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Measurement of Energy Resolution and Detection Efficiency of NaI(Tl) Scintillation Gamma Ray Spectrometer for Different Gamma Ray Energies

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Abstract

NaI (Tl) scintillation detector is widely used in experimental Physics for the measurement of induced gamma ray activity of various samples. This detector is used in the measurement of nuclear reaction Cross-section induced by neutrons and protons in activation Technique. In addition, Scintillation detector has lot of applications in the elemental analysis of various compounds, alloys using activation analysis. In each application, the precise values of detection efficiency for different gamma energies are essential. To avoid the interference of different gamma energies, knowledge of detector resolution for different gamma energies is necessary. The values of detection efficiency and resolution vary with detector size and different detector parameters. Therefore it is essential to know these values for given detector before application of detector for the quantitative analysis purpose. With this intention, in the present work, the detection efficiency and resolution of NaI(Tl) scintillation detector are measured and optimized for following gamma ray energies: 122KeV, 356KeV, 511KeV, 662KeV, 1170KeV and 1330KeV. Values of detection efficiencies for these gamma energies are found to be respectively 60.49%, 30.36%, 12.50%, 10.84%, 6.82%, and 5.89%. The values of percentage resolution for above different gamma ray energies are found to be 9.26%, 8.25%, 7.38%, 7.18, 6.32% and 5.32% respectively. The standard gamma ray sources provided by BARC are used in the present research work. The result shows that the efficiency of NaI (Tl) detector decreases with increasing gamma energy

Keywords: NaI(Tl) gamma ray spectrometer, 8K M.C.A, Efficiency, Resolution, Radioactive Gamma ray sources.

Introduction

NaI (Tl) scintillation detector has many applications in the various research fields such as, cross-section estimation of nuclear reactions produced by neutrons and charge particles[1-3] elemental analysis of different alloys, explosives, polymer grafting[4-6], using neutron activation analysis technique, development of nuclear reactor technology. All these applications based on the measurement of gamma ray activity of various samples In each application, the precise values of detection efficiency for different gamma energies are essential. To avoid the interference of different gamma energies, knowledge of detector resolution of different gamma energies is necessary.

The values of detection efficiency and resolution vary with detector type and size and different detector operating parameters. Therefore it is essential to know these values for given detector for the quantitative analysis purpose. With this intention, in the present work, the detection efficiency and resolution of 2”×2” , Nucleonix make NaI (Tl) scintillation detector are measured and optimized for the present detector assembly for following gamma ray energies 122KeV, 511KeV, 356KeV, 1170KeV and 1330KeV.

Methodology

Figure-1 shows experimental set up of NaI (Tl) gamma ray spectrometer. In present work, standard gamma ray radioactive sources provided by BARC, Mumbai, are used. The sample holder is designed for the present experimental work. The distance between source and detector window is kept 3.7cm throughout the experiment. The following detector parameters were optimized and kept constant throughout the experiment Operating Voltage is 750V, Radius of detection window is 2cm, Distance of source from detector window is 3.7cm, Counting time is 300sec

Measurement of Efficiency: The different nuclear parameters of the sources and experimental data are given in Table-1[1]. Detector efficiency is calculated by the expression[7].

$$\%\text{Efficiency} = \frac{\text{Number of pulses recorded by the detector}}{\text{Number of radiation quanta falls on the detector}} \times 100$$

$$\varepsilon(\%) = \frac{A_{out}}{A_{in}} \times 100 \qquad (1)$$

A_{out} is number of counts recorded by the detector which is directly given in terms of counts per seconds.

A_{in} is number of gamma rays falling on detector which is calculated using the equation,

$$A_{in} = \frac{r^2}{4d^2} \times A_t \quad (2)$$

$\frac{r^2}{4d^2}$ is geometrical factor. (G.F), r is the radius of detection window, d is the distance of source from detector window, A_t is source activity and it is calculated using equation[8]

$$A_t = A_0 e^{-\lambda t} \quad (3)$$

λ Is decay constant, t is the time between date of manufacturer of source and date of experiment, A_0 is initial activity at t= 0

Energy Resolution: The energy resolution is important to avoid the interference between two gamma ray energies emitted by the sample. The experimental resolution is estimated using the equation[7],

$$\%\text{Resolution} = \frac{E_2 - E_1}{E_0} \times 100 \quad (4)$$

E_2-E_1 =Δ E is Full Width Half Maximum (FWHM), E_0 is Gamma Energy.

The gamma energy spectrum was counted for each standard source from which FWHM is estimated directly using software and manually. From the gamma ray spectrum, the experimental collected data is given in Table-2.

Gamma ray spectra for different gamma energies are given in Figures 2,3,4,5 and 6 for different radioactive sources.

Results and Discussion

The measured values of efficiencies of NaI (Tl) detector for different gamma energies are given in Table-3. The variation of measured values of % Efficiency of NaI (Tl) gamma ray detector for different gamma energies is given in the Figure 7. Measured values of percentage resolution are given in Table 4.

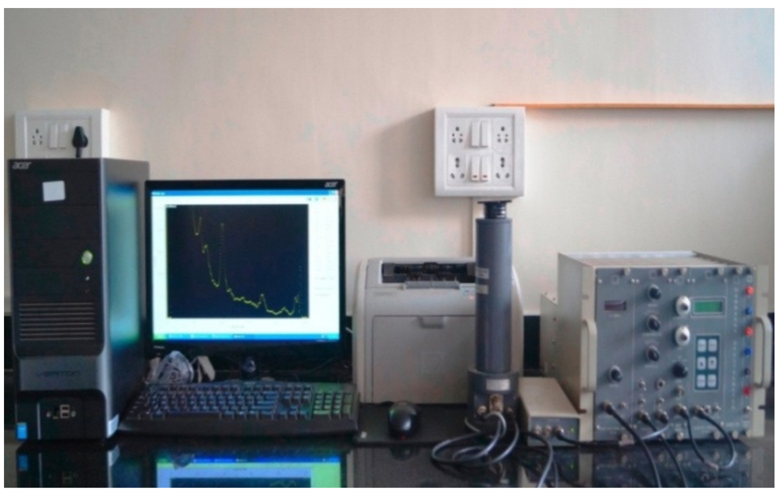

Figure-1
Experimental setup of NaI (Tl) Gamma ray Spectrometer with 8K MCA coupled to Computer

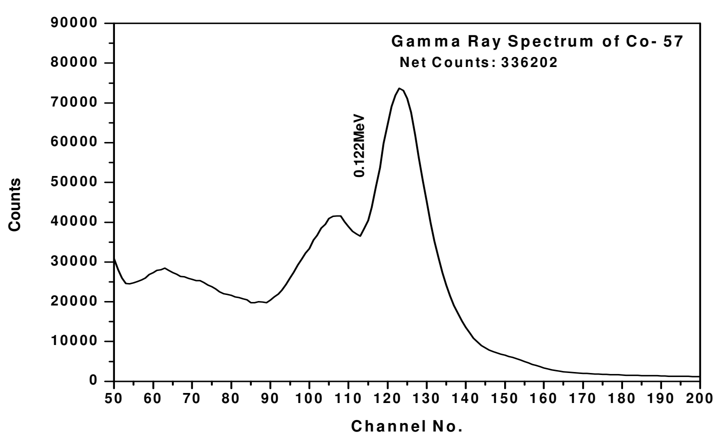

Figure-2
Gamma ray spectrum of Co-57

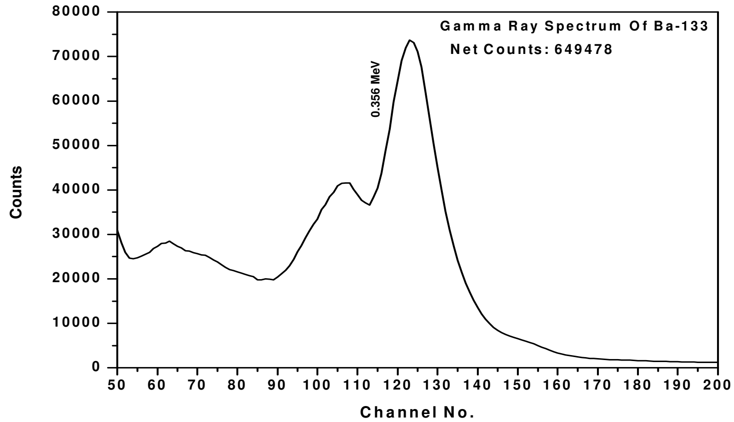

Figure-3
Gamma ray spectrum of Ba-133

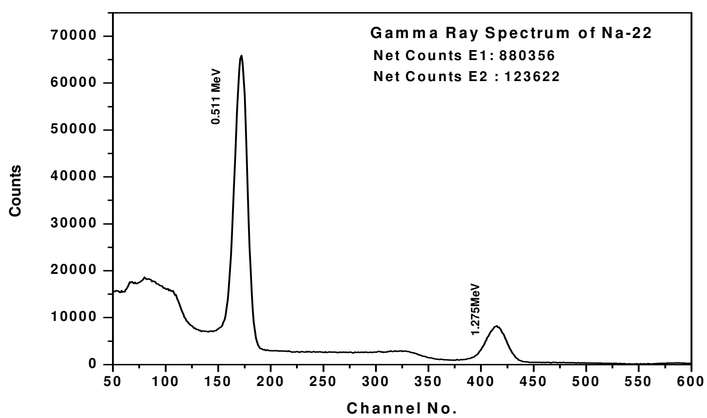

Figure-4
Gamma ray spectrum of Na-22

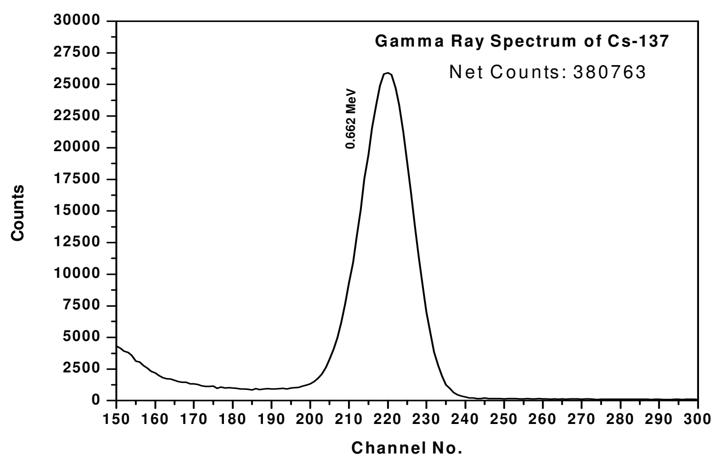

Figure-5
Gamma ray spectrum of Cs- 137

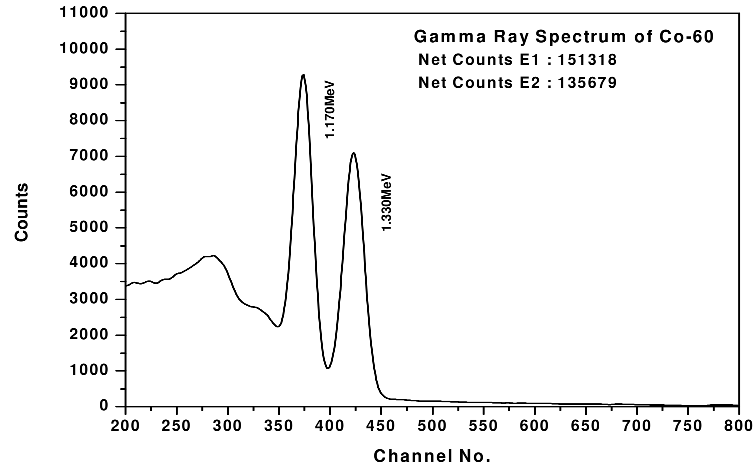

Figure-6
Gamma ray spectrum of Co-60

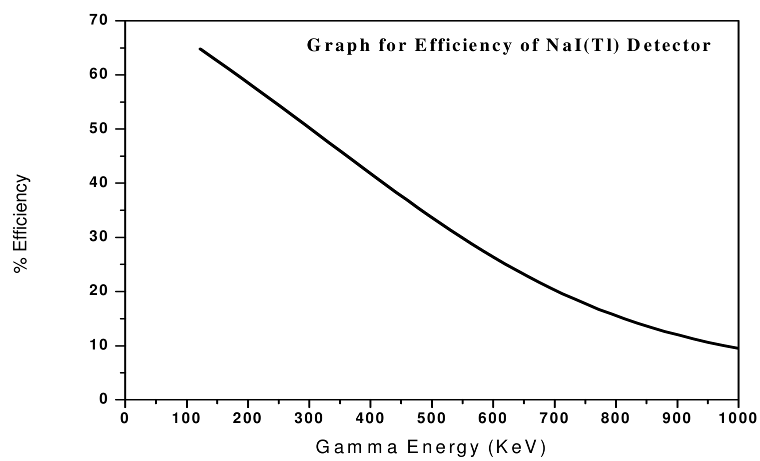

Figure-7
Variation of % Efficiency with Gamma Ray Energy

Table-1
Nuclear Parameters for Standard Gamma ray sources and experimental data obtained from NaI (Tl) Detector

Sr. No.	Gamma Source	Gamma Energy (KeV)	Initial Activity (A_0) (KBq)	Half Life	Net Counts
1	Co-57	122	88	270 Days	336202
2	Ba-133	356	234	10.5 yrs	649478
3	Na-22	511	170	2.6 yrs	880356
4	Cs- 137	662	152	30 yrs	380763
5	Co-60	1170	119	5.27 yrs	151318
		1330			135679

Table-2
Experimental data obtained from NaI (Tl) detector for FWHM = E

Sr. No.	Gamma Source	Half Life	Gamma Energy (KeV)	Peak Ch. No	Net Counts	Gross Counts	FWHM E (KeV)
1	Co- 57	270D	122	49.5	336202	424578	11.29
2	Ba - 133	1.5Y	356	119	649478	1232961	29.37
3	Na - 22	2.6Y	511	171	880356	1129379	37.718
4	Cs- 137	30Y	662	219	380763	433885	47.5316
5	Co-60	5.2Y	1170	387	151318	234108	73.944
			1330	439	135679	185808	70.756

Table-3
Experimental measured % Efficiency of NaI(Tl) Detector.

Sr. No.	Gamma Source	Gamma Energy (KeV)	% Efficiency
1	Co- 57	122	60.49
2	Ba – 133	356	30.36
3	Na – 22	511	12.50
4	Cs- 137	662	10.84
5	Co-60	1170	6.82
		1330	5.89

Table-4
Measured percentage resolution of NaI (Tl) detector

Sr.No	Standard Gamma ray source	Energy(KeV)	% Resolution
1	Co-57	122	9.26
2	Ba-133	356	8.25
3	Na-22	511	7.38
4	Cs-137	662	7.18
5	Co-60	1170	6.32
6		1330	5.32

Conclusion

Figure-7 indicates that efficiency of NaI (Tl) detector decreases with increase in gamma energy. The results in Table.4 show that the resolution of the detector for gamma rays is a function of gamma ray energy and decreases with increase in gamma energy. Both these factors also depend on other experimental conditions and applied detector voltage.

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