Objective

To perform sum peak analysis using a Multi-Channel Analyzer (MCA) and understand the effects of coincident gamma-ray emissions on the measured energy spectrum of radioactive sources.

Introduction

Sum peaks are observed in gamma-ray spectroscopy when two or more gamma photons are detected simultaneously by the detector, resulting in a single pulse whose amplitude is the sum of the individual energies. This phenomenon often occurs with radioactive isotopes that emit cascades of gamma rays in quick succession, such as Co-60 or Na-22. Sum peak analysis is crucial in nuclear physics for accurate interpretation of spectra.

Sum peak analysis helps identify coincident events, correct for these effects in quantitative measurements, and improve the understanding of the decay schemes of complex nuclei.

Apparatus and Materials Required

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

Theory

When a radioactive nucleus decays, it can emit gamma rays in rapid succession. If two gamma rays are emitted in coincidence (i.e., within the resolving time of the detector), and both are detected simultaneously, the resulting pulse is the sum of the energies of the individual gamma rays. This leads to a sum peak in the energy spectrum.

For instance, in the case of Cobalt-60, which emits gamma rays of 1173 keV and 1332 keV in coincidence, a sum peak may appear at approximately 2505 keV (1173 + 1332 keV).

The presence of sum peaks can affect quantitative analysis and must be considered, especially in high-resolution spectrometry where detectors are sensitive to coincident events.

Procedure

1. **Setup:**
   - Connect the NaI 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 reduce background radiation.
   - Power on the MCA and associated equipment, and set up the MCA software with appropriate gain and acquisition settings.
2. **Calibration of the MCA:**
   - Place a calibration source (e.g., Cs-137) near the detector. Adjust the gain settings on the MCA to align the photopeak (e.g., 661.7 keV for Cs-137) to the correct channel.
   - Use multiple calibration sources to generate an energy calibration curve, ensuring that it covers the expected energy range of interest.
   - Save the calibration data to ensure accurate energy conversion during analysis.

3. **Background Measurement:**
   - Measure the background radiation without any source for a set duration (e.g., 10 minutes) and record the spectrum. This background spectrum will later be subtracted from the measured data.
4. **Acquisition of the Gamma Spectrum:**
   - Place the radioactive source (e.g., Co-60) at a fixed distance from the detector and start data acquisition.
   - Record the spectrum for an appropriate amount of time (10-30 minutes or longer, depending on the source strength) to ensure statistically significant counts in the peaks.
   - Save the acquired spectrum for further analysis.
5. **Identification of Sum Peaks:**
   - Analyse the recorded spectrum to identify the prominent gamma peaks and any sum peaks. For Co-60, the primary peaks are expected at 1173 keV and 1332 keV, with a potential sum peak at around 2505 keV.
   - Compare the observed peaks with the expected energies of individual and summed events.
6. **Correction for Coincidence Effects:**
   - Subtract the background spectrum from the measured spectrum to obtain the net count rate.
   - Identify any sum peaks and analyse their intensities relative to the primary peaks.
   - Use coincidence summing corrections if quantitative measurements of the primary gamma peaks are required, accounting for the detector's resolving time and efficiency.

Observations and Data Recording

1. **Observation Table:**

Source	Peak Energy (keV)	Channel Number	Net Count Rate (CPS)	Identified Peak (Primary/Sum)
Co-60	1173			Primary
	1332			Primary
	2505			Sum
Na-22	511			Primary
	1274			Primary
	1785			Sum

2. **Graphical Analysis:**
   - Plot the energy spectrum and clearly mark the identified primary and sum peaks.
   - Use the calibration curve to convert the channel numbers to energy values.

Calculations

1. **Efficiency Correction:**
   - Use efficiency calibration data to correct the count rates of the primary and sum peaks.
   - Apply correction factors for coincidence summing effects if needed.
2. **Sum Peak Analysis:**
   - Calculate the theoretical sum peak energy by adding the energies of coincident gamma rays.
   - Compare the theoretical and observed sum peaks to confirm the identification.
3. **Correction for Coincidence Summing:**
   - Calculate the summing correction factor using:

$$F = 1 + \frac{\Sigma_i C_i \epsilon_i}{C_{Primary}}$$

   - C_i: Counts of individual gamma rays involved in summing.
   - ϵ_i: Efficiency of the detector at the energy of each gamma ray.
   - $C_{primary}$: Counts of the primary gamma ray peak.

Precautions

1. Handle all radioactive sources with care and use appropriate shielding to minimize exposure.
2. Ensure accurate calibration of the MCA to prevent errors in energy assignment.
3. Minimize background interference by properly shielding the detector and using lead bricks around the source and detector.
4. Keep the source and detector fixed during measurements to maintain consistency in geometry and count rates.

References

1. Knoll, G. F. (2010). **Radiation Detection and Measurement**. John Wiley & Sons.
2. Gilmore, G., & Hemingway, J. (1995). **Practical Gamma-Ray Spectrometry**. Wiley