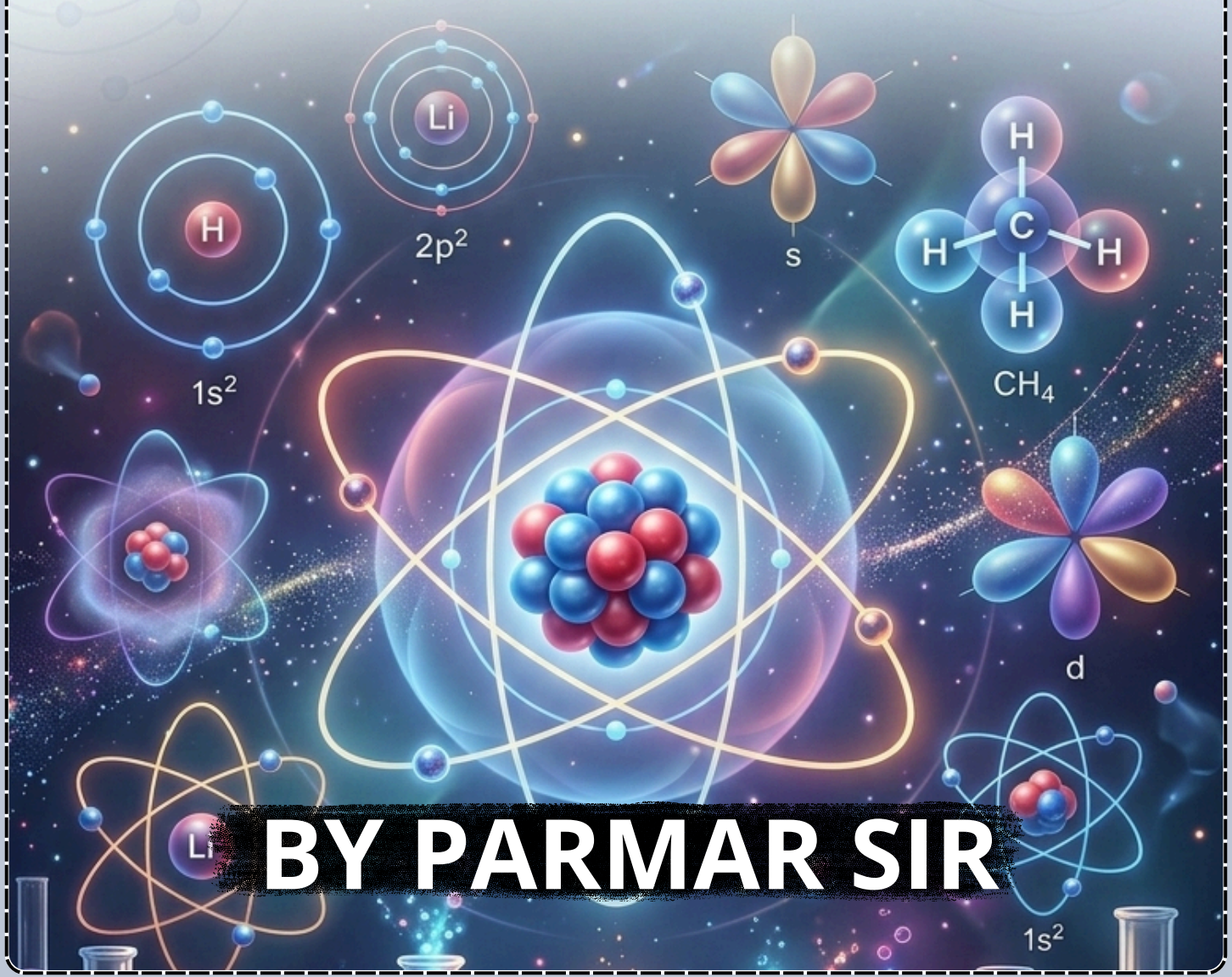
PARMAR SSC

ATOM AND IT'S STRUCTURE

Lecture - 3



BY PARMAR SIR

ATOM

- Atoms are the smallest component of an element and are building blocks of matter.
- An atom is composed of protons (p), neutrons (n) and electrons (e-).

Laws of Chemical Combination

Law of Conservation of Mass

- The law of Conservation of Mass states that in a closed system, the total mass of a system remains constant over time, meaning mass is neither created nor destroyed, but can only change form.
- This was given by Antoine Lavoisier (Father of modern Chemistry).

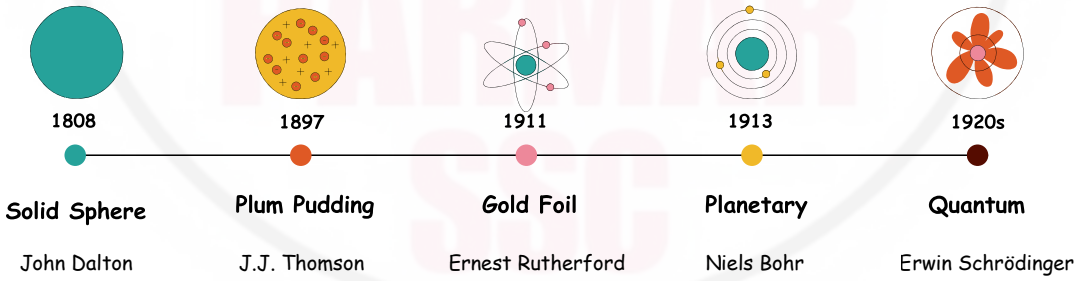
Total mass of reactants = Total mass of products

- Lavoisier heated mercury in a sealed container with air.
- Reaction: $2Hg + O_2 \rightarrow 2HgO$ (Reactant → $2Hg + O_2$, Product → $2HgO$)

Law of Constant Proportion

- The law states that a given chemical compound always contains its component elements in a fixed ratio by mass, regardless of its source or method of preparation.
- This was given by Joseph Proust.
- **Examples**: H_2O-water (2:16 = 1:8), CH_4-methane (12:4 = 3:1)

The Atomic Models



Dalton's Atomic Theory (1808)

- All matter is made of indivisible particles called atoms, which cannot be created nor destroyed.
- Atoms of the same element have identical mass and physical properties.
- Compounds are combinations of atoms of two or more elements.
- All chemical reactions involve the rearrangement of atoms.

J.J. Thomson and Discovery of Electron (1898)

- **1897:** J. J. Thomson performed Cathode-Ray Experiment by observing streams of particles emitted by cathode of a vacuum tube, which led to the discovery of the electron.

He proposed:

(i) An atom consists of a positively charged sphere and the electrons are embedded in it.

(ii) The negative and positive charges are equal in magnitude. So, the atom as a whole is electrically neutral.

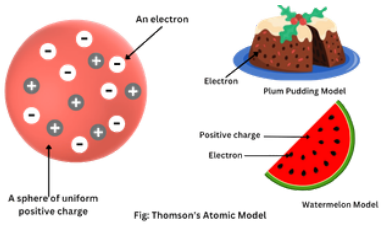


Fig: Thomson's Atomic Model

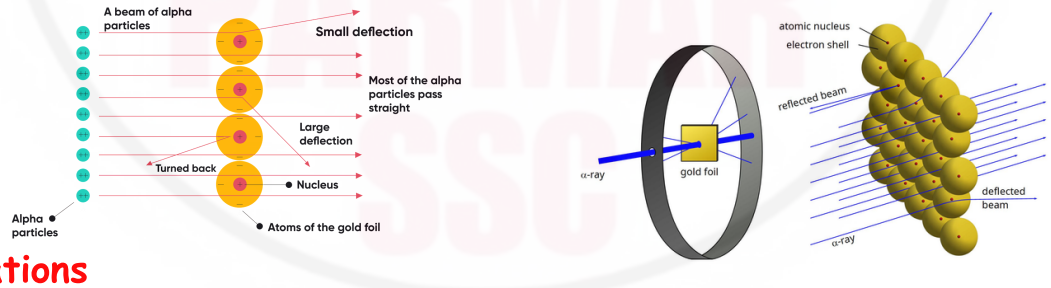
- **1904:** J. J. Thomson proposed the first atomic model, often referred to as the **"Plum Pudding Model", "Raisin Pudding Model", or "Watermelon Model".**
- In this model, the positive charge is spread throughout the atom (like the bulk of pudding or watermelon), while the electrons are embedded within it (like plums or seeds).

Ernest Rutherford's Atomic Model (1911)

- In 1909, Ernest Rutherford conducted the Gold Foil Experiment with the help of Hans Geiger and Ernest Marsden.

Findings

- Rutherford used gold foil (about 1000 atoms thick) because gold is highly malleable, allowing it to be hammered into ultra thin sheets.
- A thicker foil would have prevented the alpha particles (doubly charged helium atoms) from penetrating.
- The majority of alpha particles went through the gold foil without any deflection; however, a smaller number of alpha particles were slightly deflected from their original path.
- A few alpha-particles were deflected at small and large angles, indicating the presence of a dense, positively charged nucleus.
- A very few (1 in 8000) were deflected backwards, at angles greater than 90

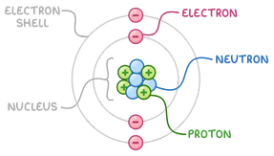


Key observations

(i) An atom has a positively charged centre, called the nucleus, where nearly all the atom's mass is concentrated.

(ii) Electrons revolve around the nucleus in circular paths (orbits).

(iii)The nucleus is extremely small compared to the overall size of the atom.



Drawbacks of Rutherford's Model:

- The atomic model failed to explain the distribution of electrons around the nucleus and the stability of atoms.
- It did not explain why atoms emit specific colours when they are heated.
- It failed to explain why different elements react differently or how electrons are arranged.
- The atomic model did not include energy levels which was later explained through Bohr's Model (1913).

Artificial Nuclear Reaction (1917):

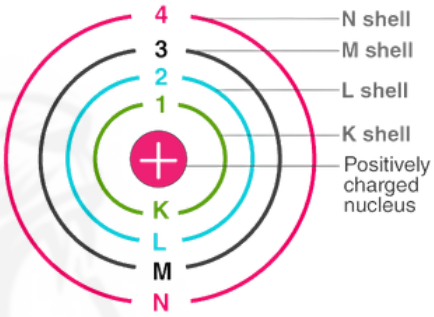
- In 1917, Rutherford performed the first artificially induced nuclear reaction by conducting an experiment in which nitrogen nuclei were bombarded with alpha particles.
- Rutherford concluded that the hydrogen nucleus is a fundamental particle present in all atoms.
- He named this positively charged particle the proton (p^+) in 1920.

Goldstein discovered positively charged canal rays.

Bohr's Model of Atom (1913)

According to this model:

- Electrons revolve around the nucleus in stable orbits (energy levels or shells) without losing energy in the form of radiation.
- The orbits or energy levels are labeled K, L, M, N, with K being the closest to the nucleus and N being the farthest.
- The ground state is the lowest energy level that an electron can occupy, typically referring to the electron's position in the K-shell (the innermost shell).



- When an electron moves between different energy levels (or shells), it either absorbs or emits energy.
- When an electron falls from a higher energy level to a lower one, it emits energy, usually in the form of electromagnetic radiation.
- When an electron moves from a lower energy level to a higher one, it absorbs energy.

Distribution of Electrons (e^-)

The maximum number of e^- that can be present in the nth shell is equal to $2n^2$

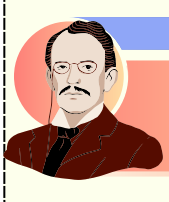
Shell	Max. e^-
K-shell (n=1)	$2 \times 1^2 = 2$
L-shell (n=2)	$2 \times 2^2 = 8$
M-shell (n=3)	$2 \times 3^2 = 18$
N-shell (n=4)	$2 \times 4^2 = 32$

Last shell/ orbit >> Valence shell >>> e- >>>> Valence e-

ELECTRON, PROTON, AND NEUTRON

Discovery

Electron



J. J Thompson

Proton



Rutherford or Goldstein

Neutron



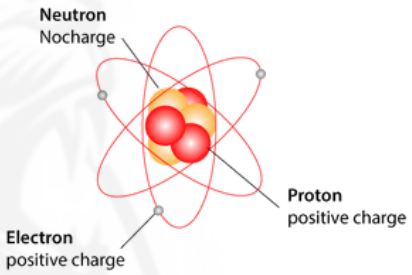
Chadwick (1932).

Positron (Antiparticle): Discovered in 1932 by Carl Anderson.

Particle	Charge on the particle	Mass of the particle	Symbol	Location in the atom
1. Electron	−1 unit (−1.602 × 10^{-19} coulomb)	9.11×10^{-31} kg (1/1840 u)	$^{0}_{-1}e$	Outside the nucleus (Extranuclear part)
2. Proton	+1 unit (+1.602 × 10^{-19} coulomb)	1.673×10^{-27} kg (1 u)	$^{1}_{1}p$	In the nucleus
3. Neutron	No charge	1.675×10^{-27} kg (1 u)	$^{1}_{0}n$	In the nucleus

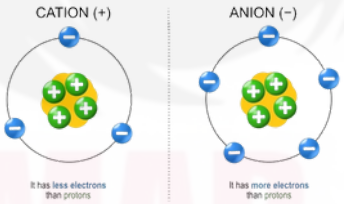
Neutron

- A neutron's mass is approx. 1836 times greater than that of an electron.
- Neutrons are sub-atomic particles that are found in the nucleus of every atom, except for hydrogen, which only has a proton in its nucleus.
- Protons and neutrons are collectively known as nucleons.



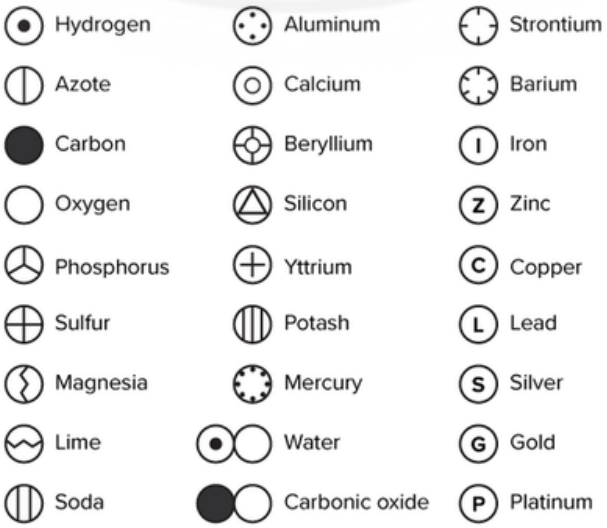
Ions

- The charged species are called Ions.
- Negative charged ions are Anion.
- Positive charged ions are Cation.



Symbols of Elements

- The symbols of elements were first given by Jacob Berzelius (1813) and were used by Dalton for the first time.
- He proposed that chemical symbols should be based on the Latin names of the elements.



ATOMIC NUMBER (Z)

$$Z = \text{no. of proton } (p) = \text{no. of electrons } (e^-)$$



- Atomic number is always a whole number, because it represents the total number of protons in an atom.
- The atomic number of an element does not change during a chemical reaction, as chemical reactions involve only rearrangement of electrons, not changes in the nucleus.

Mass Number (A)

- Mass number of an element (A) = No. of protons (p) + No. of neutrons (n) (present in the atom of an element).
- Since protons and neutrons are present in the nucleus, these particles are collectively called nucleons.
- Mass number of an element = Number of nucleons in the atom of that element.

Mass no. (No. of $p + n$) — a
Atomic no. (No. of protons) — Z_z **M**

$A = p + n$
$A = Z + n$
$A - Z = n$

E.g. Magnesium (Mg)
Protons (p^+) = 12
Electrons (e^-) = 12
Neutrons (n_0) = Mass no. — No. of protons = 12

Name Element	Symbol	Atomic Number	Number of Protons	Number of Neutrons	Number of Electrons	Distribution of Electrons (K L M N)	Valency
Hydrogen	H	1	1	-	1	1 - - -	1
Helium	He	2	2	2	2	2 - - -	0
Lithium	Li	3	3	4	3	2 1 - -	1
Beryllium	Be	4	4	5	4	2 2 - -	2
Boron	B	5	5	6	5	2 3 - -	3
Carbon	C	6	6	6	6	2 4 - -	4
Nitrogen	N	7	7	7	7	2 5 - -	3
Oxygen	O	8	8	8	8	2 6 - -	2
Fluorine	F	9	9	10	9	2 7 - -	1
Neon	Ne	10	10	10	10	2 8 - -	0
Sodium	Na	11	11	12	11	2 8 1 -	1
Magnesium	Mg	12	12	12	12	2 8 2 -	2
Aluminium	Al	13	13	14	13	2 8 3 -	3
Silicon	Si	14	14	14	14	2 8 4 -	4
Phosphorus	P	15	15	16	15	2 8 5 -	3, 5
Sulphur	S	16	16	16	16	2 8 6 -	2
Chlorine	Cl	17	17	18	17	2 8 7 -	1
Argon	Ar	18	18	22	18	2 8 8 -	0

ISOTOPES

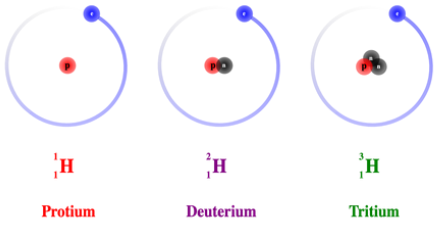
- Isotopes are atoms of same elements that have same atomic number, but different mass number.
- Isotope of an element differ only in number of neutrons present in the nucleus.

Isotopes of Hydrogen

$^{1}H(e^{-} = p = 1, n = 0)$: **Protium.**

$^{2}H(e^{-} = p = 1, n = 1)$: **Deuterium.**

$^{3}H(e^{-} = p = 1, n = 2)$: **Tritium** (radioactive in nature).

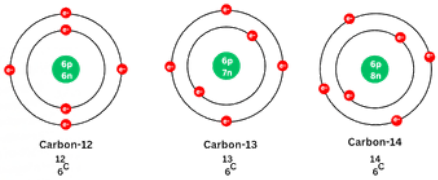


Isotopes of Carbon

$_{6}C^{12}(e^{-} = p = 6, n = 6)$: **Carbon-12.**

$_{6}C^{13}(e^{-} = p = 6, n = 7)$: **Carbon-13.**

$_{6}C^{14}(e^{-} = p = 6, n = 8)$: **Carbon-14** (used in Carbon Dating to determine age of fossils and rocks).



Characteristics of Isotopes

Same Chemical Properties

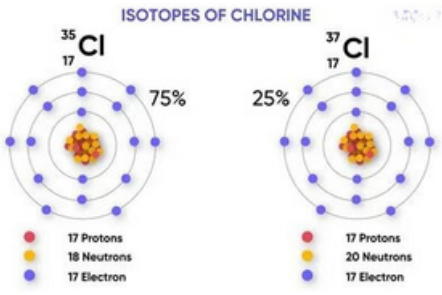
- Isotopes have same electronic configuration, hence same number of valence e-. Since chemical property depends upon the number of valence e-.
- Therefore, they have same chemical properties.

Different Physical Properties

- Since, the isotopes of an element have different masses, hence different physical properties, like melting point, boiling point, density, etc. exist.

Uses of Isotopes

- In nuclear reactors, isotopes like Uranium-235 are used as fuel to sustain a controlled nuclear chain reaction, generating heat that powers electricity production.
- In radiation therapy, isotope Cobalt-60 is used to destroy and prevent cancer cells.
- In treatment of goitre, isotope Iodine-131 is used.

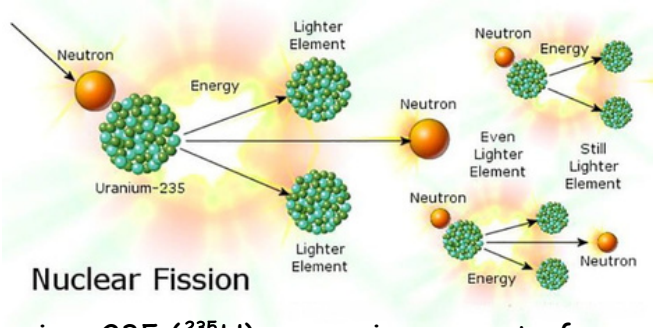


Nuclear Fusion

- **What it is:** In this process, two light nuclei combine at extremely high temperatures to form a heavier nucleus. This produces many times more energy than fission.
- **Energy of the Sun:** The light and heat in the sun and stars come from this very process. In this, two forms of hydrogen—deuterium and tritium—combine to form helium and release unlimited energy.

Nuclear Fission

- **What it is:** In this process, the nucleus of a heavy atom (like Uranium) breaks apart into two lighter nuclei, and a massive amount of energy is released.
- **Fuel:** Mainly Uranium-235 (U-235) is used. Sometimes, Plutonium is also used.
- **Use of Thorium:** Thorium is found in abundance in India (especially in the Monazite sands of Kerala). However, direct fission cannot be done with thorium; it must first be converted into Uranium-233. That is why U-235 is used more widely, as it is easier and cheaper to start the fission process with it.



When a neutron hits Uranium-235 (^{235}U), a massive amount of energy is released, and a chain reaction begins. To control this reaction and generate electricity, three main components are used in a reactor:

1. Moderator

- **Function:** To slow down the high-speed neutrons released during fission so that they can continue to break more uranium atoms.
- **Used:** Heavy water (D_2O), normal water (H_2O), or graphite.

2. Control Rods

- **Function:** These rods absorb excess neutrons, ensuring the chain reaction does not go out of control and averting the risk of a nuclear explosion.
- **Used:** Rods made of Boron, Cadmium, or Indium.

3. Coolant

- **Function:** It absorbs the extreme heat generated inside the reactor and removes it. This heat is used to convert water into steam, which ultimately rotates a turbine to generate electricity.
- **Used:** Heavy water (D_2O) or liquid sodium.

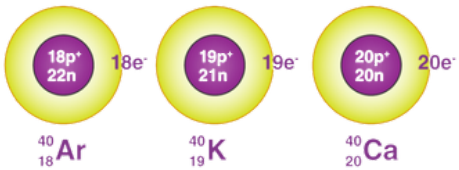
Facts and Enrichment of Uranium

- Naturally occurring uranium extracted from mines mainly contains two types of isotopes:
  - **Uranium-238 (^{238}U):** This makes up about 99.3% (it does not undergo fission easily).
  - **Uranium-235 (^{235}U):** This is only about 0.7% (less than 1%) (this is the actual fuel).
- **Enrichment:** Since we need U-235 for energy, its percentage is increased by separating U-235 from U-238 through a complex process. This is called 'Uranium Enrichment':
- **Nuclear Reactor (for electricity generation):** U-235 is enriched to only 3% to 5%. This is sufficient to generate electricity.
- **Nuclear Bomb:** For making weapons, U-235 must be enriched to 90% or more. (**Note:** Iran has enriched it up to 60%).
- **Uranium in India:** The first and most famous uranium mines in India are located in Jaduguda, Jharkhand, from where India extracts uranium ore for its nuclear program.

ISOBARS

- Atoms of different chemical elements that have the same mass number but different atomic numbers.

Example: Argon ($^{40}_{18}Ar$), Potassium ($^{40}_{19}K$), Calcium ($^{40}_{20}Ca$).



Properties of Isobars

- They are atoms of different elements.
- They have different atomic number.
- They have same mass number.
- They have similar physical properties and different chemical properties.
- They have different number of protons, electrons, neutrons.

ISOTONES

- Isotones are atoms that have the same neutron number but different proton number.

Element	Protons	Electrons	Neutrons
$^{16}_{8}O$	8	8	8
$^{15}_{7}N$	7	7	8

ISOELECTRONIC

- Atoms or ions that have the same number of electrons (e⁻ same).

N^{3-} (Nitrogen atomic number 7 + 3 gained electrons = 10 e^-)
O^{2-} (Oxygen atomic number 8 + 2 gained electrons = 10 e^-)
Mg^{2+} (Magnesium atomic number 12 - 2 lost electrons = 10 e^-)
Al^{3+} (Aluminum atomic number 13 - 3 lost electrons = 10 e^-)

ATOMICITY

- Atomicity is the total number of atoms present in a molecule of an element.
- **E.g.** Each molecule of Oxygen is composed of two oxygen atoms.
- Therefore, the atomicity of Oxygen is 2.

Element	Atomicity
Argon	Monoatomic (1)
Helium	Monoatomic
Oxygen	Diatomic (2)
Hydrogen	Diatomic
Nitrogen	Diatomic
Chlorine	Diatomic
Phosphorus	Tetra-atomic (4)
Sulphur	Poly-atomic

Mole Concept

- It is a unit of measurement that represents the amount of a substance.
- It is a base unit in the International System of Units (SI).
- One mole of a substance contains **6.022 x 10^{23}** elementary entities (Avogadro's Number), such as atoms, molecules, or ions.

$$\text{No. of Moles} = \frac{\text{Given Mass } (m)}{\text{Molecular Mass } (M)} = \frac{\text{Given no. of Particles (N)}}{\text{Avogadro No. } (N_0)} \rightarrow N = \frac{m}{M} = \frac{N}{N_0}$$



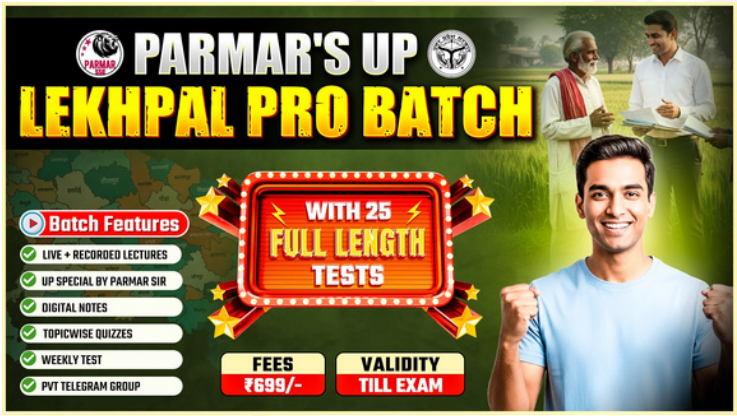


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