γ-RAY ENERGY SPECTROSCOPY USING SINGLE CHANNEL ANALYZER (SCA)

1. Objective:

To obtain the energy spectram of γ-ray using single channel analyser (SCA).

2. Introduction:

This experiment is carried out to develop the energy spectrum of **γ-ray** with the help of a Single Channel Analyzer (SCA). A NaI(TI) detector and three different **γ-rays** sources, i.e., Cs-137 (emits **γ-ray** of **662 keV**), Ba-133 (emits **γ-ray** of **356 keV**) and Co-6o (emits two **γ-rays** of **1.17 MeV and 1.33 MeV**) are used in this experiment.

γ-ray and its interaction with matter: γ-ray is an electromagnetic radiation emitted from radioactive nuclide. It is a high energy photon emitted from an excited nucleus during the process of de-excitation and its energy is above 10keV. γ-ray photon loses its energy by interacting with matter in three ways, i.e., photoelectric effect (PE), Compton scattering (CS) and Pair production (PP). In PE the γ-ray photon interacts with an atomic electron and transfers its energy to that electron to emit the electron from the atom. Obviously the energy of the photon must be higher than the binding energy of that electron and the excess energy of the incident photon then appears as the kinetic energy of that electron. The photon is lost in this process. In CS the γ-ray photon interact with a free or loosely bound electron (assumed to be at rest) and partially transfer its energy to that electron. Both the electron and the resulting low energy photon are scatter in different direction than the direction of incident photon. In PP, a photon having energy greater than 1.02 MeV (2 times the energy of the mass equivalent of an electron) when passing through the electric field of a nucleus create an electron-positron pair. The photon energy in excess of 1.02 MeV appears as the kinetic energy of the electron-positron pair.

NaI(TI) detector: In this experiment an inorganic NaI detector is used to detect γ-radiation from different sources and to produce their energy spectroscopy. Within these inorganic crystals, incident radiation interacts (by the processes as described before) and creates free electrons which are excited to the conduction band from their valance band. In presence of impurities called activators like Tl energy states are created within the forbidden gap through which the electron can de-excite to the valence band. During this de-excitation visible photons are emitted as a response to the incident radiation. A sensitive photomultiplier tube (PMT) converts this extremely weak light output into a corresponding electrical signal. NaI scintillation detectors are used for detecting γ-ray sources ranging in energy from 25keV to 2500keV.

SCA: The detector pulse (usually from the preamplifier output) is first amplified by an amplifier and then processed by the SCA. The SCA basically act as a discriminator which provides a threshold level to the signal amplitude so that the signals above the threshold are only accepted. The SCA in this experiment is operated in Window mode that provides a

lower level threshold and an upper level threshold. The signals between these two threshold values are counted. The difference between the upper and lower level threshold is kept fixed and this defines the window. Keeping the window fixed the lower level threshold can be changed from a lower bottom part of the signal (generally above the noise level) to the level of the desired signal amplitude; the discrete energy spectrum can be obtained.

3. Experimental setup:

In the experimental setup as shown in Fig. 1 a NaI(TI) detector-Preamplifier set was connected to a Nuclear Spectrometer which was supplied from a 230 V AC power source. The Spectrometer provides 705 V (not fixed) to the detector and also provides power to the Preamplifier. The Preamplifier output was fed to the Amplifier input terminal of the Spectrometer. The Amplifier provides a gain to the Preamplifier output signal and the Amplifier output signal was then connected to an Oscilloscope to observe the amplified detector signal.

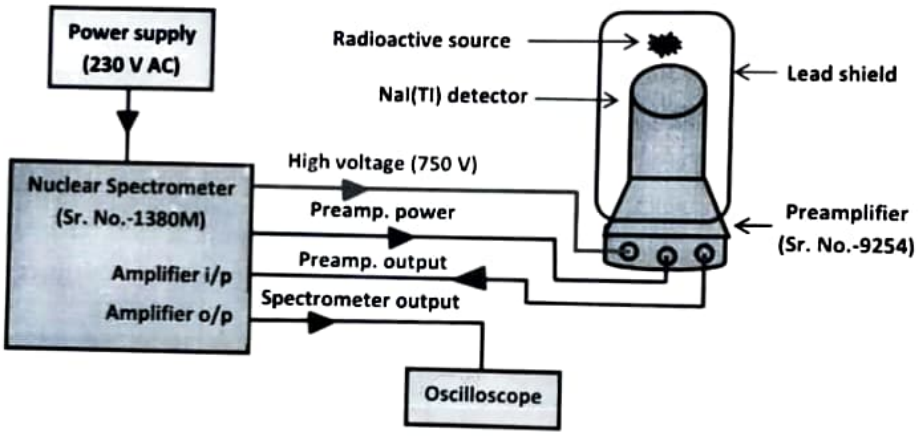

Fig. 1. Block-diagram of NaI(TI) detector setup

4. Procedure:

The experiment was carried out in few steps as following

I. A source was placed on the top of the NaI(TI) detector as shown in Fig. 1 and the amplified detector signal was seen on the Oscilloscope.

II. The amplifier gain was set in such a way that the amplitude of the detector signal was found to be almost 6 V although there were noises below and above the signal amplitude.

III. In the Spectrometer there is a baseline and a window nob is present. The base line is first fixed at 1 V. The window was kept fixed at 0.005 V for the whole experiment.

IV. The baseline that act as a lower level threshold is increase in 0.20 V step until it crosses the maximum amplitude of the signal.

V. The count for each baseline step was recorded for 30 sec.

VI. The count rate was then calculated and then the plot of the count rate Vs the voltage was plotted to obtain the γ-ray energy spectrum.

5. Results:

The energy spectrum of the Cs-137, Ba-133 and Co-60 are shown in Fig. 2, Fig. 3 and Fig 4 respectively. Here the energy of the γ-ray corresponds to the voltage of the detector pulse.

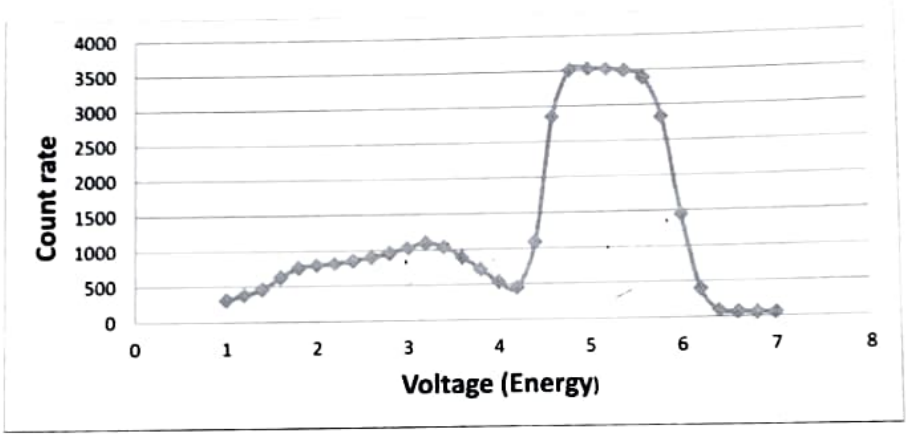

Fig. 2: Energy spectrum of Cs-137

Energy resolution of the γ-ray spectrum of the **Cs-137**
=FWHM (Full Width at Half Maximum)/Peak voltage = (6-4.6)/5.2 = 1.4/5.2 = 27%

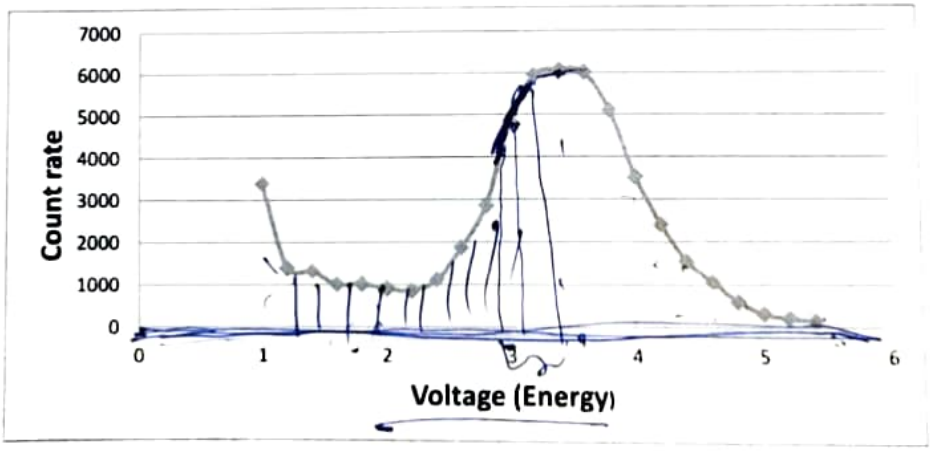

Fig. 3: Energy spectrum of Ba-133

Energy resolution of the γ-ray spectrum of the **Ba-133**
=FWHM/Peak voltage = (4.2-2.8)/3.4 = 1.4/3.4 = 41%

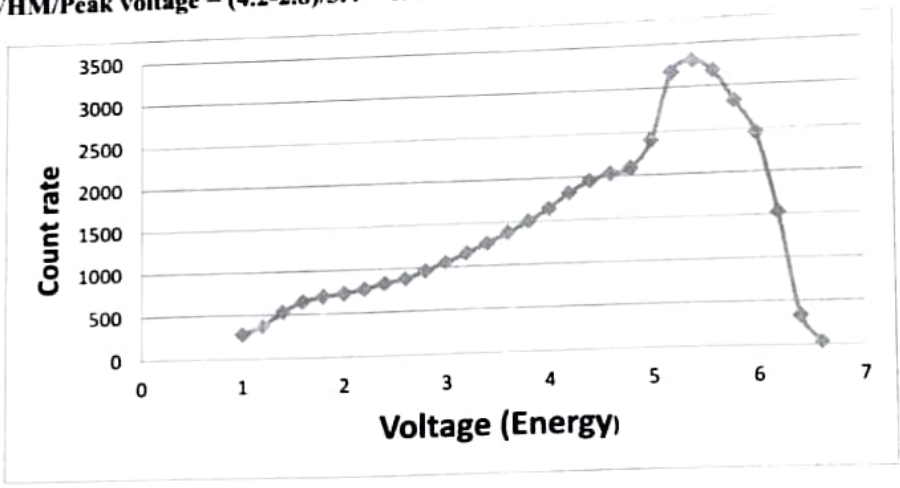

Fig. 4: Energy spectrum of Co-60

Energy resolution of the γ-ray spectrum of the C0-60
=FWHM/Peak voltage = (6.2-4)/5.4= 2.2/5.4 = 41%

6. Discussions and Conclusions:

I. The peak in the energy spectrum of Cs-137 is seen flat and this is may be due to different errors in measurement and may be due to the electronics also.

II. Due to the present of the Compton Scattering there is a high count rate before the peak (results due to PE) occurs as seen in Fig. 2.

III. The energy spectrum of cobalt is seen to have only one peak although there are two γ-ray emitted from the source and this is because of the poor resolution of the spectrum.

IV. The energy spectroscopy using SCA cannot be used in high resolution spectroscopic applications.