UNIT-IV

MICRODOSIMETRY & NANODOSIMETRY

4.5 GAMMA SPECTROMETRY: PRINCIPLES, APPLICATIONS, AND TECHNIQUES

Gamma spectrometry is a technique used to **detect and analyze gamma radiation** emitted by radioactive materials. It provides **energy spectra of gamma rays**, allowing identification and quantification of radionuclides in a sample.

Key Uses:

✓ Identifying radioactive isotopes.

✓ Measuring radiation levels in environmental and medical applications.

✓ Ensuring nuclear safety and security.

1. Principles of Gamma Spectrometry

A. Gamma Ray Emission

- Gamma rays are **high-energy photons** emitted during nuclear decay.
- Each radionuclide has a unique **gamma energy spectrum**, making it possible to identify isotopes.

B. Energy-Wavelength Relationship

The energy of gamma rays is given by:

$$E = h\nu = hc/\lambda$$

where:

E = gamma ray energy (eV or MeV)

h = Planck's constant

ν = frequency

λ = wavelength

C. Interaction of Gamma Rays with Matter

✓ **Photoelectric Effect** – Gamma ray transfers energy to an electron, ejecting it.

✓ **Compton Scattering** – Gamma photon scatters off an electron, losing energy.

✓ **Pair Production** – At very high energies (>1.022 MeV), gamma rays create an electron-positron pair.

2. Components of a Gamma Spectrometry System

A. Radiation Detector

✓ **High-Purity Germanium (HPGe) Detector** – High resolution, used in nuclear labs.
✓ **Sodium Iodide (NaI(Tl)) Detector** – Common, cost-effective, lower resolution.

B. Signal Processing Unit

✓ **Amplifier** – Increases weak signals from the detector.
✓ **Analog-to-Digital Converter (ADC)** – Converts signals into digital format.

C. Multi-Channel Analyzer (MCA)

✓ Digitally records and sorts gamma energy levels.

D. Software for Spectrum Analysis

✓ Identifies peak energies and quantifies isotope concentrations.

3. Gamma Spectroscopy Spectrum Analysis

A. Key Features in a Spectrum

✓ **Peak Energy (keV or MeV)** – Identifies radionuclides.
✓ **Peak Area** – Indicates radiation intensity or activity.
✓ **Background Radiation** – Must be subtracted for accurate results.

B. Example of Common Isotopes and Their Gamma Energies

Isotope	**Gamma Energy (keV)**	**Application**
Cesium-137	661.6	Radiation monitoring, industrial sources
Cobalt-60	1173, 1332	Cancer therapy, industrial radiography
Uranium-238	1001	Nuclear fuel, environmental monitoring
Iodine-131	364	Medical diagnostics, thyroid treatment

4. Applications of Gamma Spectrometry

A. Environmental Monitoring

✓ Detects radioactive contamination in air, water, and soil.
✓ Identifies fallout from nuclear accidents (e.g., Chernobyl, Fukushima).

B. Medical Applications

✓ Used in **nuclear medicine** for imaging and cancer treatment monitoring.
✓ Identifies isotopes in **radiopharmaceuticals** (e.g., Technetium-99m).

C. Nuclear Safeguards and Security

✓ Monitors radioactive materials in nuclear power plants.
✓ Detects illicit trafficking of radioactive substances.

D. Industrial and Material Analysis

✓ Measures elemental composition in **steel, cement, and mining industries**.

5. Advantages & Limitations of Gamma Spectrometry

A. Advantages

✓ **Non-destructive technique** – Does not alter the sample.
✓ **High sensitivity** – Can detect very low levels of radioactivity.
✓ **Isotope-specific identification** – Differentiates between radionuclides.

B. Limitations

⊘ **Expensive equipment** – HPGe detectors require **liquid nitrogen cooling**.
⊘ **Limited by detector resolution** – NaI(Tl) detectors have lower accuracy.
⊘ **Background radiation interference** – Can affect measurement precision.

6. Conclusion

Gamma spectrometry is a powerful tool for **radiation detection, isotope identification, and nuclear safety**. Advanced detectors and software continue to improve its applications in medicine, industry, and security.