30

RADIOACTIVE ISOTOPES

30.1 INTRODUCTION

In the previous chapter we have seen about radioactivity and its types. In this topic we are going to see how different radioactive radiations can be measured. Based on its ability to ionize and excite molecules radioactivity can be detected and measured.

OBJECTIVES

After reading this lesson, you will be able to:

- describe the measurement of Radioactivity
- describe about tracer technique
- explain clinical and biochemical uses of radioactive substances
- describe health effects of radiations

30.2 MEASUREMENT OF RADIOACTIVITY

The 3 commonly used methods are

1. Ionisation of gases
2. Excitation of solids and liquids
3. Ability to expose photographic emulsions i.e.autoradiography

1. Ionization of gases

Principle: Radiation causes ionization of gaseous particles in its path. When this takes place between electrodes in a closed chamber, an electric pulse is generated. The magnitude of it depends upon applied potential and number of radiation particles entering the chamber.

Instrumentation: Ionization chamber consists of a gas chamber with insulated base. It consists of an anode wire and metallic cathode. The circuit is closed by connecting to a battery and Resistor. The electric pulse produced is measured by amperometer.

Types

30.2.1 Ionization Chambers or simple ionization

In this type only one ion pair is produced per collision

Disadvantages:

- Current production is low
- Sensitive devices are needed for detection

30.2.2 Proportional Counters or gas amplification

At high voltage ionized electrons moves with high speed. This causes secondary and tertiary ionization. Finally, large number of electrons reaches the anode. This is known as Townsend avalanche effect.

Advantages

- Current production is high

Disadvantages

- Constant voltage is needed as it affects ionization and amplification

Uses

- To detect alpha emitting isotopes

30.2.3 Geiger-Mueller Counters

All the isotopes including beta emitters induce complete ionisation. Current flow is independent of primary ions. Maximal gas amplification is seen. The output pulse is same in considerable voltage range. Number of times the pulse produced will give the radioactivity. Dead time is the time taken by the ion pairs to reach their respective electrodes. This is usually 100-200μS.

Advantages

- Can detect beta radiation

Disadvantages

- Ionising particles entering into the tube during the dead time cannot be detected.
- Some ions escape from the electrodes and gives continuous discharge

Uses

- Routine check of radioactive laboratory for contamination
- Qualitative analysis of radioactivity.
- Quick screening of gels & chromatographic fractions for labeled components

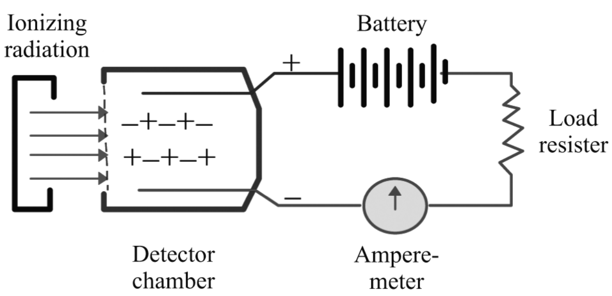

Fig. 30.1: Key Component in a Simple Ionization Chamber

30.3 EXCITATION OF SOLIDS AND LIQUID

Principle: Radioactive isotopes can excite a compound called fluor. This emits photons of light which can be detected and quantified using a photomultiplier tube. This is called scintillation counting.

Types: There are 2 types of scintillation counting

1. Solid scintillation counting and
2. Liquid scintillation counting

30.3.1 Solid Scintillation counting

Instrumentation: In solid scintillation counting the fluorescing substance is held in a light tight aluminium chamber. Radiations can penetrate through the aluminum and can cause excitation of solid crystals to emit photons of light. This fluorescence can be detected and quantified using a photomultiplier tube.

In photomultiplier tube, the electric pulse that results from the conversion of light energy to electrical energy. This is directly proportional to the radioactive event.

Crystal used for alpha isotopes: Zinc sulfide

Crystal used for beta isotopes: Anthracene

Crystal used for gamma isotopes: Sodium iodide

Advantages

- Gamma isotopes have weak penetrating power hence it rarely collides with molecules to cause excitation. In solid scintillation the atoms are densely packed in h crystal so the probability of collision is more

Disadvantages

- Cannot detect weak beta emitters like ^{3}H, ^{14} C& ^{35}S as they are not able to pass through the wall of the counter.

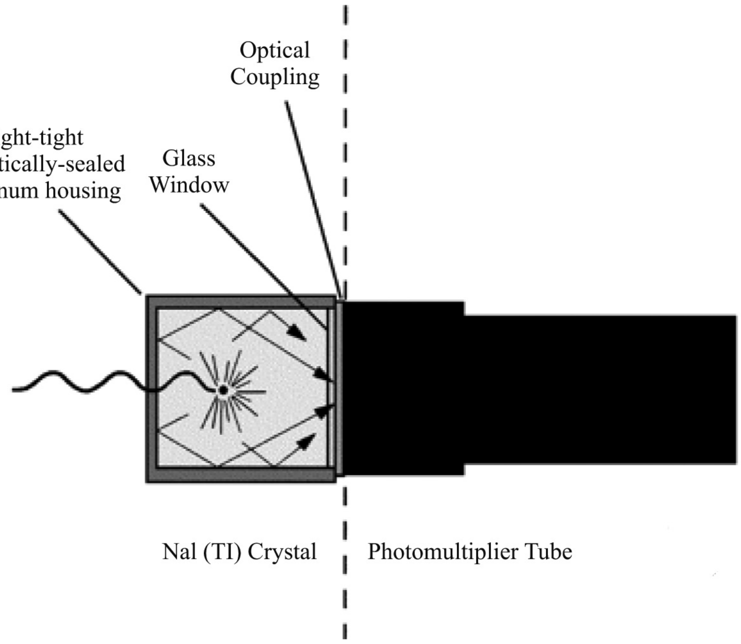

Fig. 30.2: Solid scintillation counter

30.3.2 Liquid scintillation counting

In liquid scintillation counting the sample is mixed with a scintillation cock tail containing solvent and one or more fluors

Instrumentation

In liquid scintillation counting, the radioactivity cause fluorescence of solvent. This emitted light in turn causes fluorescence of another compound called primary fluor. This emitted light in turn causes fluorescence of another compound called secondary fluor. This wavelength can be detected efficiently by the photomultiplier tube.

Advantages

- Can detect weak beta emitters like ^{3}H, ^{14}C& ^{35}S
- More than one isotope can be detected at a time
- Counting efficiency is high

Disadvantages

- Costly
- Quenching is the interference given by several substances in detecting actual fluorescence

30.4 ABILITY TO EXPOSE PHOTOGRAPHIC FILMS (AUTORADIOGRAPHY)

Principle: Ionising radiations acts upon photographic emulsions to produce a latent image

Instrumentation: A radiation source and photographic emulsion consisting of silver halides embedded in solid phase such as gelatin are needed. Radiation converts silver halide to metallic silver which forms a latent image. This can be developed as a blackening of the film and can be stored as a permanent image.

Uses: Distribution of radioactivity in biological specimens.

30.5 TRACER TECHNIQUE

It is technique in which one or more atoms of a chemical compound have been replaced by a radio isotope to trace the metabolic pathways. A radioactive tracer can also be used to track the distribution of a substance within a natural system such as a cell or tissue. Radioactive tracers form the basis of a variety of imaging systems, such as, PET scans, SPECT scans and technetium scans.

Principle

It is based on the principle that a stable isotope is replaced by a radioisotope. The radioisotope is capable of emitting radiations that can be detected and analysed. It is powerful than chemical reactions as they can be detected even in lower concentration as seen inside a cell. In general, isotopes of hydrogen, carbon, phosphorus, sulphur, and iodine have been used extensively to trace the path of biochemical reactions.

Uses

1. Tracing Metabolic pathways

When a labeled chemical compound undergoes reaction inside the cell ,one or more of the products will contain the radioactive label. Analysis of it provides detailed information on the mechanism of the chemical reaction.

2. Distribution of the compound

Radioactive compound provides a means to construct an image showing the way in which gets distributed in the organism

Application

1. In metabolism research, Tritium(^{3}H) and ^{14}C-labeled glucose are commonly used to measure rates of glucose uptake, fatty acid synthesis, and other metabolic processes.
2. In medicine, tracers are applied in a number of tests, such as ^{99m}Tc in autoradiography and nuclear medicine, including single photon emission computed tomography (SPECT), positron emission tomography (PET) and scintigraphy.
3. The urea breath test for helicobacter pylori commonly used a dose of ^{14}C labeled urea to detect H. pylori infection

30.6 CLINICAL AND BIOMEDICAL USES OF RADIOACTIVE SUBSTANCES

The Radioactive substances can be used to study various metabolic pathways. They are also used to diagnose and treat various diseases (eg cancer). Medical uses of few radioactive substances are given in the table below.

Clinical and biomedical uses of radioactive substances.

Radioactive isotope	Uses
Calcium- 47	Studying cellular function & bone formation
Carbon-14	Metabolism
Cesium-137	Cancer treatment
Chromium-51	RBC studies
Cobalt-57	Diagnosis of pernicious anemia
Cobalt-60	Sterilization of surgical instruments
Copper-67	Treat cancer
Iodine-123,125	Diagnose thyroid disorders
Iodine- 131	Treat thyroid disorders
Phosphorus-32,33	Molecular biology & genetic research
Selenim-75	Protein studies
Sulphur-35	Molecular biology & genetic research
Technetium-99m	Organ imaging & blood flow studies
Tritium	Drug metabolism
Xenon-133	Lung ventilation & blood flow

30.7 HEALTH EFFECTS OF RADIATIONS

We already know that radioactive radiations are able to ionize & excite the molecules they encounter. The effects of radiation depend upon the duration and its type.

30.7.1 Effects

The effects of radiation are

- *Generalised effect:* Biological effects are due to the ionization process that causes cell mutation. A given total dose will cause more damage if received in a shorter time period. A **fatal dose is (600 R)**
- *Acute Somatic Effects*: Relatively immediate effects to a person acutely exposed. Severity depends on dose. Death usually results from damage to bone marrow or intestinal wall. Acute **radio-dermatitis** is common in radiotherapy; chronic cases occur mostly in industry.

- *Critical Organs*: Organs generally most susceptible to radiation damage include: Lymphocytes, bone marrow, gastro-intestinal, gonads, and other fast-growing cells. The central nervous system is relatively resistant. Many nuclides concentrate in certain organs rather than being uniformly distributed over the body, and the organs may be particularly sensitive to radiation damage, e.g., isotopes of iodine concentrate in the thyroid gland. These organs are considered "critical" for the specific nuclide.

30.7.2 Basic Radiation Exposure Control Methods

The three basic ways to decrease the exposure to radiation are

- Decrease Time
- Increase Distance
- Increase Shielding
- **Time**: Minimize time of exposure to minimize total dose. Rotate employees to restrict individual dose.
- **Distance**: Maximize distance to source to maximize attenuation in air. The effect of distance can be estimated from equations.
- **Shielding**: Minimize exposure by placing absorbing shield between worker and source.

INTEXT QUESTIONS 30.1

1. Match the following:

1.	Carbon-14	(a)	Thyroid disorders
2.	Iodine-125	(b)	RBC studies
3.	Sulfur-35	(c)	Treat cancer
4.	Copper-67	(d)	Metabolism
5.	Chromium-51	(e)	Molecular biology

2. Fill up:

1. Gamma radiations can be detected .... counting.
2. Weak beta emitters can be detected by .... counting.
3. Dead time is seen .... counters.
4. Fatal dose of radiation is ....
5. The ability to expose photographic films is called ....

WHAT HAVE YOU LEARNT

- Radiations can be measured by methods based upon radiation, excitation and ability to expose photographic films
- In methods based on radiation Geiger muller counter is important
- In scintillation methods gamma radiations can be detected by solid scintillation counting
- In liquid scintillation counting more than one radioactive substance can be detected at a time
- Autoradiography can be used to study whole animal samples
- Effects of radiation can be minimized by increasing shielding and distance from the radioactive substance and decreasing the exposure time.

TERMINAL QUESTIONS

1. What are different types of measurement of radioactivity?
2. Write about ionization method of detection of radioactivity.
3. Write short notes on Geiger-muller counters
4. What is scintillation counting. and what are its types
5. Write short notes on solid scintillation counting
6. Write short notes on liquid scintillation counting
7. Writ about autoradiography
8. Write about different radio isotopes used clinically
9. Write about the deleterious effect of radiation
10. What are the different methods to control external radiation?

ANSWERS TO INTEXT QUESTIONS

30.1

1. 1. (d) 2. (a) 3. (e) 4. (c) 5. (b)

30.2

2. 1. Solid Scintillation 2. Liquid Schintillation
   3. Geiger - mueller 4. 600R
   5. Autoradiography