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The Study of Photon Cross Sections of Nickel Doped Nano Materials at Low Energies of Gamma Rays

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ABSTRACT : The photon cross section studies of nickel doped nano materials are measured using gamma ray spectrometry based NaI (TI) scintillation detector with the energies, i.e.,30.85 KeV,32.1 KeV, 42.0 KeV, and 59.54 KeV respectively. The samples, such as nickel doped nano materials are prepared in the laboratoryby citrate-gel auto combustion method. From the experiment by using gamma ray spectrometer, the mass attenuation coefficients are measured first, and then the photon cross section values are extracted. The Photon cross section values are compared with theoretical values of XCOM programme. The Photon cross section values are very good agreement with theoretical values XCOM programme.
Keywords : gamma ray spectrometer, Photon cross section studies of nickel doped nano materials, energies 30.85 KeV,32.1 KeV, 42.0 KeV, and 59.54 KeV.

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I. INTRODUCTION:

In the present work, we have used synthesized nickel doped nano materials $\mathbf{Zn_{0.93}(Ni_{0.06}\ Y_{0.01})O}$, $\mathbf{Zn_{0.91}(Ni_{0.06}\ Y_{0.03})O}$, $\mathbf{Zn_{0.89}(Ni_{0.06}\ Y_{0.05})O}$, $\mathbf{Zn_{0.87}(Ni_{0.06}\ Y_{0.07})O}$, $\mathbf{Zn_{0.85}(Ni_{0.06}\ Y_{0.09})O}$ as the alloy to get scattered photon cross sections by using gamma ray spectrometer. This is process is called scintillation process. For the preparation of samples we used citrate-gel auto combustion method. In this method, metal alkoxides are dissolved in an organic solvent like benzene, toluene etc, to get a sol, which is further decomposed to get the metal oxides, but most of the metal alkoxides, whose valence is less than four, are not soluble in organic solvents. This sol-gel technique has been modified by the use of metal nitrates, which undergo self combustion when the gel is dried, producing the metal oxides.

This method is more advantages than other preparation techniques. Oxides and their composites can be prepared at very low temperatures (200 ^{o}C), the resultant products are homogeneous and crystalline, soft, highly porous due to the liberation of large amount of gases during the reaction and fine with high surface area, narrow and nano particle distribution, less agglomeration, large scale synthesis is possible and this method is relatively very cheap.

However, the photon cross section studies on metals or alloys are having more importance in various fields like industrial, medical, agriculture etc.

The photon cross section studies of nickel doped nano materials are measured using gamma ray spectrometry based NaI (TI) scintillation detector with low energies, i.e.,30.85 KeV,32.1 KeV, 42.0 KeV and 59.54 KeV respectively.

Experimental Details:

In this investigation, we have two separate experiments, one is citrate-gel auto combustion method and second one is photon cross section experiment. Citrate-gel auto combustion method was used to synthesize nickel based nano materials. The process of citrate-gel auto combustion method was clearly explained in the previous publication [G.Aravind et all.,].

The second experiment is gamma ray spectrometry based NaI (TI) scintillation detector. The radioactive isotopes used in the present investigation are listed in the Table.1, along with their energies and half-lives. These radioactive isotopes Barium (133Ba), Europium(152+154Eu), were obtained from the BRIT, Bhabha Atomic Research Center, Trombay, Mumbai, India and Americium (241Am) of strength 30mCi source obtained from isotope division, Americium Laboratories, Americium, Buckinghamshire, England, U.K.

Sl.No:	**Radioisotope**	**Half-life Time**	**Energy of the Photons selected in KeV[a]**	
			X-Rays	**γ-rays**
1	^{241}Am	433 Years	--	59.54
2	^{133}Ba	10.7 Years	30.85	81
3	$^{(142+154)}$Eu	16.0 Years	42	--

(a C.M. Leadere and V.S. Shirly. Tables of Isotopes Wiley New Yark)

Table.1: Radio Isotopes and photon energies used in the present work.

By using this various type of gamma ray sources we have studies photon cross sections at the energy's 30.85 KeV,32.1 KeV, 42.0 KeV, and 59.54 KeV. The transmission (I/I0) lies between 0.1 to 0.6.

(1) Analysis of experimental data:

In this process, the collected data was calculated by using the standard formulas and methods. Hence, the obtained results are very much approached the theoretical results. These results are tabulated and shown in the tables below. For that results we have been drown a graphs between theoretical XCOM and experimental values versus energy's which was used in the photon cross experiment. These graphs are also shown in the results and discussion.

In this work the data obtained from experimental procedure were analysed by using the standard formulations. The mass attenuation coefficients for wrought Nickel Base alloys at different energies were determined by performing scattering experiments, and by using semi empirical relations were the experimental values are compared.

$I = I \exp(-\mu_m t)$ (1)

Where I_0 and I are the un-attenuated and attenuated photon intensities and the sample thickness is t(g/cm^2)and the linear mass attenuation coefficient is $\mu_m = \mu/\rho$ (cm^2/g).

For any chemical compound or mixture of elements, the mixture rule will give the total mass attenuation coefficient μ_m.

$$\mu_m = \Sigma_i W_i(\mu_m)_i \quad (2)$$

Where, $W_i$is the weight fraction (the proportion by weight) (μ_m) is the mass attenuation coefficient of ith element.

For a material composed of multi element the fraction by weigh is given by,

$$w_i = \frac{n_i A_i}{\sum_i n_i A_i} \quad (3)$$

Where A_i is the atomic weight of the ith element and n_i is the number of formula units.

The total atomic cross-section (σ_t) for materials can be obtained from the measured values of µm using the following relation

$$\sigma_t = \frac{\mu_m N}{N_A} \quad (4)$$

Where $N = \sum_i n_i A_i$ atomic mass of materials, N_A is the Avagadro's number.

The total electronic cross-section (σ_e) for the element is expressed by the following equation

$$\sigma_e = \frac{1}{N_A}\sum \frac{f_i N_i}{Z_i}(\mu_m)_i = \frac{\sigma_i}{Z_{eff}} \quad (5)$$

Where f_i denotes the fractional abundance of the element I with respect to the number of atoms such that f1+f2+f3+f4+….fi =1 Z_i is the atomic number of ith element

The total atomic cross-section (σ_t) and total electronic cross-section (σ_e) are related to the effective atomic number (Z_{eff}) of the material through the following relation

$$Z_{eff} = \frac{\sigma_t}{\sigma_e} \quad (6)$$

Finally, the average distance between two successive interactions, called the photon mean free path (λ), is given by

$$\lambda = \frac{\int_0^\infty x \ \exp(-\mu x)dz}{\int_0^\infty \exp(-\mu x)dx} = \frac{1}{\mu} \quad (7)$$

Where (μ_l) is the linear attenuation coefficient and x is the absorber thickness.

In the present Measurement the statistical error is limited to less than 1% by collecting a sufficient number of counts under the photo peak for the selected region of interest (ROI). The percentage deviation due to the non-uniformity of the absorbers was estimated using the relation. This has been minimized by following the counting sequence of Conner et all.(1970). The errors due to this method will be almost of the order of 0.5%. The extrapolation technique described earlier eliminates the error due to multiple scattering. The overall errors introduced on the total photon mass attenuation coefficients are thus around 2%.

II. RESULTS AND DISCUSSION:

The study of photon cross sections of nickel doped nano materials at low energies of gamma raysi.e.,30.85 KeV, 32.1 KeV, 42.0 KeV, and 59.54 KeV respectively, this experiment has been carried with the help of good experimental arraignment. And, the obtained results were tabulated and drown graph.

Table.1: Total Photon Cross Sections of synthesized Nano Material $Zn_{0.93}(Ni_{0.06}\ Y_{0.01})O$.

S.No	Energy in KeV	Total Photon Cross Sections in (gm/cm^2) X 10^2	
		Theoretical Values from XCOM	Practical Values
1	30.85	542.5	537.9
2	42	220.9	217.6
3	59.54	78.43	77.42

Graph.1: Total Photon Cross Sections of synthesized Nano Material $Zn_{0.93}(Ni_{0.06}\ Y_{0.01})O$

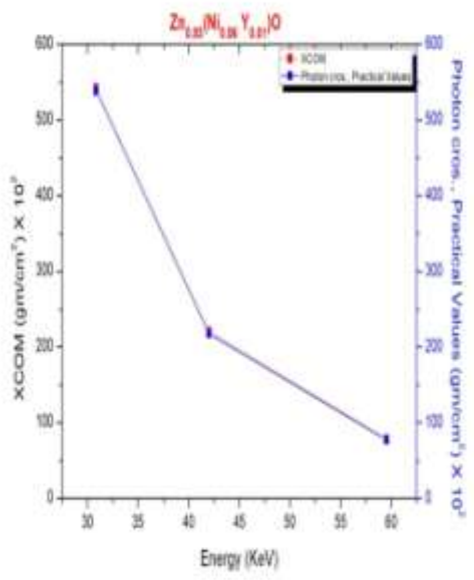


Table.2: Total Photon Cross Sections of synthesized Nano Material $Zn_{0.91}(Ni_{0.06}\ Y_{0.03})O$.

S.No	Energy in KeV	Total Photon Cross Sections in (gm/cm^2) X 10^2	
		Theoretical Values from XCOM	Practical Values
1	30.85	552.8	549.7
2	42	225.4	221.6
3	59.54	80.16	80.01

Graph.2: Total Photon Cross Sections of synthesized Nano Material $Zn_{0.91}(Ni_{0.06}\ Y_{0.03})O$.

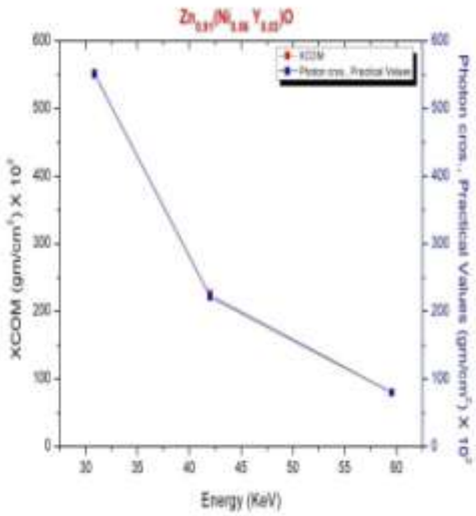


Table.3: Total Photon Cross Sections of synthesized Nano Material $Zn_{0.89}(Ni_{0.06}\ Y_{0.05})O$

S.No	Energy in KeV	Total Photon Cross Sections in (gm/cm^2) X 10^2	
		Theoretical Values from XCOM	Practical Values
1	30.85	563.1	552.7
2	42	230.0	228.7
3	59.54	81.89	81.64

Graph.3: Total Photon Cross Sections of synthesized Nano Material $Zn_{0.89}(Ni_{0.06}\ Y_{0.05})O$

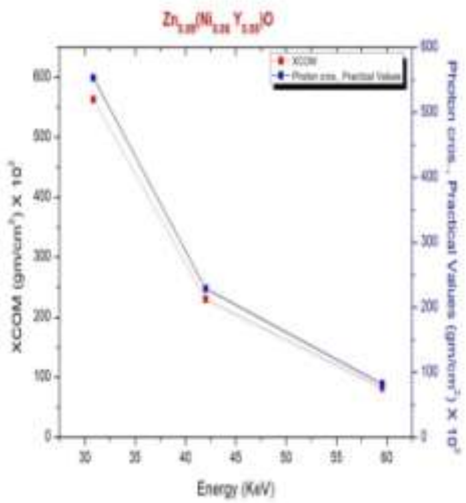


Table.4: Total Photon Cross Sections of synthesized Nano Material $Zn_{0.87}(Ni_{0.06}\ Y_{0.07})O$.

S.No	Energy in KeV	Total Photon Cross Sections in (gm/cm^2) X 10^2	
		Theoretical Values from XCOM	Practical Values
1	30.85	573.4	571.6
2	42	234.5	233.1
3	59.54	83.61	82.76

Graph.4: Total Photon Cross Sections of synthesized Nano Material $Zn_{0.87}(Ni_{0.06}\ Y_{0.07})O$.

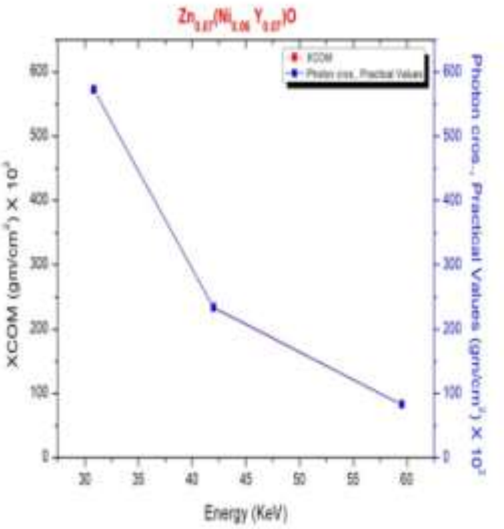
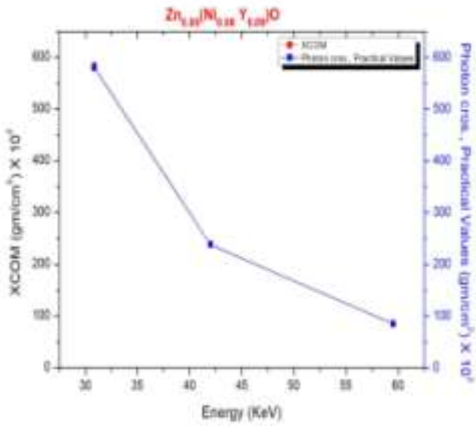


Table.5: Total Photon Cross Sections of synthesized Nano Material $Zn_{0.85}(Ni_{0.06}\ Y_{0.09})O$.

S.No	Energy in KeV	Total Photon Cross Sections in (gm/cm^2) X 10^2	
		Theoretical Values from XCOM	Practical Values
1	30.85	583.8	579.3
2	42	239.0	238.4
3	59.54	85.34	85.21

Table.5: Total Photon Cross Sections of synthesized Nano Material $Zn_{0.85}(Ni_{0.06}\ Y_{0.09})O$.



III. CONCLUSION:

1) The total photon cross sections for fourteen rare earth element Yttrium derived from the total photon cross sections of compounds in the present investigation provide some new data points in the elements energy chart of total photon cross sections, reported for the first time. These cross sections are in good agreement with the theoretical compilations of XCOM data
2) The total photoelectric cross sections that were obtained by subtraction method are in very good agreement with the theoretical values of Storm and Israel. They are also in agreement with the compilation data of XCOM within the range of error. However, there is general agreement between various theoretical, compiled and available earlier investigations.
3) The total photon cross sections derived from total photon cross sections at 30.85KeV, 42.0 KeV and 59.54 KeV photon energies for nickel based alloys are in good agreement with theoretical prediction of XCOM data.
4) Total effective atomic numbers (Z_{eff}) were obtained for yttrium element at three photon energies. The variation of Z_{eff} with energy is within the experimental errors. Hence no definite conclusion can be drawn, even though there is slight decrease in the value of Z_{eff} with increasing energy.

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