0.0047	0.0043	0.0047	0.0096	0.022	0.024
0.099	0.095	0.091	0.086	0.077	0.076

The measured total absorption cross sections for various elements at 360 keV have been listed in Table 2 along with those obtained from the J.H.Hubble (Ref.12)

Table IV. Photoelectric cross sections (b/atom). For each photon energy and element In the case of Mg ,Ni , Zn ,Ag, Au and Pb the theoretical values of J.H.Hubble (Ref.12) are also given in the second row.

			Photoelectric cross section (b/atom)		
Magnesium	Nickel	Zinc	Silver	Gold	Lead
1.8863	4.5507	5.0843	10.3544	37.931	42.79
1.8763	4.6007	5.1043	10.4044	37.951	42.78

CONCLUSION

From the results of the present study, it is observed that the errors quoted are due to mainly counting statistics, since the sample impurity corrections are negligible. The agreement seems to be good within experimental error. The photoelectric cross sections have been obtained by subtracting the coherent and incoherent scattering cross sections, given in Table III, and are presented in Table IV .In the case of Mg,Ni, Zn,Ag, Au and Pb the corresponding interpolated theoretical values reported by J.H.Hubbell[12] have also been quoted. The errors in the estimated photoelectric cross sections are the same as those in the measured total absorption cross sections. The agreement between measured values and the theoretically predicted values lies within 1-4 %for all of the elements [13].

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