1. Write a note on Personal radiation dosimeters

A personal radiation dosimeter is a device worn by individuals to measure and record the cumulative dose of external ionizing radiation they are exposed to over a period of time. These devices are essential for workers in environments such as nuclear facilities, medical imaging departments, and research laboratories. The primary goal of a personal dosimeter is to monitor exposure to ensure it remains within safe limits.

Personal dosimeters are classified into two main categories namely, (a) passive dosimeters and (b) active (or electronic) dosimeters.

(a) Passive Dosimeters:

These devices passively store information about radiation exposure, which is then processed and analyzed in a laboratory at regular intervals. Based on the principle involved, passive dosimeters are divided into, (i) Thermoluminescent Dosimeters, (ii) Optically Stimulated Luminescence Dosimeters and (iii) Film Badges.

(i) Thermoluminescent Dosimeters: They contain a sensitive crystalline material that stores energy from radiation exposure. When heated, the material emits light that is proportional to the absorbed dose. Thermoluminescent Dosimeters are sensitive and widely used, but the reading process typically erases the stored information.

(ii) Optically Stimulated Luminescence Dosimeters: Optically Stimulated Luminescence Dosimeters use a layer of aluminum oxide that, when stimulated by a laser or LED light in a lab setting, emits light proportional to the radiation dose. A key advantage of these kind is that they can be re-read multiple times for verification or audits, as only a fraction of the signal is depleted during each reading.

(iii) Film Badges: Film Badges use a piece of photographic film which darkens in proportion to the radiation exposure. The film is developed in a lab to determine the dose.

(b) Active Dosimeters (Electronic Personal Dosimeters - EPDs)

EPDs are battery-operated electronic devices that provide immediate, real-time feedback on both cumulative dose and current dose rate via a digital display. EPDs produce audible, visual, and vibrating alarms that alert the user if the dose or dose rate thresholds are exceeded. They are useful in high-dose areas or emergency response situations where real-time monitoring is critical.

When not in use, dosimeters should be stored in a safe, low-background radiation area, away from heat and direct sunlight, to prevent false readings.

2. What are radioactive tracers? Explain any three applications of them.

Radioactive tracers are substances with a radioactive atom used to track movement in biological, chemical, or industrial systems, revealing chemical reactions and locations via the radiation they emit. They are used in medical imaging (PET/SPECT scans for tumors), environmental studies (tracing pollutants), and industry (leak detection, process optimization).

A radioactive compound is introduced into a living organism and the radio-isotope provides a means to construct an image showing the way in which that compound and its reaction products are distributed around the organism.

The principle behind the use of radioactive tracers is that an atom in a chemical compound is replaced by another atom, of the same chemical element. The substituting atom, however, is a radioactive isotope. This process is often called radioactive labeling. When a labeled chemical compound undergoes chemical reactions one or more of the products will contain the radioactive label. Analysis of what happens to the radioactive isotope provides detailed information on the mechanism of the chemical reaction.

The advantage of the technique is due to the fact that radioactive decay is much more energetic than chemical reactions. Therefore, the radioactive isotope can be present in low concentration and its presence detected by sensitive radiation detectors such as Geiger counters and scintillation counters.

Applications:

1. Medical diagnosis: A radiotracer bound to a biologically active molecule, is injected into the body. Areas with high metabolic activity (like tumors) absorb more of the tracer. They are used to detects cancers, heart conditions, and brain disorders by creating images that show the regions the tracer accumulates, highlighting abnormal tissues or damaged organs.
2. Environmental Monitoring: A tracer is introduced into water systems (rivers, groundwater) or soil. It helps to determine water flow rates, to map underground aquifers, and track the movement of pollutants or contaminants through the environment, aiding in environmental cleanup.
3. Industrial Process Optimization (Leak Detection/Flow Studies): A tracer is added to a fluid (oil, gas, chemicals) in a pipeline or vessel, or used in manufacturing. It detects leaks in pipes, measures flow rates in complex systems, and optimizes mixing in chemical reactors, saving costs and improving efficiency.

3. Explain the principle and procedure of Proton Therapy.

Principle of Proton Therapy:
Proton therapy is an advanced form of radiation therapy that uses high-energy protons to treat cancer. Its working principle is based on the **Bragg peak phenomenon**, in which protons release very little energy while passing through healthy tissues and deposit the maximum amount of energy at a specific depth inside the body. Beyond this point, there is a rapid fall-off in dose, resulting in almost no exit radiation. By varying the energy of the proton beam, the depth of the Bragg peak can be precisely adjusted to match the tumor location. This enables highly accurate targeting of cancer cells while minimizing radiation damage to surrounding normal tissues and critical organs.

Procedure of Proton Therapy:
The procedure begins with detailed imaging studies such as CT, MRI, or PET scans to determine the exact size, shape, and position of the tumor. Based on these images, a personalized treatment plan is developed using computer-based planning systems. Protons are produced from hydrogen atoms and accelerated to very high energies using a **cyclotron or synchrotron**. The accelerated proton beam is shaped using collimators and modulators and directed toward the tumor from one or more angles. During treatment, the patient is positioned carefully on a treatment table to ensure accuracy. As the proton beam enters the body, it travels through healthy tissues with minimal energy loss and delivers its maximum energy at the tumor site, destroying cancer cells. Multiple sessions are usually given to ensure effective tumor control while reducing side effects.

4. Write a note on Radiation safety.

Radiation safety refers to the practices used to protect patients, workers, and the public from the harmful effects of ionizing radiation.

- The principle of **ALARA** (As Low As Reasonably Achievable) is followed to minimize radiation exposure.
- Time of exposure should be kept as short as possible to reduce radiation dose.
- Distance from the radiation source should be maximized, as radiation intensity decreases with distance.
- Shielding such as lead aprons, lead gloves, and protective barriers should be used to absorb radiation.
- Proper collimation and filtration of X-ray beams help reduce unnecessary exposure.
- Radiation monitoring devices like film badges or TLDs are used to measure exposure to workers.
- Only trained and authorized personnel should operate radiation equipment.
- Warning signs and controlled areas must be maintained around radiation sources.
- Regular inspection and maintenance of radiation equipment ensure safe operation.