Radioactive Isotopes

Dr. Praveen Katiyar

The Atom

- All matter is made up of elements (e.g. carbon, hydrogen, etc.).
- ✤ The smallest part of an element is called an atom.

The atom consists of two parts:



The Atom

- Atoms of different elements contain different numbers of protons.
- The mass of an atom is almost entirely due to the number of protons and neutrons.



lsotopes

Definition:

- Isotopes are atoms with the same atomic number but different mass numbers
- They are the subspecies of the same chemical element & occupy the same position in periodic table, but have different properties.



Isotopes: Classification

Two classes of isotopes:

1- Stable Isotopes-

These do not have distinguishing characteristics other than their masses.

These are obtained from natural resources by fractional procedure.

2- Unstable –

Isotopes that continuously and spontaneously break down/decay in other lower atomic weight isotopes.

These are called Radio active isotopes.

Radio activity

Radioactivity is the spontaneous degradation of nucleus & transmission of one element to another with consequent emission of rays (or) particles.

In other words-

Radioactivity is the process whereby unstable atomic nuclei release energetic subatomic particles.

First discovered in 1896 by the French scientist Henri Becquerel, after whom the SI unit for radiation, the Becquerel, is named.

Radio isotopes

Radioisotopes/radioactive isotopes of an element can be defined as atoms that contain an unstable nucleus and dissipate excess energy by spontaneously emitting radiation in the form of alpha, beta and gamma rays.

How do radioisotopes occur?

Natural-

Occur in nature in traces, as in radium-226, Carbon-12 Artificial-

They are prepared artificially by altering the atoms, using a nuclear reactor or a cyclotron.

Properties of Radioactive Isotopes

- 1. Emits radiation
- 2.Half life(t ¹/₂)
- 3.Penetration property
- 4.Same chemical properties
- 5. Different physical properties

Emits radiation

Radioactive isotopes are unstable so they undergo radioactive decay emitting radiations, till they become stable.

3 types of radiations

- Alpha particles(α)
- Beta particles(β)
- Gamma rays(γ)



Alpha Decay

- An alpha particle is identical to a helium nucleus
- It contains two protons and two neutrons.
- Hence, it can be written as He2+.
- Alpha particles are a highly ionising form of particle radiation
- As its ionising power is so high it does not penetrate very deeply into matter
- Thus it has very low penetrating power (absorbed by 10 cm of air, 0.01 mm lead or a sheet of paper).





Beta Decay



- Beta decay occurs when a neutron changes into a proton (+) and an electron (-).
- A beta particle is identical to electron. It is Emitted from the nucleus of an atom undergoing radioactive decay.
- Beta particles are high-energy, high-speed electrons emitted by certain types of radioactive nuclei such as potassium-40.
- Form of ionising radiation also known as beta rays.
- The high energy electrons have greater range of penetration than alpha particles, but still much less than

particle

gamma rays.



Gamma Decay

- Gamma rays are not charged particles like α and β particles. They are *released with these particles*.
- Gamma rays are electromagnetic radiation with high frequency.
- When atoms decay by emitting α or β particles to form a new atom, the nuclei of the new atom formed may still have too much energy to be completely stable.
- This excess energy is emitted as gamma rays (gamma ray photons have energies of ~ 1 x 10⁻¹² J).
- These have Low ionising power.
- These have Very high penetrating power.



Comparison between three types of radiation

Type of radiation	alpha particles (α)	beta particle (β)	gamma rays (γ)
	each particle is 2	each particle is	electromagnetic
	protons + 2	an electron	waves similar to X-
	neutrons (it is	(created when	rays
	identical to a	the nucleus	
	nucleus of helium-4)	decays)	
Relative charge	+2	-1	0
lonising effect	strong	weak	very weak
Penetratig	not very	penetrating,	very penetrating,
effect	penetrating:	but stopped by	never completely
	stopped by a thick	a few	stopped, though
	sheet of paper, by	millimetres of	lead and thick
	skin or by a few	aluminium	concrete will
	centimetres of air	or other	reduce intensity
		metal	
Eeffect of field	deflected by	deflected by	not deflected by
	magnetic and	magnetic and	magnetic or
	electric field	electric field	electric fields
Application	Radiation hazard	Research/Diagnosis	Diagnosis/treatment

Half Life of Radioisotopes

- Half life of radio isotope is the time period required for radionuclide to decay to one half the amount originally present.
- abbreviated $t_{1/2}$
- **t**_{1/2} = 0.693/λ.
- λ is decay constant , a characteristic of a given isotope decaying in unit time .

The half-lives of some radioactive isotopes

Radioactive isotope

Uranium-238, 238 U Carbon-14, ¹⁴₆C Radium-226, 226/88 Ra Strontium-90 38Sr Iodine-131, ¹³¹₅₃I Bismuth-214, ²¹⁴₈₃Bi Polonium-214, 214 Po 4.5×10^9 years 5.7×10^3 years $1.6 imes 10^3$ years 28 years 8.1 days 19.7 minutes 1.5×10^{-4} seconds

Half-life

Penetration Property

Radioactive radiations have different penetrating ability.
Depends upon thickness & density of material.



Same chemical properties

- Isotopes of same elements have same chemical properties
- Due to same number of electrons in the outermost shell.

Different physical properties

- Differ from isotopes to isotopes.
- Based on number of neutrons.

Differences between stable isotopes & radioactive isotopes

STABLE ISOTOPE	RADIOACTIVE ISOTOPE	
Most abundantly found in nature	Less abundance of natural radioisotopes	
No emission of radiation	Spontaneous emission of radiations(α, β, γ)	
Atomic number and mass are constant	Constantly changing	
Detection by chemical/spectroscopic methods	Detection by external detectors like gas chambers/scintillation	
Not hazardous(except toxic chemicals)	Deleterious effects on biological tissues	
No special handling precautions(unless explosives/strong acids/carcinogens)	Special precautions while handling.	
No special applications	Special applications in research(mutagenesis)/diagnosis(RIA) /therapy(Rx of cancer)	

Radioactivity: Units

- Bequerel is the SI unit of radioactivity defined as one disintegration per second (1 d. p. s.).
- Curie defined as the quantity of radioactive material in which the number of nuclear disintegrations per second is same as the 1gm of radium (3.7 X 10¹⁰ Bq).
- Specific activity is defined as disintegration rate per unit mass of radioactive atoms.

Detection & Measurement of Radioactivity

- Ionization
- Ionization chamber
- Geiger counters
- Semi conductor detectors
- Scintillation:
- Solid scintillators
- Liquid scintillators
- Atuoradiography

Ionization

- The passage of high energy radiation through matter results in the formation of ions as a result of collision of electron with atoms.
- So much energy is transferred to the orbital electrons that on escape from the atom , it gives rise to a slow positively charged ions & a very fast secondary electron.
- Electrons slowed by multiple collision can be captured by reactive gas molecules & give rise to negative ions.
- An ion strongly accelerated in an electric field may collide with a neutral gas molecule and therapy give rise to fresh positive ion & electron.
- X & gamma rays must also first give rise to free electron before they can be detected & since the probability of ionization occurring decreases rapidly with increasing energy. Such a radiation is more difficult to detect.

Ionization chambers

 While ionization chamber measurements from the absolute basis of descimetry, the method is too slow & insensitive for detecting short lived radioactivity.

Geiger Counters

- These are gas filled counters operating at reduced pressure.
- These do not measure continuous currents but register collision ionization.
- The primary ions in the counter gas are multiplied by applying an electric field of 800 to 2000 V.
- In the range of 200 to 600 V, no. of ions present is strictly proportional to the no. of primary ions & for this reason proportional counters can be used to distinguish Beta rays from highly ionizing particles.
- The life time of a gas filled counter is limited by the capacity of the gas to a total of 10⁹ to 10¹⁰ collision discharges.

Semi conductor detectors

- When silicon crystals are irradiated , ionization occurs & secondary electrons are released with the aid of electron donors (for example lithium). These can be conducted to electrodes & measured as current pulses.
- Such drift detectors are suitable for detecting corpuscular & low energy x& gamma rays at room temperature.

Scintillation

- In scintillation process the radiation causes excitation & ionization of fluorescent material, the absorbed energy produces a flash of light.
- The principal types of scintillation detectors found in clinical laboratory are
 - 1-Solid Scintillator (sodium iodide crystal scintillation detector)
- The commonest type in use in nuclear medicine consists of single crystals of thalium activated sodium iodide.

2-The organic liquid scintillation detector

• The radiation from preparations emitting beta rays, soft x rays or gamma rays can be measured with particularly high pulse yield if they are mixed directly with a scintillator solution.

Autoradiography

- In autoradiography a photo graphic emulsion is used to visualize molecules labelled with a radioactive element.
- The emulsion consists of a large number of silver halide crystals embedded in a solid phase suchas gelatin.
- As energy from radioactive material dissipated in the emulsion, the silver halide becomes negatively charged & is reduced to metallic silver.
- Photographic developers are designed to show these silver grains as blackening of the film, & fixers remove any remaining silver halide.

Autoradiography

Techniques of autoradiography have become more important in molecular biology Weak β – emitting isotopes (³H ,¹⁴ C ,³⁵ S) are most

suitable for autoradiography, particularly for cell & tissue localization experiments.

Low energy of negatrons & short ionizing track of isotope will result in discrete image.

 β emitting radioisotopes are used when radioactivity associated with subcellular organelles is being located.

³H is the best radioisotope , since it's all energy will get dissipated in the emulsion .

Autoradiography

Electron microscopy can then be used to locate the image in the developed film.

For location of DNA bands in electrophoretic gel, ³²P

labelled nucleic acid probes are useful.

After hybridization ,hydrolysis & separation of DNA fragments by electrophoresis , a photographic plate is applied to the covered gel & allowed to incubate.

Autoradiography: choice of emulsion & film

- Xray films are generally suitable for macroscopic samples such as whole body, electrophoretographs, chromatographs.
- When light (or) electron microscopic , detection of image (cellular, subcellular localization of radioactivity) very sensitive films are necessary.
- Time of exposure & film processing depends upon the isotope, sample type, level of activity, film type & purpose of the experiment.
- In Direct autoradiography, the Xray film or emulsion is placed as close as possible to the sample.

Fluorography

- Fluorography is used to cutshort the time of exposure.
- A fluorescent material such as (PPO or sodium silicate) is infiltrated into the gel.
- Negatrons emitted will excite fluorescent material & mit light, which will react with the film.

Applications of Radioactive Isotopes

- a) Scientific research
- b) Analytical
- c) Diagnostic
- d) Therapeutic

Applications of Radioisotopes in Biological Sciences/Research

- Radioisotopes are frequently used for tracing metabolic path ways .
- Mixing radiolabelled substrates & samples of the experimental material & collecting samples at various times, extract & separate the products by chromatography.

Uses in Biological Sciences/ Research

- It is possible to predict the fate of individual carbon atoms of (¹⁴C) acetate through TCA cycle.
- Methods have been developed to isolate intermediates of the cycle & to ascertain the distribution of carbon atoms within each intermediate(this is called as specific labeling pattern).
- Radioisotopes are used in ascertaining the turnover times for particular compounds.

Group of rats injected with radio labelled amino acid left for 24 hours allowing to assimilate into proteins.

The rats are killed at suitable time intervals & radioactivity in organs or tissue of interest is determined .

Uses in Biological Sciences/ Research

- Radioisotopes are widely used in study of the mechanism & rate of absorption, accumulation & translocation of inorganic & organic compounds in the animal.
- Radiolabeled drugs are useful in pharmokinetic studies (site of accumulation, rate of accumulation, rate of metabolism & metabolic products).

Analytical applications of Radioisotopes

- Virtually any enzyme reaction can be assayed using radioactive tracer methods.
- Radioisotopes have been used in study of
 - The mechanism of enzyme action &
 - In studies of ligand binding to membrane receptors.
- Isotope dilution analysis : when a known amount of radioactive tracer is introduced into an unknown volume, after thorough mixing, the concentration of radio tracer is estimated.

V = N / n

- V = volume to be measured
- N = total number of counts injected n = number
- of counts per ml

Analytical applications of Radioisotopes

- By isotope dilution analysis plasma volume, total body water, E.C.F volume, RBC cell volume, total exchangeable sodium can be measured.
- 131 I labeled human serum albumin useful in diagnosing
 - protein losing enteropathy .
- 51 Cr labeled RBC are given intra venously if there is any GI blood loss radioactivity can be measured.
- Radio immuno assays are useful in analysis of hormones, growth factors, tumour markers, cytokines, bacterial antigens, vitamin D & various biological molecules.
- In RIA either antigen or antibody is radiolabeled. Radiolabelling must not interfere in the binding of antigen & antibody, has to be compared with unlabeled ones.

Applications of Radioisotopes in Diagnostic purposes

- The branch of medicine that deals with the diagnostic applications of radioactivity is referred to as Nuclear Medicine. A quick and accurate diagnosis can be made by radioimaging of organs like thyroid, liver, bone etc.
- Radio active iodine uptake & imaging reveals the functional status of thyroid tissue, including nodules, the whole thyroid gland & metastatic foci.

¹³¹I is used for thyroid cancer imaging & management.

¹²³ I is used for thyroid scan.

Schilling test : used to detect the malabsorption of vitamin B12. Measurement of urinary radio labelled B12 following a saturation dose of non labelled stable B12. 1000µg of non labelled B12 is given IM.1µg of labelled B12 is given orally. Less than 5% excretion of radio labelled dose indicates malabsorption of Vit. B12.
- Technetium 99 m (99 m Tc) pertechnetate: it is trapped by the thyroid gland, it can give a reasonable thyroid image.
- 99m Tc MIBI (2 methoxy 2 methyl propyl isonitrile) used in preoperative localization of parathyroid gland.
- Thalium 201 facilitates detection of 131 I negative metastatic thyroid cancer lesions in total body scan.
- Iodo cholesterol ¹³¹ labeled 6 iodo methyl -19 norcholesterol, used in adrenocortical imaging in cushing disease, cortisol producing adenoma, primary aldosteronism.

- MIBG (¹³¹ l or ¹²³ l meta iodo benzyl guanidine) scan is useful in adrenomedullary imaging in pheochromocytoma , neural crest tumors , carcinoid, medullary carcinoma thyroid .
- Isotope bone scan (Tc-99 with methylene diphosphonate or MDP) is extremely useful in pagets disease of bone.
- Bone scanning: 9oSr (radioactive strontium) is employed. Osteoblastoma (cancer arising from bone forming cells) could be detected very early by this method, even before the appearance of radiological changes.
- Indium 111 octreotide scan a somatostatin analogue used to show : neural crest tumors, pheochromocytoma, carcinoid, paraganglioma & medullary carcinoma thyroid.

- Fluorodeoxy glucose/FDG PET helpful in detection of ¹³¹I negative thyroid carcinoma, & MIBG negative pheochromocytoma.
- Strontium 89 & Samarium 153 are two radionuclides that are preferentially taken in bone, particularly sites of new bone formation, capable of controlling bone metastasis.
- Xenon 133 is useful in lung function tests & is useful in diagnosing malfunctions of lung ventilation.
- (133 I) iodohippuric acid used in diagnosis of kidney infections, kidney blockages or imbalance of function between two kidneys.

5¹Cr – EDTA , ^{99m}Tc-DTPA(diethylene-triaminepentaacetate)& ¹²⁵I –iothalamate have clearance closest to inulin (useful in measurement of GFR).

99^m Tc-DTPA has the advantage that it can also be used for gamma camera imaging.

Therapeutic applications of Radioisotopes

Radioisotopes have role in management of malignancies.
Tumor tissues are attacked by beam of radiation.

Two routes

- 1-From outside the patient's body ((External sources)
- 2-From within the body (Internal sources)

Therapeutic applications of Radioisotopes

1-External sources

a)Teletherapy :

⁶⁰Co is the source of radiation , radiation occurs from a

distant source .

Treatment of various malignant disorders.

Advantage: penetrate deep into tissues; does not cause skin reactions.

b)Beads, needles and applicators:

- Radioactive material is impregnated into body in form of beeds or needles or as surface applicants.
- e.g: ⁶°Co for CA Cervix, encapsulated in gold or silver needles, wires, rods or cylinders. ³2P applied to paper or polythene sheets for SCC, superficial angiomas, mycoises fungoides & senile keratosis. ⁹°Sr applicators used for lesions of cornea, conjunctiva & sclera.

Application of such sources directly on cancer tissue is called **Brachytherapy.**

Therapeutic applications of Radioisotopes 1-External sources

c)Heavy particles:

Produce dense ionisation in tissues e.g: Heavy particle proton irradiation used in diabetic retinopathy to improve vision.

d)Extracorporeal irradiation of blood:

e.g: C/c leukaemia- blood is taken out of patient via forearm artery, circulated around ¹³⁷Cs source which emits powerful γ rays, and then irradiated blood is returned to the same patient via forearm vein.

Advantage: avoid bone marrow depression by 'radiomimetic alkylating agents'.

Therapeutic applications of Radioisotopes

1-External sources

e)Boron-10 Neutron irradiation:

Produce dense ionisation in tissues, e.g. inoperable glioblastoma multiforme – Boron-10 i.v \rightarrow taken up by brain tissue \rightarrow head exposed to beam of slow neutrons \rightarrow tumor tissue absorbs neutrons \rightarrow transformed to Boron-11 \rightarrow disintegrates immediately to α -particles and Li isotope. Advantage: ionising property of α -particles destroy tumor cells, low penetrability leaves adjacent normal cells unharmed.

Therapeutic applications of Radioisotopes

2-Internal sources

a)Regional applications:

- ⁴⁸Au (gold) is used for treatment of malignant pleural & peritoneal effusions.
- Yttrium⁹⁰ synovectomy is useful in management of arthritis in hemophelics

b)IV applications:

- Yttrium^{90 & 198}Au (gold) in the form of tiny ceramic microspheres deliver local radiation to tumour cells of lung, prostate, hepatic and bone.
- c)Intralymphatic applications

Therapeutic applications of Radioisotopes 2-Internal sources

d)Systemic uses:

³²P is used for Rx of –

CML, PCV Multiple myeloma 1º hemmorhagic thrombocytosis CA Breast CA Prostate

¹³¹ is used for treatment of – Thyroid cancers, primary thyrotoxicosis.

Contraindicated in pregnancy, age< 25 years Adverse effect : permanent hypothyroism

¹³¹- used for producing hypothyroid state in intractable angina pectoris and intractable congestive cardiac failures, and to control resistant ectopic rhythms.

Fractionation of Doses

- Cancer cells are more actively dividing. In a cancer tissue, about 5-10% cells are in division, while in normal cells only less than 1% cells are dividing at particular time. Radiotherapy takes advantage of this difference between normal and cancer cells.
- Since radiotherapy affects only cells in division cycle (especially S phase), the radiation affects mainly the cancer cells. Recovery from radiation damage is quicker in normal cells than in cancer cells.
- The aim is to inflict maximum damage to cancer cells, while retaining the power of repair of the surrounding normal tissues.
- However, radiation given in a single dose is not effective. Because dividing cells are only 5% in the cancer population and radiation kills only this fraction. Moreover, a single large dose will be lethal. Instead, small divided doses are given to the cancer tissue. Thus the fractionated dose is employed. By the next day more cells are entering in the S phase which are killed by the second dose.
- The total radiation dose is usually given in 15-20 fractions, administered within 25-35 days.

Fractionation of Doses

Cellular death after radiation depends on the number of cells in division. This produces a curious effect, each increment in dose kills a constant fraction of the cancer cells; but not a constantnumber of cells.

While the first dose kills 1x109 cells, the 3rd dose can kill 1x107 cells only. However the percentage of cells killed is the same by each dose.

In other words, the size of tumor is rapidly diminished in the initial phases of radiotherapy, but the last few cells are difficult to destroy. In fact, all the cancer cells cannot be eradicated by radiotherapy. The last few residual cells are annihilated by the immunological system

Day	Dose in rads	Initial number of cells	Fraction of cells in division	No. of remain- ing cells	No. of cells killed
1.	400	1x10 ¹⁰	10%	9x10 ^a	1x10 ⁹
2.	400	1x10 [®]	10%	9x10 ^s	1x10ª
3.	400	1x10 ⁸	10%	9x10 ⁷	1x10 ⁷
4.	400	1x10 ⁷	10%	9x10 ^e	1x10 ^e

Effect of Radiotherapy differs

Radiation hazards

Radiation hazards- mechanisms

Radiation may...

- Deposit Energy in Bod
- Cause DNA Damage
- Create Ionizations in Body

Leading to Free Radicals

Which may lead to biological damage.

Response to radiation depends on:

- Total dose
- Dose rate
- Radiation quality
- Stage of development at the time of exposure

Effects of radiation

Depending on the basis of relationship between dose and appearance of effects:

- Acute or Nonstochastic
- Late or Stochastic (Delayed)

Acute or Nonstochastic

- Occur when the radiation dose is large enough to cause extensive biological damage to cells so that large numbers of cells die off.
- Have a threshold dose beyond which all exposed individuals are affected.
- Evident hours to a few months after exposure (Early)
- Skin burns, erythema, epilation
- Cataract
- Bone marrow depletion, aplastic anemia, myelofibrosis.

Late or Stochastic (Delayed)

- Appear randomly in exposed populations.
- Severity of effect does not depend on dose exposure.
- Incidence of effect ↑s with the dose.
- Exhibit themselves over years after acute exposure.
 - Radiation induced cancers
 - ↑d mutation rates
 - Chromosomal abberations
 - Leukemia
 - Genetic effects

Radiosensitivity of cells

Low Sensitivity	Mature red blood cells
	Muscle cells
	Ganglion cells
	Mature connective tissues
Intermediate	Gastric mucosa
Sensitivity	Mucous membranes
	Esophageal epithelium
	Urinary bladder epithelium
High Sensitivity	Primitive blood cells
	Intestinal epithelium
	Spermatogonia
	Lymphocytes

Effects of Radiation

- Immediate effects
- Delayed effects
- Genetic effects

Immediate effects-

- 1. Bone marrow syndrome
- 2. Gastrointestinal track syndrome
- 3. Central nervous system syndrome

Immediate effects

Bone marrow syndrome :

- Severe damage to hematopoietic system, leads to pancytopenia, gross immunosupression & ↑d susceptibility to infection. Occurs with exposure of 200-1000 rads.
- Death within 10-20 days.

Gastrointestinal tract syndrome :

- Severe damage to mucosal epithelium → fluid loss, electrolyte imbalance, GI hemmorhage.
- Exposure of 1000 5000 rads is the cause .
- Death occurs in 3-5 days

Immediate effects

Central nervous system syndrome :

- BBB is lost →cerebral vasculitis, meningitis and choroid plexitis.
- Exposure of 5000 10000 rads is the cause .
- Death occurs in 8-48 hours.
- Delayed effects : carcinogenesis by damaging DNA

Delayed effects

- Carcinogenesis
- In Utero radiation exposure
- Shortening of life span
- Miscellaneous effects

Delayed effects

Carcinogenesis

- Ionising radiations
- BM & rapidly dividing cells more susceptible
- Leukemia, Thyroid cancer, Polycythemia vera, Breast CA, Bone CA.
- Hiroshima & Nagasaki(1945) higher leukemia mortality rate.

In Utero radiation exposure: 3 types of

damages

- Growth retardation- exposure of embryo after implantation.
- Congenital malformation-exposure at the time of organogenesis or later.
- Fetal/neonatal death- exposure of pre- implantation embryo.

Delayed effects

Shortening of life span

- Observed in animals(mice/rats)
- Experimentally irradiated with moderate doses

Miscellaneous effects

- Endocrine imbalance
- Nephrosclerosis
- ↓d fertility or sterility
- Cataract

Genetic effects

- ✤ Target molecule- DNA
- Damage mutagenesis
- Manifestation depends on efficiency of DNA repair mechanism.
- Magnitude of changes depend on:
 - Stage of germ cell development
 - Dose rate
 - Interval between exposure and conception

Radiation safety & protection

- The most popular triad of radiation protection is time, distance & shield (TDS).
- Minimum possible time should spent near the radiation zone.
- Handling of radioactive material should be done from maximum possible distance.
- Person should be shielded by lead .

Room shielding





Lead lined plaster board

Lead glass viewing window

Personal Protective Equipment





Fig 3. Overshoes Often worn routinely in the Radiopharmacy for sterility reasons. Not always otherwise worn routinely to prevent the spread of contamination, but widely used for this purpose following a spillage.



Radiation protection in X-ray



e size fits wil neck sazes. The rolicity tastament gives planity of laust adjustments.





scatter radiation reduction at 80 kV amounting to: 94% for material in Pb 0.25 mm 97% for material in Pb 0.35 mm 99% for material in Pb 0.50 mm

Radiation Safety -Laboratory Rules-

- 1. Smoking, eating, and drinking are not permitted in radionuclide laboratories.
- 2. Food and food containers are not permitted in the laboratory.
- 3. Radionuclide work areas shall be clearly designated and should be isolated from the rest of the laboratory.
- 4. All work surfaces shall be covered with absorbent paper which should be changed regularly to prevent the buildup of contamination.
- 5. Protective clothing shall be worn when working with radioactive materials. This includes laboratory coats, gloves, and safety glasses.
- 6. Dosimeters shall be worn when working with relatively large quantities of radionuclides which emit penetrating radiation.

Radiation Safety -Laboratory Rules-

- 7. All containers of radioactive materials and items suspected or known to be contaminated shall be properly labeled with tape or tagged with the radiation logo and the word "RADIOACTIVE".
- 8. All contaminated waste items shall be placed in a container specifically designed for radioactive waste.

Radioactive Waste Disposal

- Radioactive waste includes anything that contains or is contaminated with radioactive material.
- Collect radioactive waste in proper containers.
- Keep containers closed and secured unless you are adding waste.
- Report the proper information on the radioactive waste tag when material is put in the waste container.
- Keep a tag on the waste container at all times.

S.No.	Radioisotope	Uses
01	CALCIUM-47	Important aid to biomedical researchers studying cellular functions and bone formation in mammals
02	CESIUM-137	Used to treat cancerous tumors To measure correct dosages of radioactive pharmaceuticals
03	CHROMIUM-51	Used in research in red blood cells survival studies.

S.No.	Radioisotopes	Uses
04	COBALT-57	Used as a tracer to diagnose pernicious anemia.
05	COBALT-60	Used to sterilize surgical instruments Used in cancer treatment, food irradiation and radiography
06	COPPER-67	When injected to monoclonal antibodies into a cancer patient, helps the antibodies bind to and destroy the tumor.
07	GALLIUM-67	Used in medical diagnosis

S.No.	Radioisotopes	Uses
08	IODINE-123	Widely used to diagnose thyroid disorders and other metabolic disorders including brain functions
09	IODINE-125	Major diagnostic tool used in clinical test and to diagnose thyroid disorders. Also used in biomedical research.
10	IODINE-129	Used to check some radioactivity counters in in-vitro diagnostic testing laboratories.
11	IODINE-131	Used to treat thyroid disorders(Graves's disease).

S.No.	Radioisotope	Uses
12	IRIDIUM-192	In brachytherapy/tumor Irradiation.
13	PHOSPHORUS-32 & PHOSPHORUS-33	Used in molecular biology and genetics research
14	TECHNETIUM-99m	Most widely used radioactive pharmaceutical for diagnostic studies in nuclear medicine. Different chemical forms are used for brain, bone, liver, spleen and kidney imaging
15	URANIUM-234	Used in dental fixtures like crowns and dentures to provide a natural color and brightness.
16	XENON-133	Used in nuclear medicine for lung ventilation and blood flow studies.

