RADIO active ISOTOPES

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DEFINITIONS

- **Isotopes** are the atoms with the same atomic number but different mass numbers .

DEFINITIONS

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

DEFINITIONS

- **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.

The Atom

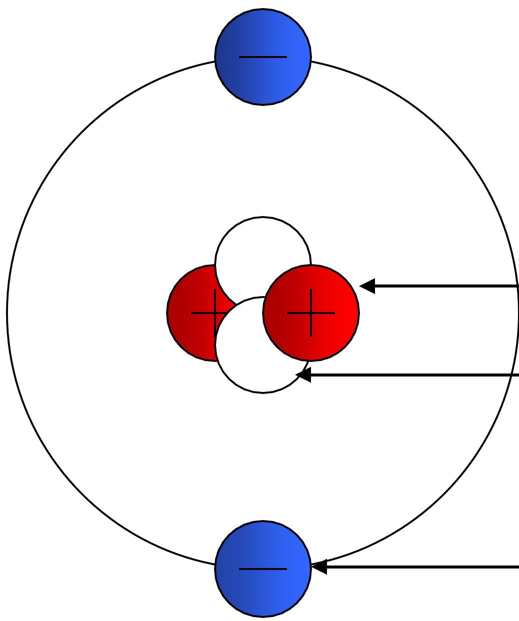
All matter is made up of elements (e.g. carbon, hydrogen, etc.).

The smallest part of an element is called an atom.

The Atom

The atom consists of two parts:

1. The nucleus which contains:



protons

neutrons

2. Orbiting electrons.

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.

Mass number = number of protons + number of neutrons

$$^{A}_{Z}\mathrm{X}$$

Element symbol

Atomic number = number of protons

$$^{A}_{Z}X$$

A = number of protons + number of neutrons

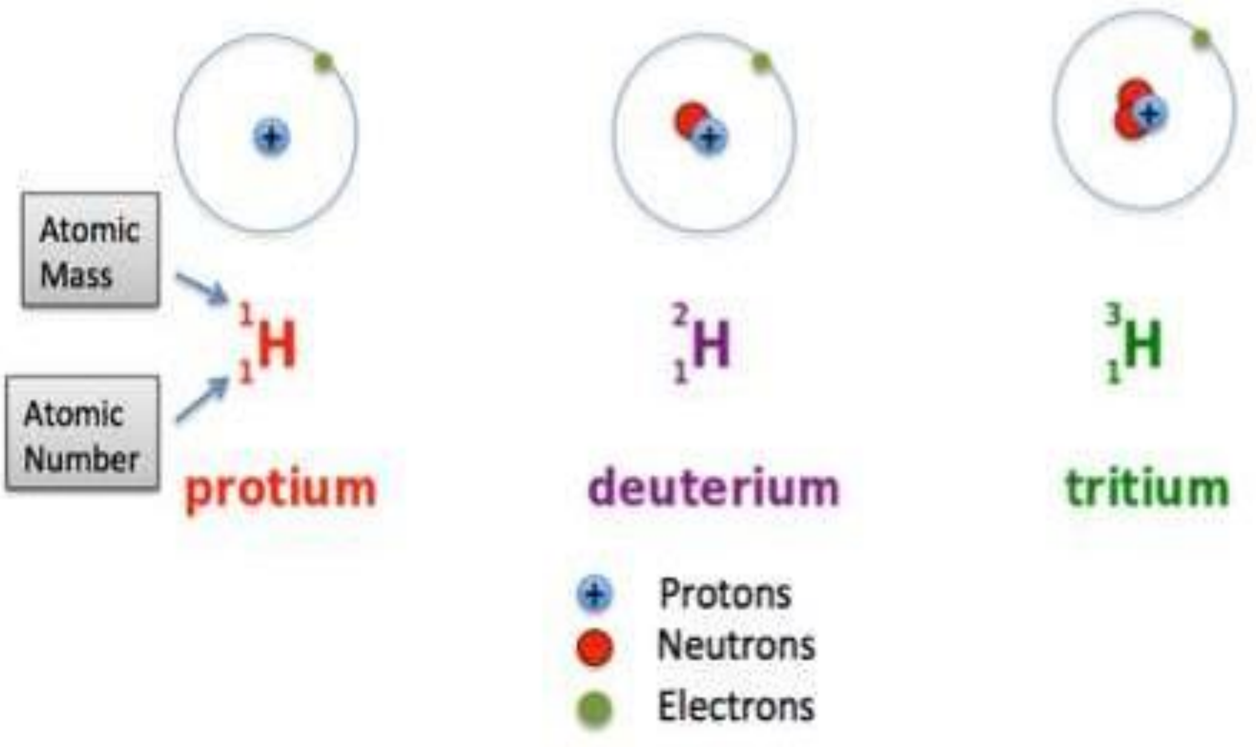
Z = number of protons

A – Z = number of neutrons

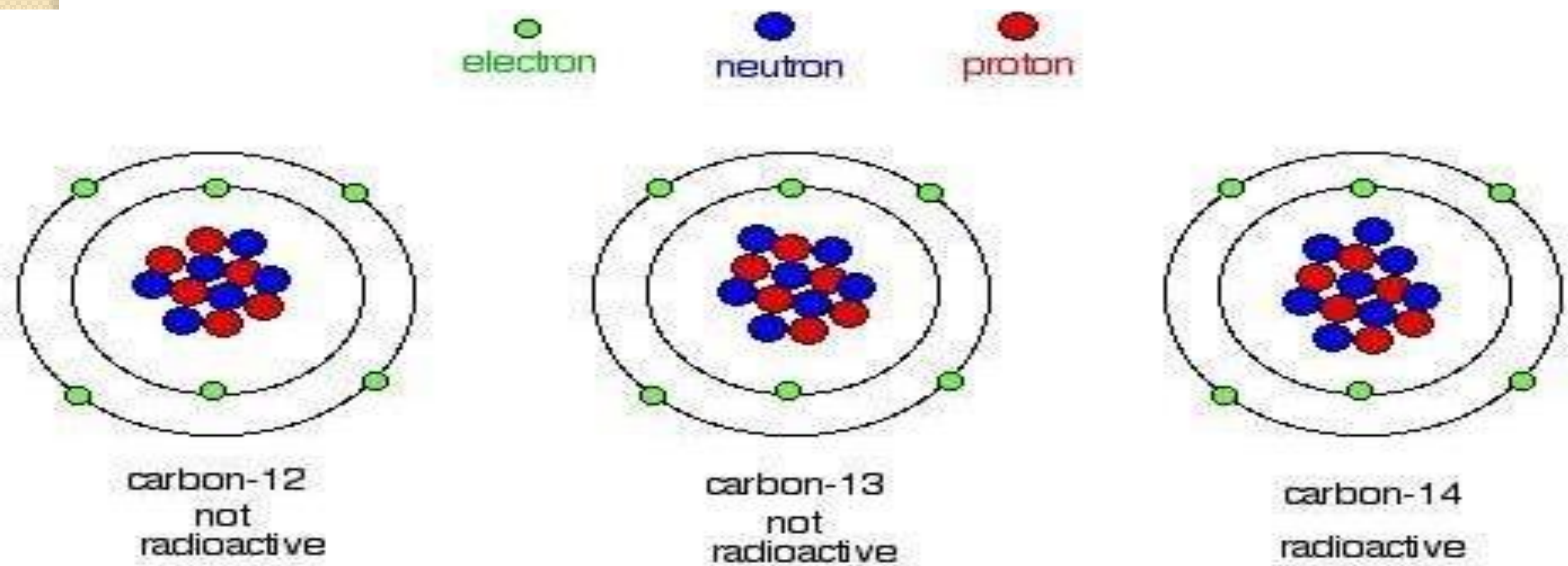
Number of neutrons = Mass Number – Atomic Number

- **Isotopes** are atoms with the same atomic number but different mass numbers .

ISOTOPES OF HYDROGEN



ISOTOPES OF CARBON



There are many "isotopes" of uranium:

$^{235}_{92}U$ $^{238}_{92}U$

A	235
Z	92
Number of protons	92
Number of neutrons	143

A	238
Z	92
Number of protons	92
Number of neutrons	146

Isotopes of any particular element contain the same number of protons, but different numbers of neutrons.

Uranium-238-naturally-occurring uranium (0.7%)
Uranium-235- less stable , or more radioactive, which has three less neutrons.

How do radioisotopes occur?

***Naturally-** as in radium-226, Carbon-12
***Artificially** altering the atoms by by using a nuclear reactor or a cyclotron.

Most of the isotopes which occur naturally are stable.

A few naturally occurring isotopes and all of the man-made isotopes are unstable.

Unstable isotopes ***can become stable*** by releasing different types of particles.

This process is called **radioactive decay** and the elements which undergo this process are called **radioactive isotopes/radioisotopes/radionuclides**.

Radioactivity

- 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.

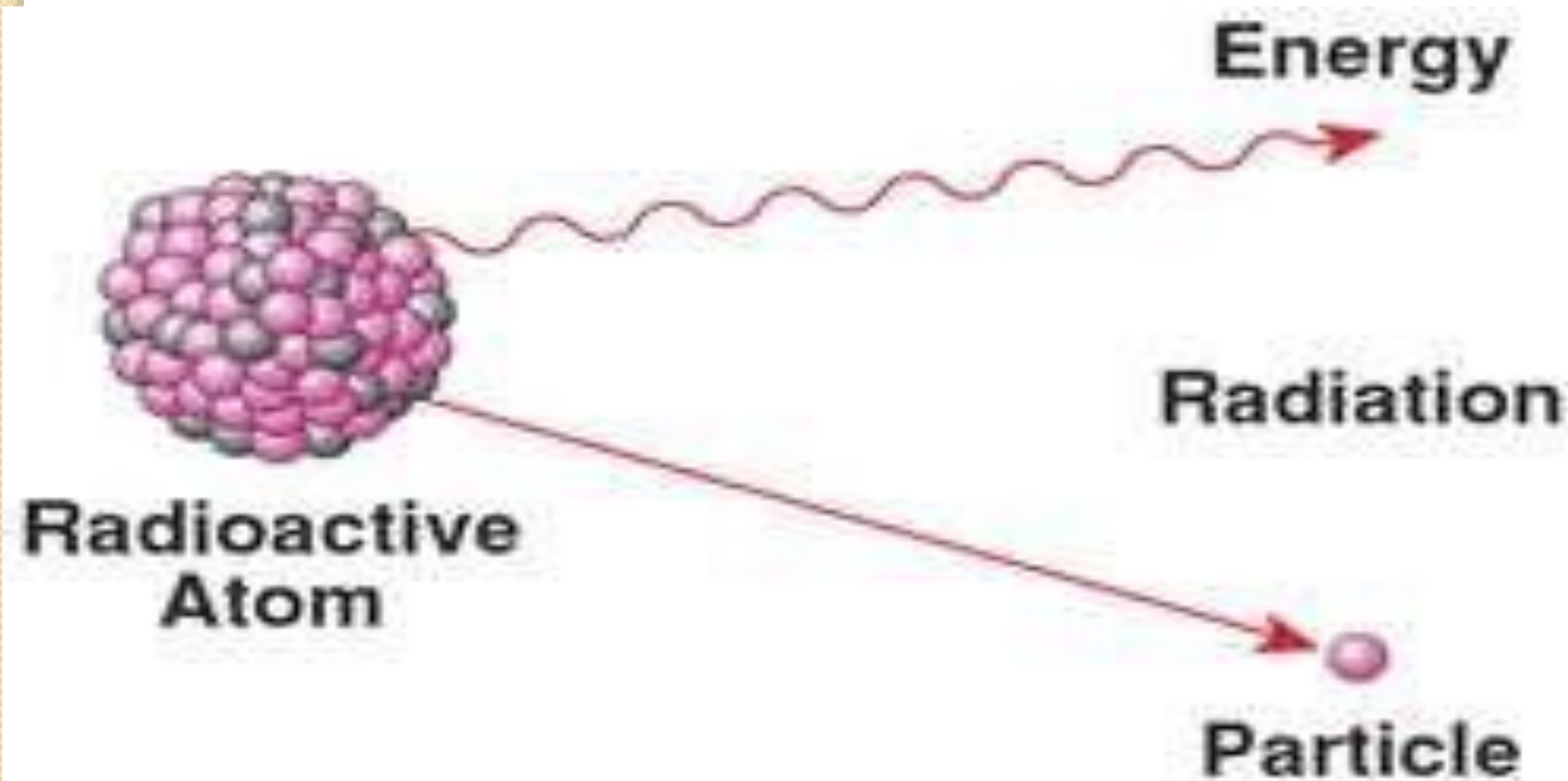
PROPERTIES OF RADIOACTIVE ISOTOPES

- 1. Emits radiation
- 2.Half life(t ½)
- 3.Penetration property
- 4.Same chemical properties
- 5. Different physical properties

Emits radiation

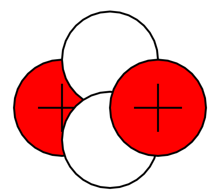
- Radioactive isotopes are unstable so they undergo **radioactive decay** emitting radiations.
- Till they become stable

- **3 types of radiations**
- Alpha particles(α)
- Beta particles(β)
- Gamma rays(γ)


Energy
Radiation
Radioactive
Atom
Particle

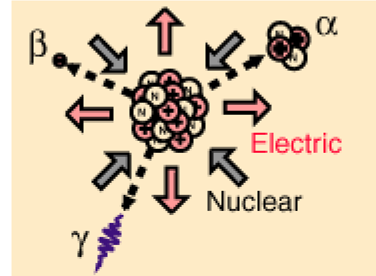
Alpha Decay

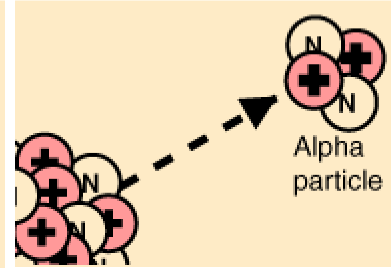
An alpha particle is identical to a helium nucleus.



It contains two protons and two neutrons.

Hence, it can be written as He2+.



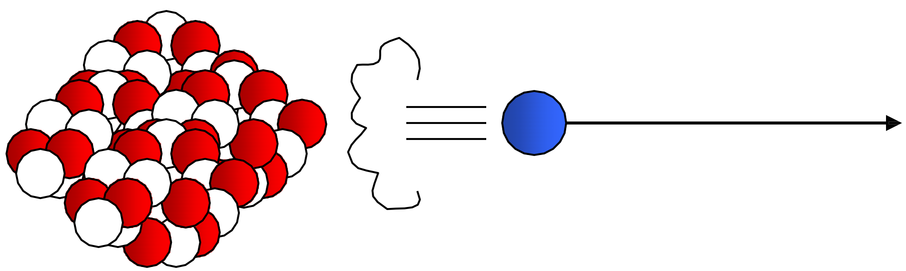


Alpha Particle

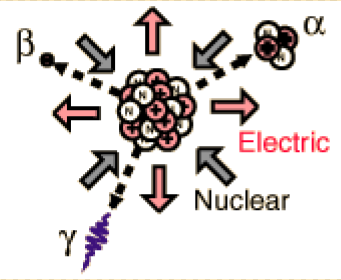
- Alpha particles are a highly ionising form of particle radiation
- As its ionising power is so high it does not penetrate very deeply into matter
- Thus it has very low penetrating power (absorbed by 10 cm of air, 0.01 mm lead or a sheet of paper).

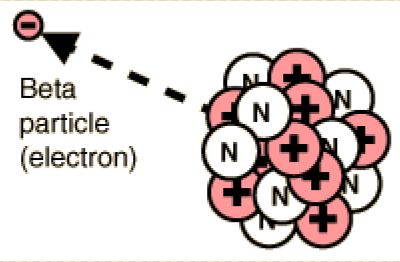
Beta Decay

A beta particle is identical to electron.
Emitted from the nucleus of an atom undergoing radioactive decay.



Beta decay occurs when a neutron changes into a proton (+) and an electron (-).





Beta Particle

- 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 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 ~ 1×10^{-12} J).

Gamma Rays

- Low ionising power.
- Very high penetrating power.

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

Nuclear Equation

- Nuclear equations can be used to show the decay process.
- These must balance for nucleon number and proton number.

- **Alpha decay**
  - When alpha decay occurs a group of 2 protons and 2 neutrons (helium nucleus) comes out of the nucleus. Therefore the proton number decreases by 2 but the nucleon number decreases by 4. The resulting daughter nucleus is of an element 2 positions to the left of the 'parent' in the periodic table.

$$ {}^{A}_{Z}X \rightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}\alpha $$

- **Alpha decay**
  - Example:

$$^{238}_{92}U \rightarrow ^{234}_{90}Th + ^{4}_{2}He$$

- Beta decay
  - When beta decay occurs a neutron within the nucleus emits the particle and changes into a proton. Therefore the proton number increases by one but the nucleon number stays the same. The resulting daughter nucleus is of an element 1 position to the right.

$$^{A}_{Z}X \longrightarrow \; ^{A}_{(Z+1)}Y + \; ^{0}_{-1}e$$

- Beta decay
  - Example:

$$^{14}_{6}C \rightarrow ^{14}_{7}N + ^{0}_{-1}\beta$$

- **Gamma Emission**
  - Sometimes, after its emission of an alpha or beta particle, the nucleus is still in an excited state, called a metastable state.
  - In order to get to a lower energy state it emits a quantum of energy in the form of a gamma ray.

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 $\mathbf{t_{1/2}}$
- $\mathbf{t_{1/2}} = 0.693/\lambda$.
- λ is decay constant , a characteristic of a given isotope decaying in unit time .

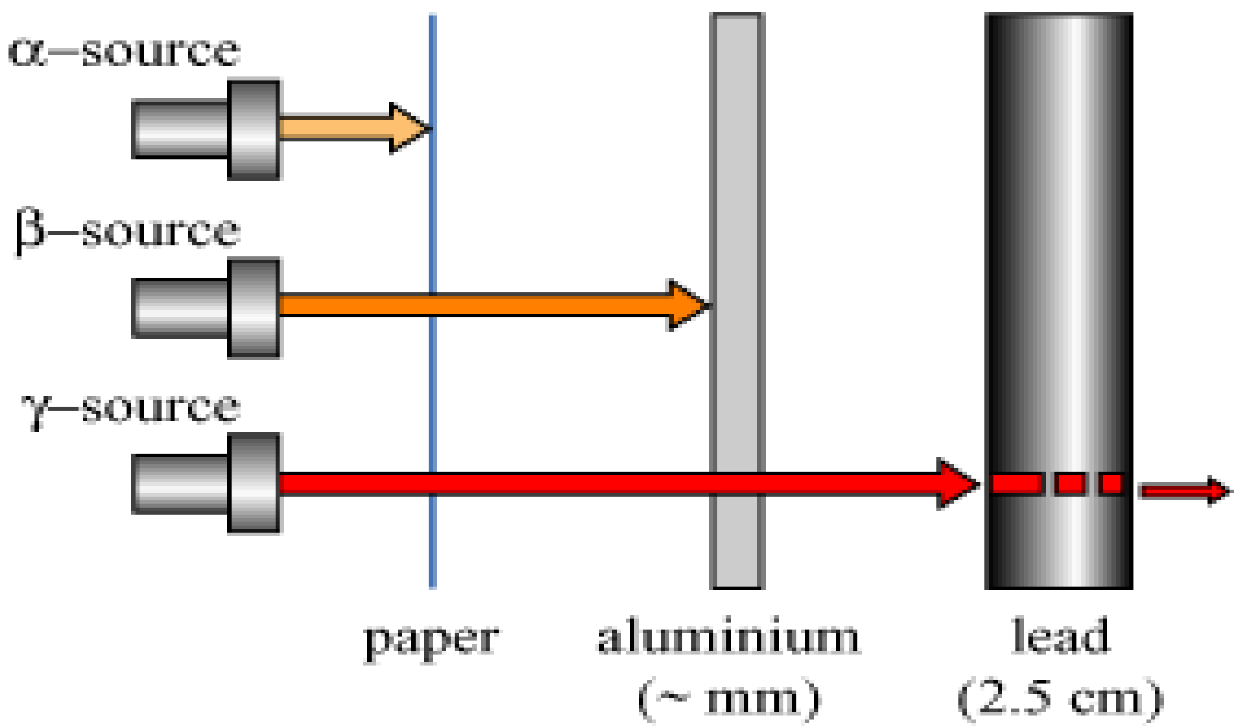
The half-lives of some radioactive isotopes

Radioactive isotope	Half-life
Uranium-238, $^{238}_{92}U$	4.5×10^{9} years
Carbon-14, $^{14}_{6}C$	5.7×10^{3} years
Radium-226, $^{226}_{88}Ra$	1.6×10^{3} years
Strontium-90 $^{90}_{38}Sr$	28 years
Iodine-131, $^{131}_{53}I$	8.1 days
Bismuth-214, $^{214}_{83}Bi$	19.7 minutes
Polonium-214, $^{214}_{84}Po$	1.5×10^{-4} seconds

Penetration Property

- Radioactive radiations have different PENETRATING ability.
- Depends on "thickness and density" of material

Penetration property



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)

UNITS OF RADIOACTIVITY

- **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 (3.7×10^{10} Bq).
- **Specific activity** is defined as disintegration rate per unit mass of radioactive atoms.

Detection & Measurement of Radioactivity

- 1) Autoradiography ,
- 2) gas ionization detectors &
- 3) fluorescent scintillation

These are the basis to detect & measure radioactivity in clinical laboratory .

APPLICATIONS OF RADIOACTIVE ISOTOPES

a) SCIENTIFIC RESEARCH
b) ANALYTICAL
c) DIAGNOSTIC
d) THERAPEUTIC

APPLICATIONS OF RADIOISOTOPES IN BIOLOGICAL SCIENCES

- 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

- Radioisotopes are used in ascertaining the turnover times for particular compounds .
- Group of rats injected with radio labeled 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

- Radioisotopes are widely used in study of the mechanism & rate of absorption , accumulation & translocation of inorganic & organic compounds in the animal .

ANALYTICAL APPLICATIONS OF RADIOISOTOPES

- Virtually any enzyme reaction can be assayed using radioactive tracer methods.

The mechanism of enzyme action

Radioisotopes used in Diagnostic purposes

- Radio active iodine uptake & imaging reveals the functional status of thyroid tissue , including nodules , the whole thyroid gland & metastatic foci .

- ^{131}I is used for thyroid cancer imaging & management .

- ^{123} I is used for thyroid scan .

Therapeutic uses of radioisotopes

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

- Two routes

  - From outside the patient's body(External sources)

  -From within the body(Internal sources)

Radiation hazards

Radiation hazards- mechanisms

- Radiation may…
  - Deposit Energy in Body
  - 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

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 .

- Minimize the time and you will minimize the dose.
  - Pre-plan the experiment/procedure to minimize exposure time.

- Doubling the distance from the source can reduce your exposure intensity by 25%.
- Move the item being worked on away from the radiation area if possible.
- Know the radiation intensity where you perform most of your work, and move to lower dose areas during work delays.

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

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

RADIOISOTOPE	USES
1)Calcium-47	Important aid to biomedical researchers studying cellular functions and bone formation in mammals.
2)Cesuim-137	Used to treat cancerous tumors… To measure correct dosages of radioactive pharmaceuticals…
3)Chromium-51	Used in research in red blood cells survival studies.

RADIOISOTOPE	USES
4)Cobalt-57	Used as a tracer to diagnose pernicious anemia.
5)Cobalt-60	• Used to sterilize surgical instruments… • Used in cancer treatment, food irradiation and radiography.
6)Copper-67	When injected to monoclonal antibodies into a cancer patient, helps the antibodies bind to and destroy the tumor.

RADIOISOTOPE	USES
7)Gallium-67	Used in medical diagnosis.
8)Iodine-123	Widely used to diagnose thyroid disorders and other metabolic disorders including brain functions.
9)Iodine-125	Major diagnostic tool used in clinical test and to diagnose thyroid disorders. Also used in biomedical research.

RADIOISOTOPE	USES
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)
12)Iridium-192	In brachytherapy/tumor Irradiation.
13)Phosphorus-32 and Phosphorus-33	Used in molecular biology and genetics research.


Thank you