UNIT 4: NUCLEAR IMAGING

4.1 RADIO ISOTOPES

Radioisotopes play a vital role in **nuclear imaging**, a branch of medical imaging that uses small amounts of radioactive material to diagnose and treat various diseases. These isotopes emit gamma rays or positrons, which can be detected by imaging devices to provide functional and anatomical information about tissues and organs.

Radioisotopes Used in Nuclear Imaging

1. **Technetium-99m (Tc-99m)**

- **Usage**: Most widely used isotope in nuclear imaging.
- **Half-life**: 6 hours.
- **Applications**: Bone scans, cardiac imaging, brain scans, renal function assessment, and cancer detection.
- **Advantages**: Emits low-energy gamma rays and has a short half-life, minimizing radiation exposure.

2. **Fluorine-18 (F-18)**

- **Usage**: Used in positron emission tomography (PET).
- **Half-life**: ~110 minutes.
- **Applications**: Cancer diagnosis, brain function imaging, and cardiac imaging (e.g., glucose metabolism in tissues via FDG-PET).
- **Advantages**: High-resolution imaging and ability to study metabolic activity.

3. **Iodine-123 (I-123)**

- **Usage**: Thyroid imaging.
- **Half-life**: 13 hours.
- **Applications**: Evaluation of thyroid function and thyroid cancer.
- **Advantages**: Produces high-quality images with minimal radiation exposure.

4. **Iodine-131 (I-131)**

- **Usage**: Both diagnostic and therapeutic.
- **Half-life**: 8 days.
- **Applications**: Treating hyperthyroidism and thyroid cancer, along with imaging.
- **Advantages**: Dual diagnostic and therapeutic capability.

5. **Gallium-67 (Ga-67)**
- **Usage**: Detecting infections, inflammation, and tumours.
- **Half-life**: 78 hours.
- **Applications**: Lymphoma and infection localization.
- **Advantages**: Ability to highlight inflammatory or neoplastic areas.

6. **Thallium-201 (Tl-201)**
- **Usage**: Myocardial perfusion imaging.
- **Half-life**: 73 hours.
- **Applications**: Assessing coronary artery disease and myocardial viability.
- **Advantages**: Helps evaluate blood flow in cardiac tissues.

7. **Rubidium-82 (Rb-82)**
- **Usage**: Cardiac PET imaging.
- **Half-life**: 75 seconds.
- **Applications**: Myocardial perfusion studies.
- **Advantages**: Very short half-life reduces radiation dose to the patient.

Principles of Nuclear Imaging

1. **Radioisotope Administration**:
- Introduced into the body via injection, ingestion, or inhalation.
- Selectively accumulates in the target organ or tissue.

2. **Emission Detection**:
- Radioisotopes decay and emit radiation (gamma rays or positrons).
- Detected by gamma cameras, single-photon emission computed tomography (SPECT), or PET scanners.

3. **Image Reconstruction**:
- Radiation data is processed to create detailed 2D or 3D images of the organ's structure and function.

Advantages of Using Radioisotopes

- **Functional Imaging**: Unlike other imaging modalities (e.g., X-rays or CT scans), nuclear imaging shows organ function and metabolism.

- **Early Diagnosis**: Detects diseases at an early stage before structural changes occur.
- **Therapeutic Applications**: Some isotopes (e.g., I-131) can treat conditions like thyroid cancer.

Safety Considerations

- **Radiation Exposure**: Kept minimal by using isotopes with short half-lives.
- **Patient Monitoring**: Appropriate precautions to prevent unnecessary exposure to healthcare staff and others.

Alpha, beta, and gamma radiations are three common types of radiation emitted by radioactive isotopes during radioactive decay.

1. Alpha Radiation (α):

- **Nature**: Alpha particles consist of 2 protons and 2 neutrons, making them equivalent to a helium nucleus.
- **Charge**: Positively charged (+2).
- **Mass**: Relatively heavy compared to beta particles and gamma rays.
- **Penetrating Power**: Low. Alpha particles can be stopped by a sheet of paper, human skin, or a few centimetres of air.
- **Ionizing Power**: Very high. Alpha particles cause significant ionization in their immediate surroundings.
- **Examples of Emitters**: Uranium-238, Radium-226, Polonium-210.
- **Uses**: Smoke detectors, cancer treatment (targeted alpha therapy).

2. Beta Radiation (β):

- **Nature**: Beta particles are high-energy, high-speed electrons or positrons emitted during beta decay.
  - **Beta-minus (β^-)**: Emission of an electron (when a neutron turns into a proton).
  - **Beta-plus (β^+)**: Emission of a positron (when a proton turns into a neutron).
- **Charge**:
  - β^-: Negatively charged.
  - β^+: Positively charged.
- **Mass**: Much smaller than alpha particles, similar to that of an electron.

- **Penetrating Power**: Moderate. Can be stopped by a few millimetres of aluminium or a few centimetres of plastic.
- **Ionizing Power**: Lower than alpha particles but higher than gamma rays.
- **Examples of Emitters**: Carbon-14, Strontium-90, Iodine-131.
- **Uses**: Medical imaging, cancer therapy, radiotracers in research.

3. Gamma Radiation (γ):

- **Nature**: Gamma rays are electromagnetic waves or photons of very high energy, emitted alongside alpha or beta particles.
- **Charge**: Neutral (no charge).
- **Mass**: No mass.
- **Penetrating Power**: Very high. Requires dense materials like lead or several centimetres of concrete to block effectively.
- **Ionizing Power**: Low compared to alpha and beta particles, but it can penetrate deeper into materials and tissues.
- **Examples of Emitters**: Cobalt-60, Cesium-137, Technetium-99m.
- **Uses**: Sterilization, cancer treatment (radiotherapy), food irradiation, and imaging (e.g., PET scans).