Experiments with HPGe Detector

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1 | Objective

- Energy calibration of HPGe detector
- Absolute efficiency calibration of HPGe detector
- Identification of radionuclides and measurement of their activity concentration present in environmental soil sample and tap water sample.

2 | Apparatus

2.1 | Introduction

High Purity Germanium (HPGe) detectors are semiconductor detectors widely used in gamma spectroscopy due to their superior energy resolution compared to other detector types like NaI(Tl) scintillation detectors. They are particularly effective for identifying and quantifying gamma-emitting radionuclides in various samples, including environmental samples.

Due to higher atomic number (Z=32), Ge has a much larger linear attenuation coefficient for gamma rays than Si (Z=14). Which leads to a shorter mean free path for gamma rays in Ge than in Si. This property makes Ge detectors more efficient at detecting gamma rays, especially at higher energies.

The HPGe detectors must be operate at cryogenic temperatures (typically around 77 K, the boiling point of liquid nitrogen) to reduce thermal noise and improve their performance. This cooling is necessary because germanium has a relatively small bandgap, and at room temperature, thermal energy can excite electrons across the bandgap, leading to increased noise and reduced energy resolution.

2.2 | Principle of operation

When a gamma ray interacts with the germanium crystal in the HPGe detector, it can undergo several types of interactions, including the photoelectric effect, Compton scattering, and pair production. These interactions result in the creation of electron-hole pairs within the crystal. **The number of electron-hole pairs generated is proportional to the energy of the incoming gamma ray**.

An electric field is applied across the germanium crystal, causing the electrons and holes to drift towards their respective electrodes. This movement of charge carriers generates a current pulse, which is then amplified and processed by the detector's electronics. The amplitude of the pulse is directly proportional to the energy of the incident gamma ray, allowing for precise energy measurements.

2.3 | Construction and Cryostatic colling

The HPGe detector consists of a high-purity germanium crystal, typically in the form of a cylindrical or coaxial shape. The crystal is housed in a vacuum-sealed cryostat to maintain the low temperatures required for operation. The cryostat is often cooled using liquid nitrogen, which is circulated around the detector to keep it at the desired temperature.

The main components of the system are the cooling rod (usually made of copper), the Dewar container (for storage of liquid nitrogen), and the fill collar (for refilling the Dewar). The cryostatic cooling systems provide the following features: cooling of the detector to obtain stable operating temperatures; high quality vacuum in the cryostat to avoid adsorption of contaminants on the detector surface and provides thermal insulation; suppression of heat transfer between cool inner parts and warm outer surface of the cryostat; mounting for the electrical contacts; and isolation from external vibration to avoid system noise interference.

The Shielding involves an outer jacket of 10 mm carbon steel, an inner shield of 100-mm-thick Lead and a graded liner of tin and copper. Such graded shielding minimizes the background noise that has a very high probability of interference with measurement data. It is manufactured for use with a detector in a vertical configuration.

Component	Specification
Detector model	GC3018
Relative efficiency	$\geq$ 30% relative to NaI(Tl)
Energy resolution	$\leq$ 1.8 keV at 1.33 MeV (Co-60)
Depletion voltage	+ 2400 Vdc
Recommended operating voltage	+ 2900 Vdc

Table 2.1: Specifications of the HPGe Detector System

Component	Specification
Diameter of crystal	61.7 mm
Length of crystal	40 mm
Distance from crystal to front face	4.9 mm
Window material	1.5 mm thick Aluminum
Active volume	$\sim$ 113 cm^3
End cap	3.00 inch diameter $\times$ 5.25 inch length

Table 2.2: Physical Characteristics of the HPGe Detector System

2.4 | Electronics components associated

The HPGe detector system is complemented by a suite of electronic components that facilitate signal processing, amplification, and data acquisition. Key components include:

- **Pre-amplifier:** Located close to the detector, it amplifies the small current pulses generated by the detector.
- **Shaper:** This circuit shapes the pulse from the pre-amplifier into a more usable form for further processing.
- **Analog-to-Digital Converter (ADC):** Converts the shaped analog signal into a digital signal for analysis.
- **Data Acquisition System (DAQ):** Collects and stores the digital data for analysis.

3 | Theory

4 | Observation

5 | Conclusion

6 | References