

Objective

To measure the activity of radioactive sources using a Multi-Channel Analyzer (MCA) and determine the energy spectrum of gamma rays emitted by the source.

Introduction

A Multi-Channel Analyzer (MCA) is an essential instrument in nuclear physics that measures and analyses the energy of radiation detected by a scintillation detector. The MCA sorts the detected pulses according to their amplitude (which corresponds to the energy of the radiation) into channels, creating an energy spectrum that helps identify radioactive isotopes and measure their activity. By analysing the energy spectrum, the activity of the source can be calculated.

Apparatus and Materials Required

1. Multi-Channel Analyzer (MCA) with software for data acquisition and analysis
2. NaI(Tl) scintillation detector
3. Radioactive sources (e.g., Cesium-137, Cobalt-60, Sodium-22)
4. Pre-amplifier and amplifier
5. High voltage power supply for the detector
6. Lead shielding (to reduce background radiation)
7. Source holder
8. Calibration sources (e.g., Cesium-137)

Theory

Radioactive sources emit gamma rays of characteristic energies that are specific to each isotope. When these gamma rays interact with a scintillation detector, they produce electrical signals proportional to their energy. These signals are then amplified and sent to the MCA, which sorts the pulses into channels based on their amplitude.

The MCA produces a spectrum that shows the number of counts versus the energy (in keV or MeV). By analysing the peaks in this spectrum, the energy of the gamma rays and the number of disintegrations can be determined.

The activity A of the source can be calculated using:

$$A = \frac{C}{\epsilon * t * I}$$

where:

- C = Net count rate (counts per second)
- ϵ = Efficiency of the detector for the energy of interest
- t = Time of measurement (in seconds)
- I = Intensity of the gamma peak (probability of emission per decay)

Procedure

1. **Setup:**
 - Connect the scintillation detector to the pre-amplifier, amplifier, and high-voltage power supply (in some cases the pre-amplifier, amplifier and high voltage supply and in built in an MCA)
 - Ensure proper connection to the MCA.
 - Place the detector inside lead shielding to minimize background radiation.
 - Power on the MCA system and ensure all components are functioning correctly.
 - Adjust the gain in the MCA

- Open the MCA software (Anuspect) on the computer and set the required parameters (e.g., time of acquisition).
2. **Calibration of the MCA:**
 - Place a known calibration source (e.g., Cs-137) near the detector and start the data acquisition.
 - Adjust the MCA gain settings to ensure that the prominent peak (e.g., 661.7 keV for Cs-137) is correctly aligned with its expected channel number.
 - Use multiple calibration sources to establish a reliable energy calibration curve.
 - Save the calibration data and use it to convert channel numbers to energy values in keV.
 3. **Background Measurement:**
 - Without any radioactive source, measure the background radiation for a set time (e.g., 10 minutes). Record the background counts and note the spectrum.
 - This background spectrum will be subtracted from subsequent measurements to obtain net counts.
 4. **Activity Measurement of the Radioactive Source:**
 - Place the radioactive source at a fixed, known distance from the detector. The source should be securely held to avoid any movement during measurement.
 - Start the data acquisition and record the spectrum for an appropriate time (e.g., 10-30 minutes, depending on source strength).
 - Ensure that the main peaks are clearly visible in the spectrum and that counting statistics are sufficient for accurate analysis.
 5. **Data Analysis:**
 - Identify the prominent peaks in the spectrum corresponding to the gamma-ray energies of the source.
 - Subtract the background spectrum from the measured spectrum to obtain the net counts.
 - Integrate the counts under the relevant peaks to determine the net count rate **C**.
 6. **Efficiency Calculation:**
 - Use known standard sources to determine the efficiency ϵ of the detector at specific energies.
 - Efficiency calibration involves plotting the known activity of calibration sources versus the measured count rates and deriving a curve for the detector's efficiency.
 7. **Calculation of Activity:**
 - Use the formula $A = \frac{C}{\epsilon * t * I}$ to calculate the activity of the unknown source.
 - Repeat the measurement several times to reduce statistical error and improve accuracy.

Observations and Data Recording

1. Observation Table:

Source	Energy (keV)	Channel Number	Net Count Rate (C)	Efficiency (ϵ)	Intensity (I)	Activity (Bq)
Cs-137	661.7					
Co-60	1173, 1332					
...						

2. Graphical Analysis:

- Plot the energy spectrum showing the peaks corresponding to different gamma energies.
- Use the calibration curve to convert channel numbers to energy values.

Calculations

1. Efficiency Calculation:

- Plot efficiency versus energy using standard calibration sources and fit an appropriate curve.

2. Activity Calculation:

- Using the measured net count rates and efficiency values, calculate the activity of the unknown radioactive source.

Precautions

1. Handle radioactive sources carefully, using appropriate safety measures such as tongs, and lead shielding.
2. Ensure the detector and MCA system are properly calibrated before taking measurements.
3. Avoid unnecessary exposure to radiation; maintain safe distances and minimize measurement time.
4. Ensure the background radiation is periodically checked to ensure accurate subtraction.

References

1. Knoll, G. F. (2010). **Radiation Detection and Measurement**. John Wiley & Sons.
2. Gilmore, G., & Hemingway, J. (1995). **Practical Gamma-Ray Spectrometry**. Wiley.
3. Martin, J. E. (2006). **Physics for Radiation Protection**. Wiley-Interscience