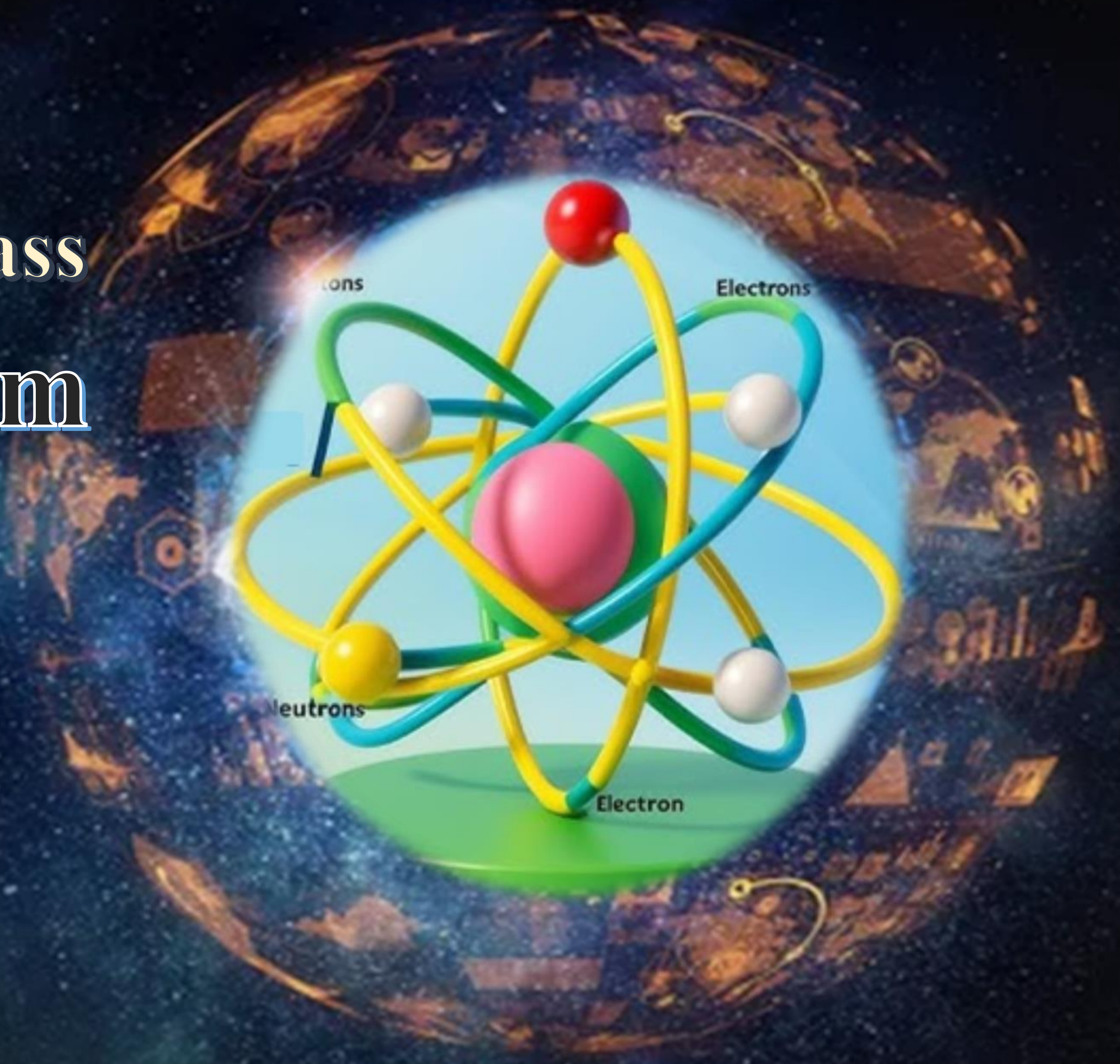
9th Class

Structure of the Atom



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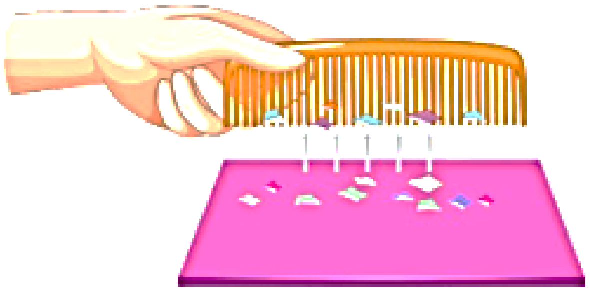
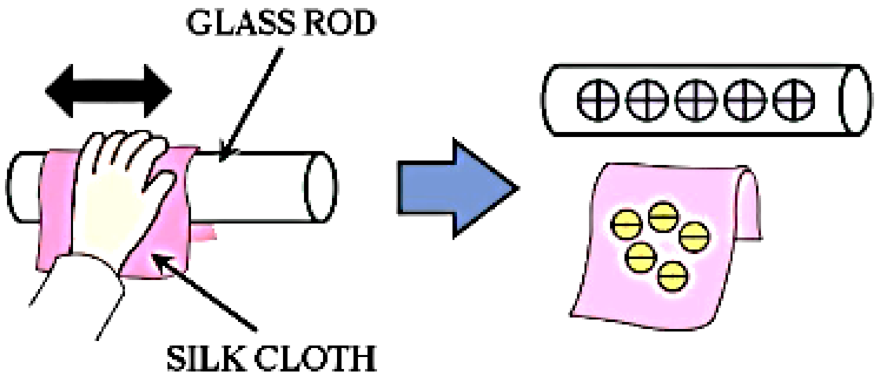
CHARGED PARTICLES IN MATTER

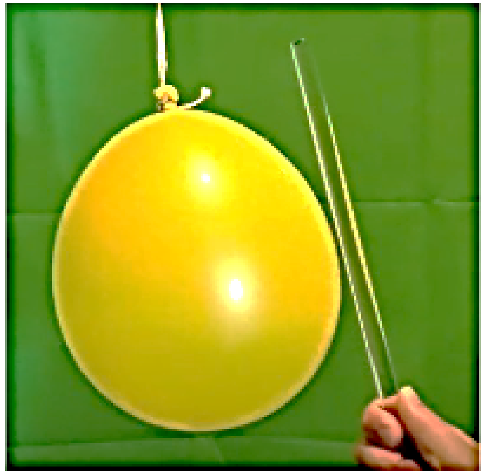
Activity to understand the nature of charged particles in matter

A. Comb dry hair. It can attract small pieces of paper.

B. Rub a glass rod with a silk cloth and bring the rod near an inflated balloon. Balloon is attracted to the rod.



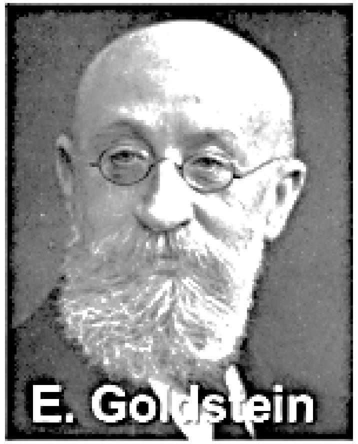


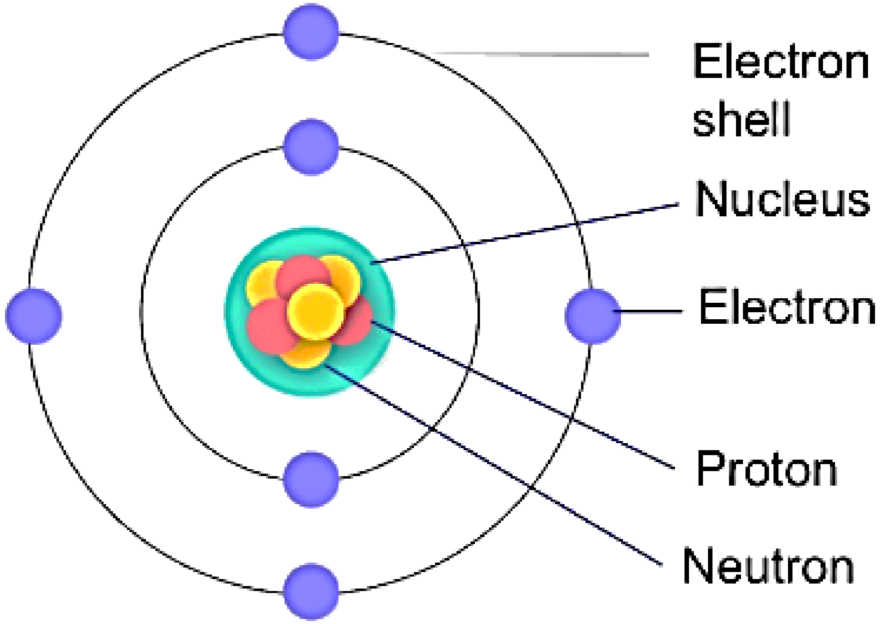


- It means that **rubbing two objects** together, they become **electrically charged.**
- The charge originates because **atoms are divisible** and contain **charged particles.**
- By 1900, it was understood that atoms contain sub-atomic particles.

CHARGED PARTICLES IN MATTER

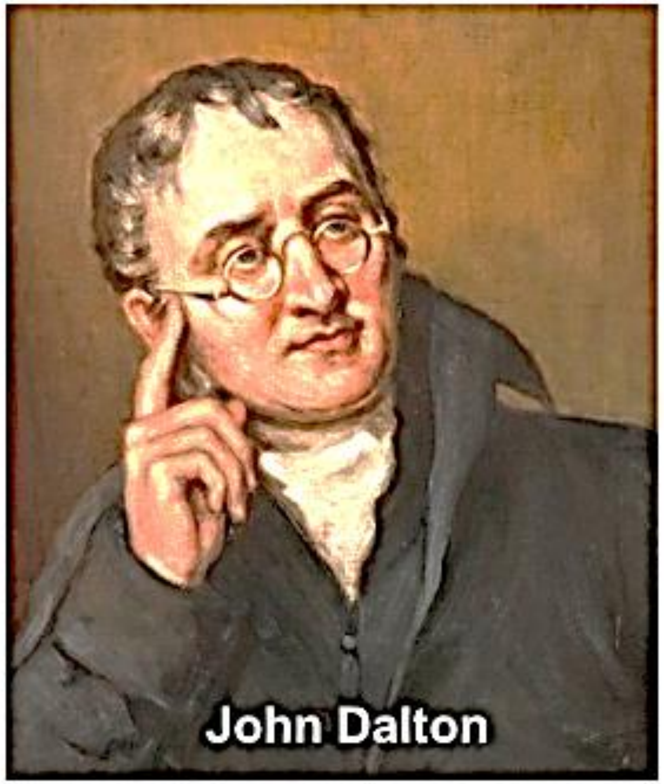
- **J.J. Thomson** identified the **electron (e^-).**
- In 1886, **E. Goldstein** had discovered positively charged radiations **(canal rays)** in a gas discharge. It led to the discovery of **proton (p^+).**
- The proton has a charge equal in magnitude but opposite in sign to the electron, with a mass about 2000 times greater.
- Mass of a **proton** is taken as one unit and its charge as **+1.** Mass of an **electron** is negligible and its charge is **-1.**
- An atom appears to be composed of protons and electrons, mutually balancing their charges.
- Protons are located in the interior of the atom. So it is harder to remove them compared to electrons.

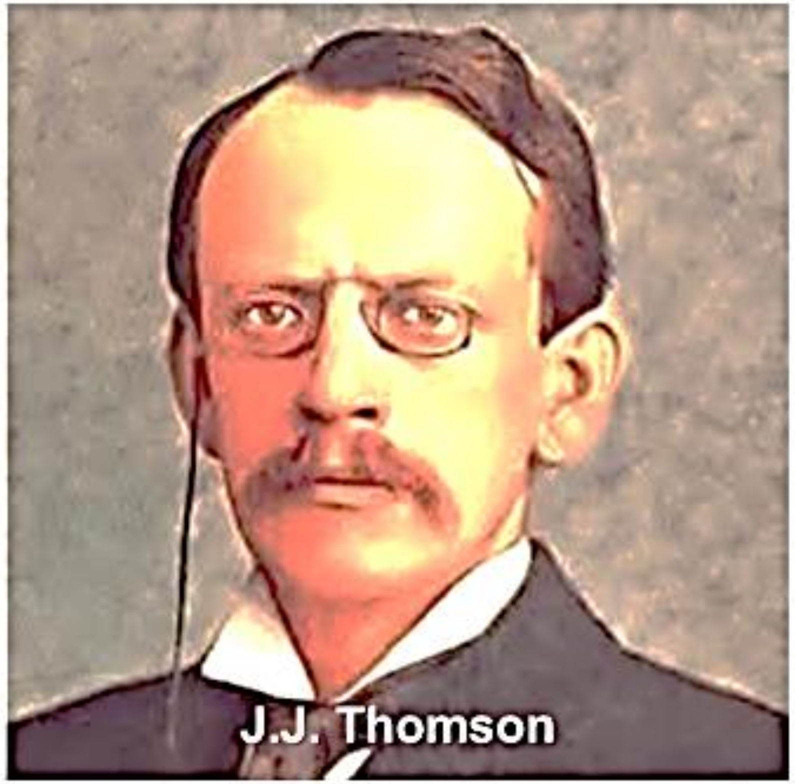


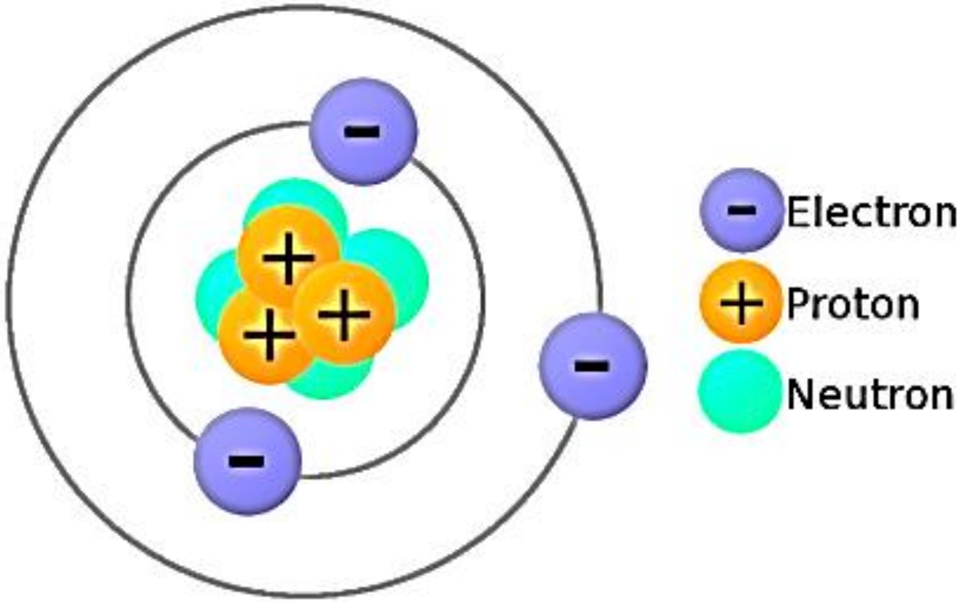


THE STRUCTURE OF AN ATOM

- **Dalton's atomic theory** says that the atom is indivisible and indestructible, but this aspect failed with the discovery of **electrons** & **protons** (fundamental particles).
- **J.J. Thomson** was the first to propose a model for the structure of an atom.



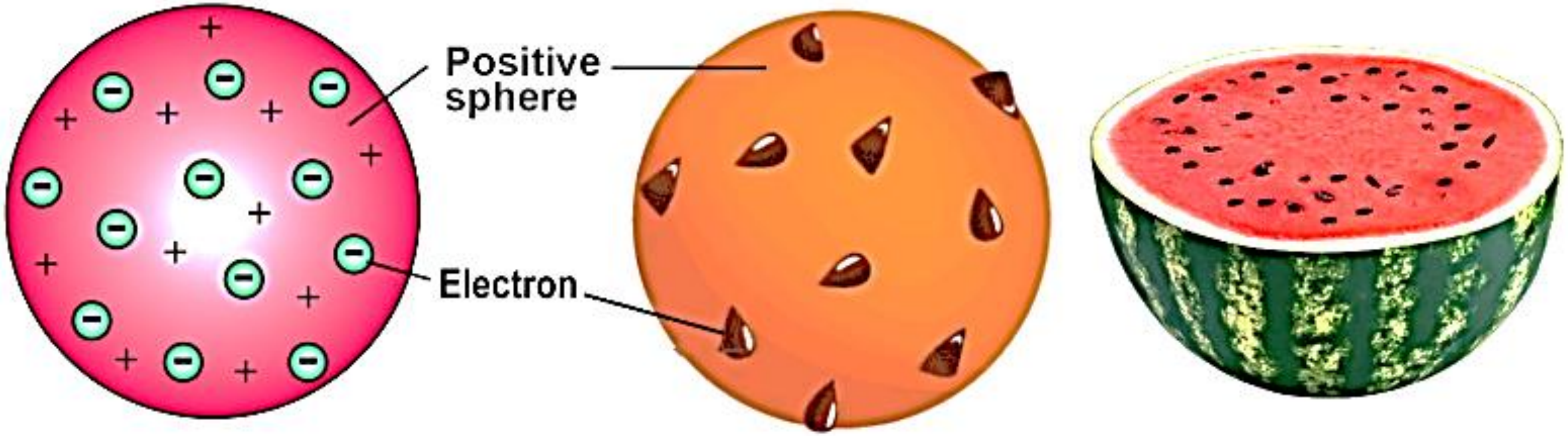




THE STRUCTURE OF AN ATOM

THOMSON'S MODEL OF AN ATOM

Thomson proposed a model of the atom resembling a **Christmas pudding.** Here, electrons are embedded like currants in a sphere of positive charge (pudding).



This model can also be compared to a **watermelon.**

Red edible part = Positive sphere

Seeds = electrons.

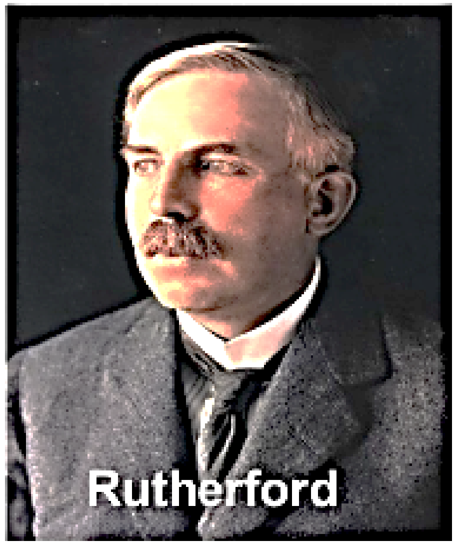
Thomson proposed that:

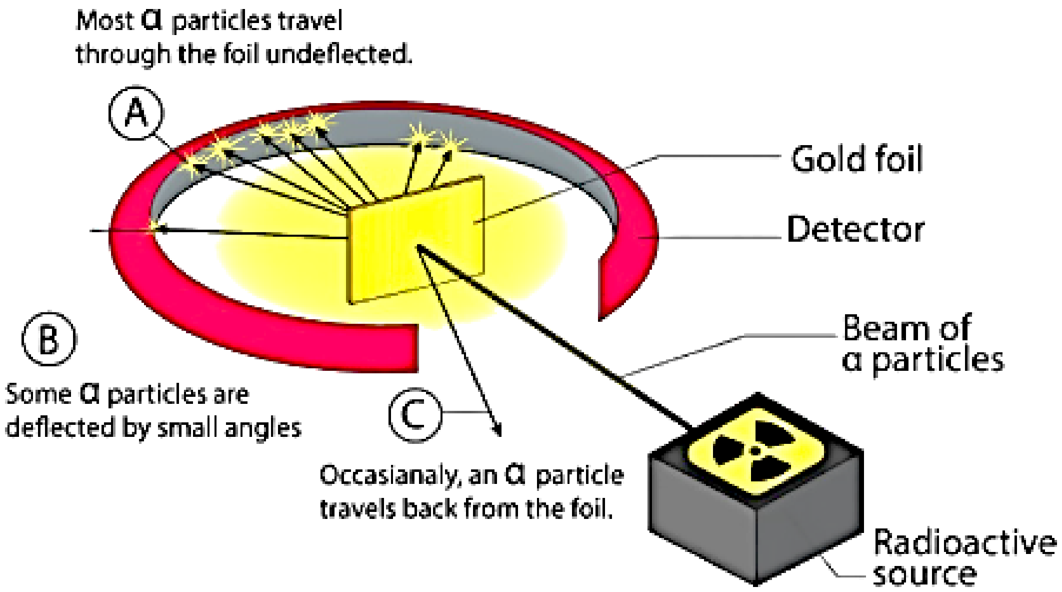
- An atom consists of a **positively charged sphere** and the electrons are embedded in it.
- Negative & positive charges are equal in magnitude. So, the atom is electrically neutral.

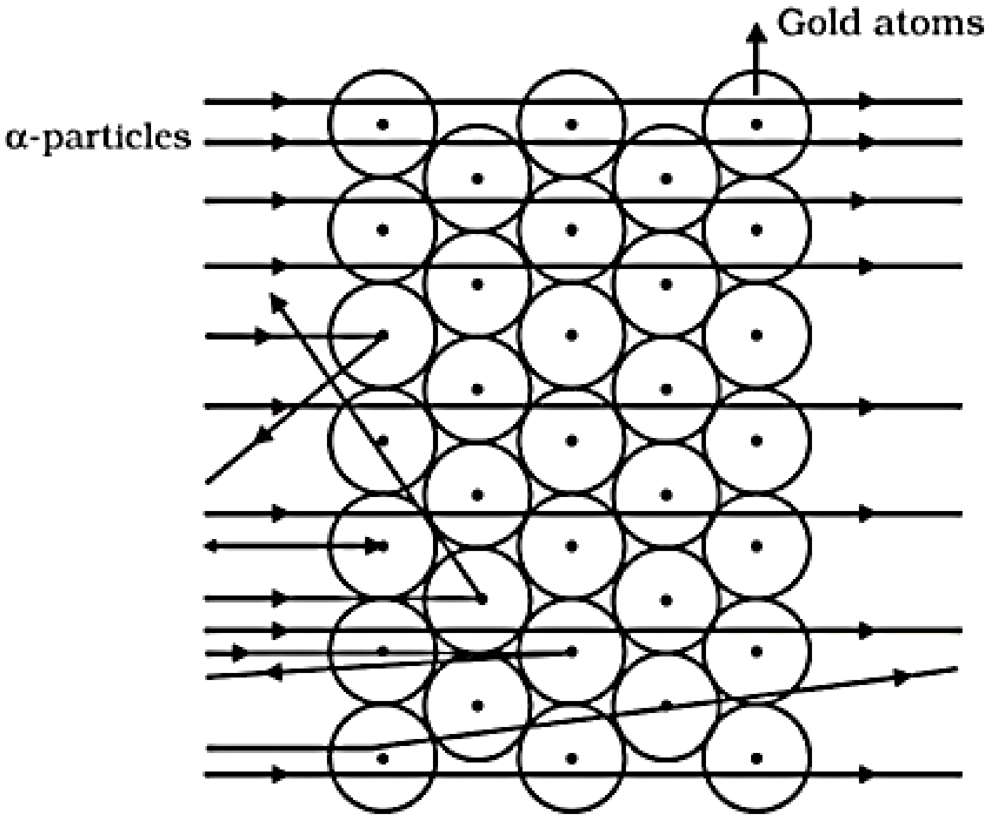
However, this model could not explain some experimental results from other scientists.

THE STRUCTURE OF AN ATOM — RUTHERFORD'S MODEL OF AN ATOM

- **Ernest Rutherford** conducted an experiment to know the arrangement of electrons in an atom.
- He directed fast-moving **alpha (α)-particles** on a **thin gold foil,** which was about 1000 atoms thick.
- α-particles are **doubly-charged helium ions** with a mass of **4 u.** This gives them a considerable energy when moving at high speeds.







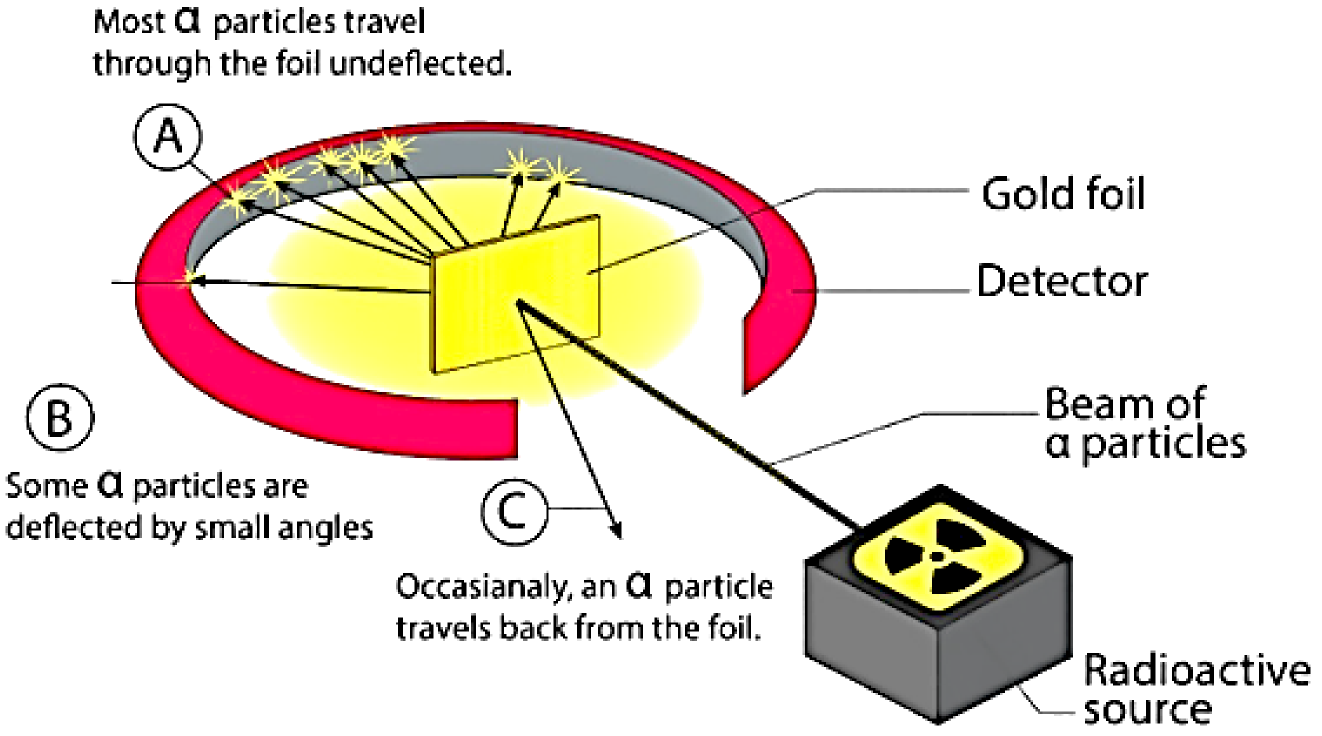
Scattering of α-particles by a gold foil (α-particle scattering experiment)

THE STRUCTURE OF AN ATOM | RUTHERFORD'S MODEL OF AN ATOM

Since α-particles are much heavier than protons, only small deflections were expected when they interacted with subatomic particles in gold atoms.

Major observations:

- **Most α-particles passed straight through the gold foil.**
- **Some α-particles were deflected by small angles.**
- **About 1 in 12,000 α-particles rebounded.**



Rutherford said that ***it was incredible as firing a 15-inch shell at a piece of tissue paper and having it rebound.***

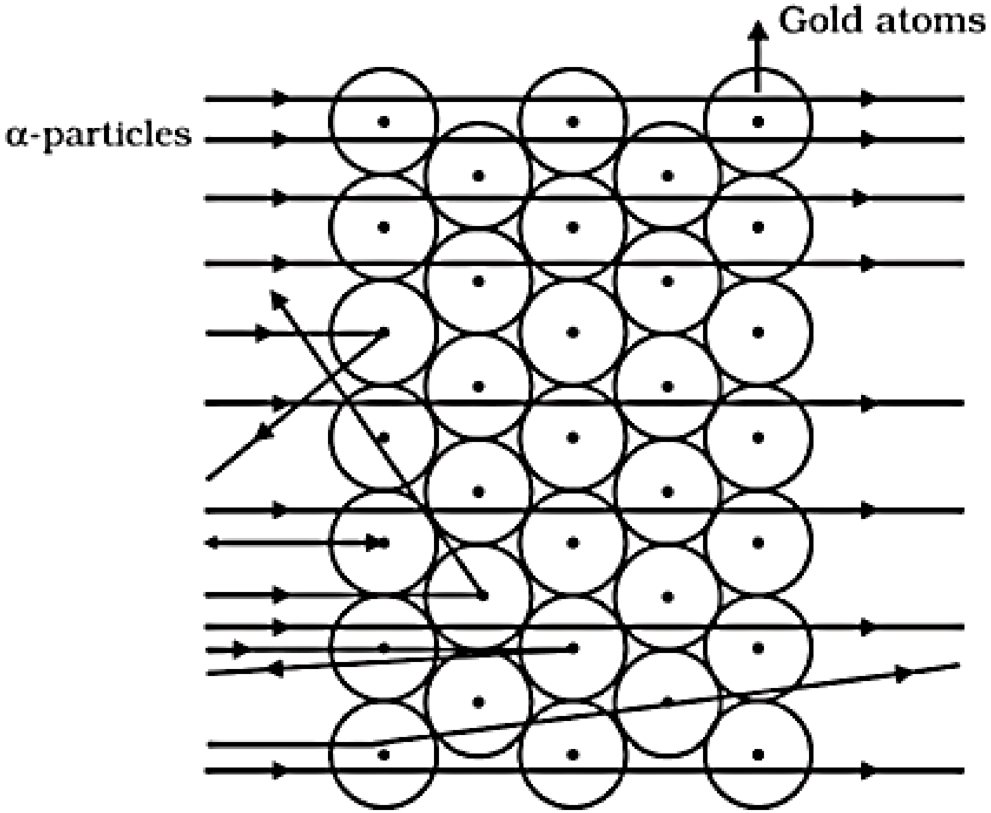
THE STRUCTURE OF AN ATOM

RUTHERFORD'S MODEL OF AN ATOM

To illustrate the experiment, imagine a blindfolded child throwing stones at a wall and hearing a sound each time a stone hits. If the child threw stones at a barbed-wire fence with many gaps, most stones would pass through without hitting anything, resulting in no sound.

Rutherford's conclusion:

- **Most of the atom's space is empty** because most α-particles passed through gold foil without deflection.
- Only a few particles were deflected from their path. It indicates that the **positive charge of the atom occupies very little space.**
- A tiny fraction of α-particles was deflected by 180°. It indicates that the **positive charge and mass of the atom are concentrated in a very small region.**

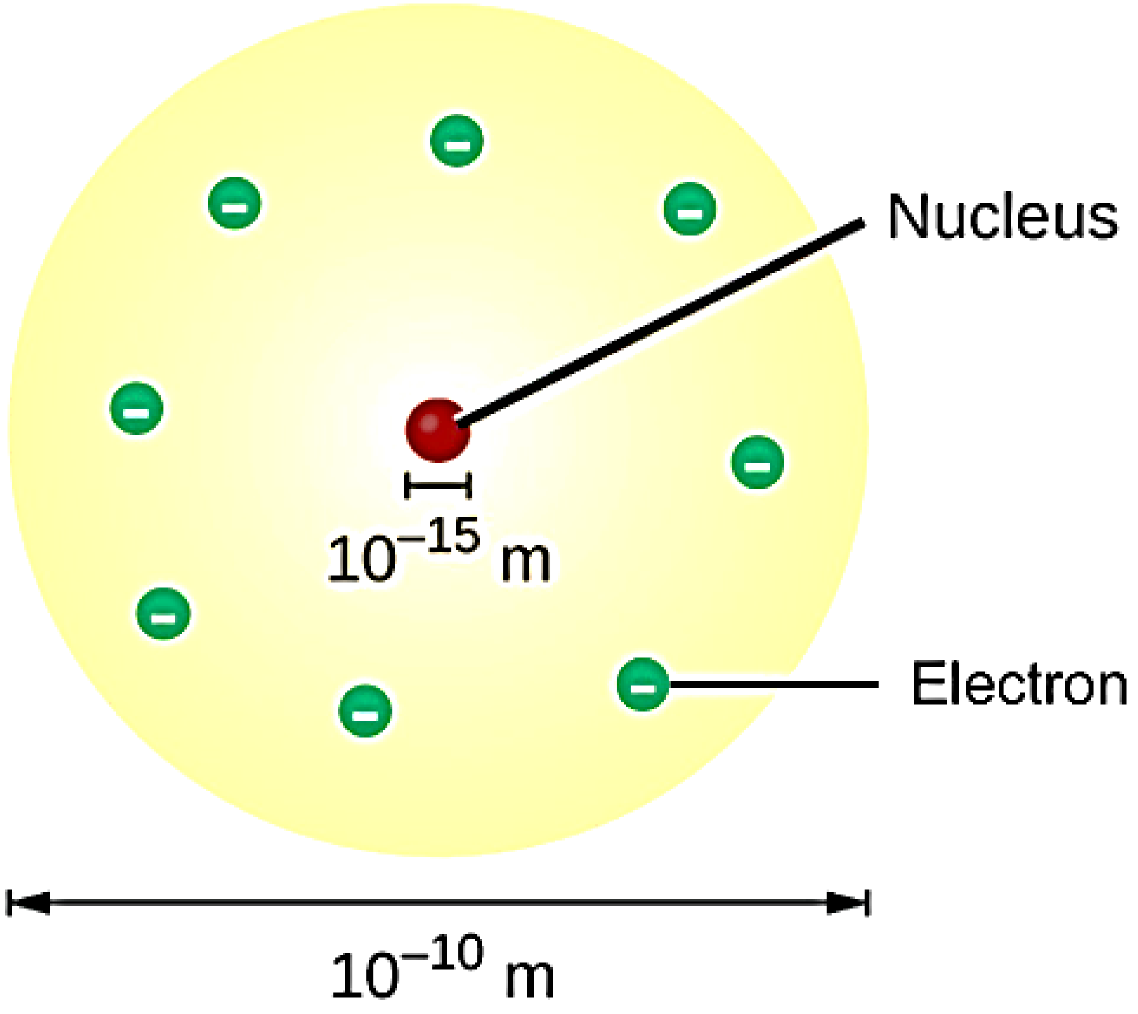


THE STRUCTURE OF AN ATOM | RUTHERFORD'S MODEL OF AN ATOM

Rutherford estimated that the **radius of nucleus** is **10^5 times smaller** than the radius of the atom.

He proposed the **nuclear model** of the atom:

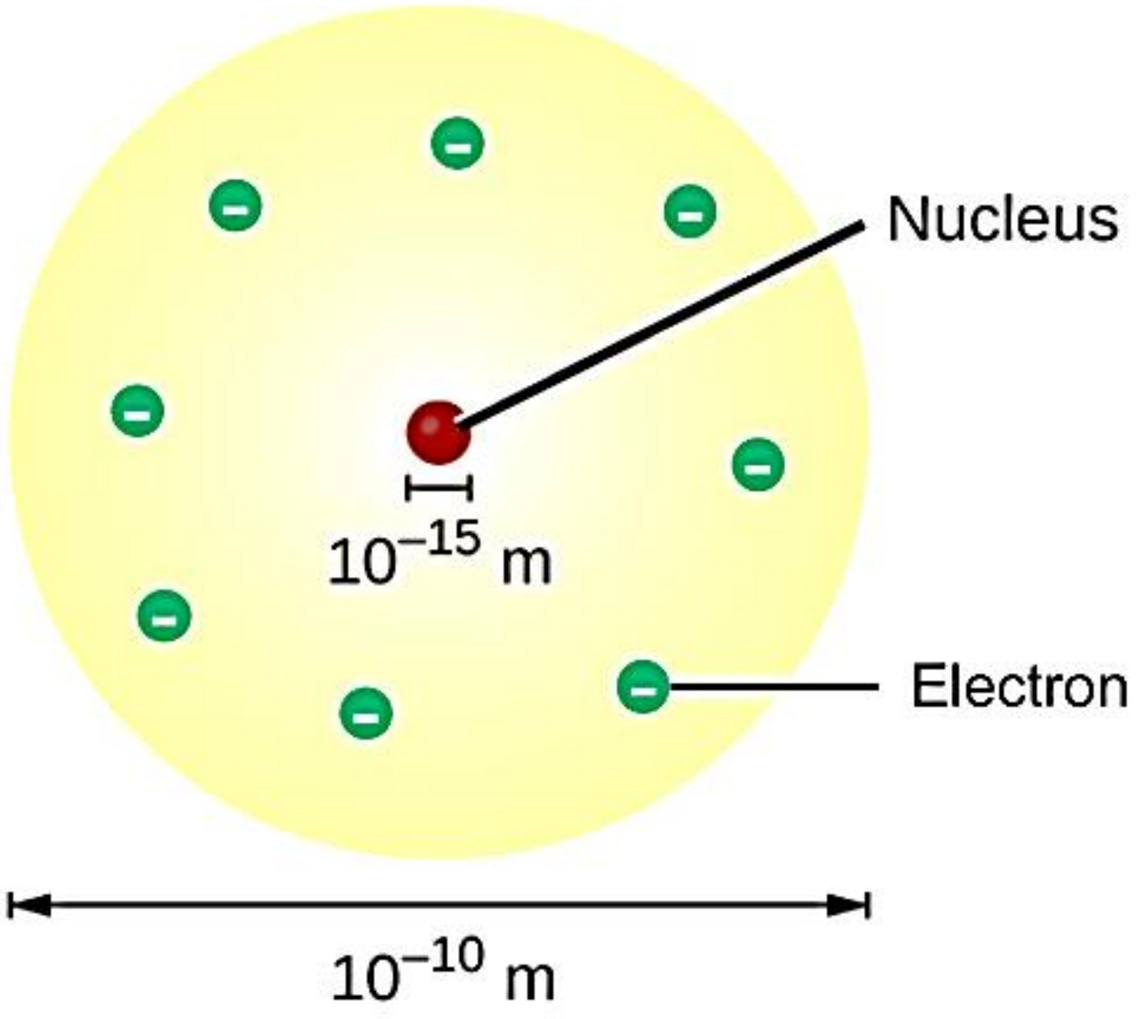
- Atoms have a **positively charged nucleus** where nearly all the mass of an atom resides.
- **Electrons revolve** around the nucleus in circular paths.
- **Nucleus is very small** compared to the size of atom.



THE STRUCTURE OF AN ATOM | RUTHERFORD'S MODEL OF AN ATOM

Drawbacks of Rutherford's model of the atom

- Electrons in circular orbits are not expected to be stable because they undergo **continuous acceleration.**
- Accelerating charged particles, like electrons, would **radiate energy,** causing them to lose energy and fall into the nucleus. This makes the **atoms highly unstable.** It is against the fact that atoms are stable.



THE STRUCTURE OF AN ATOM — BOHR'S MODEL OF AN ATOM

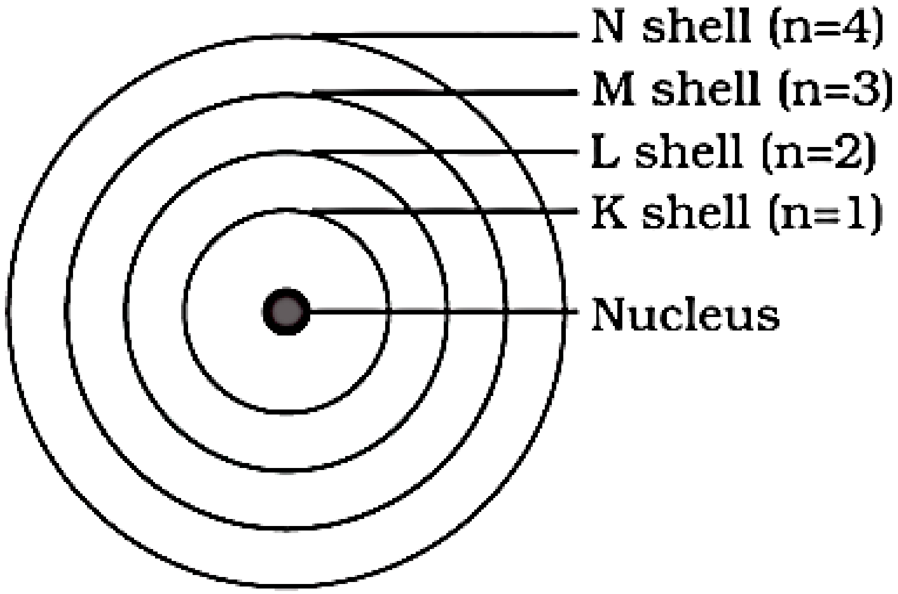
To overcome the drawbacks of Rutherford's model, **Neils Bohr** proposed some postulates:

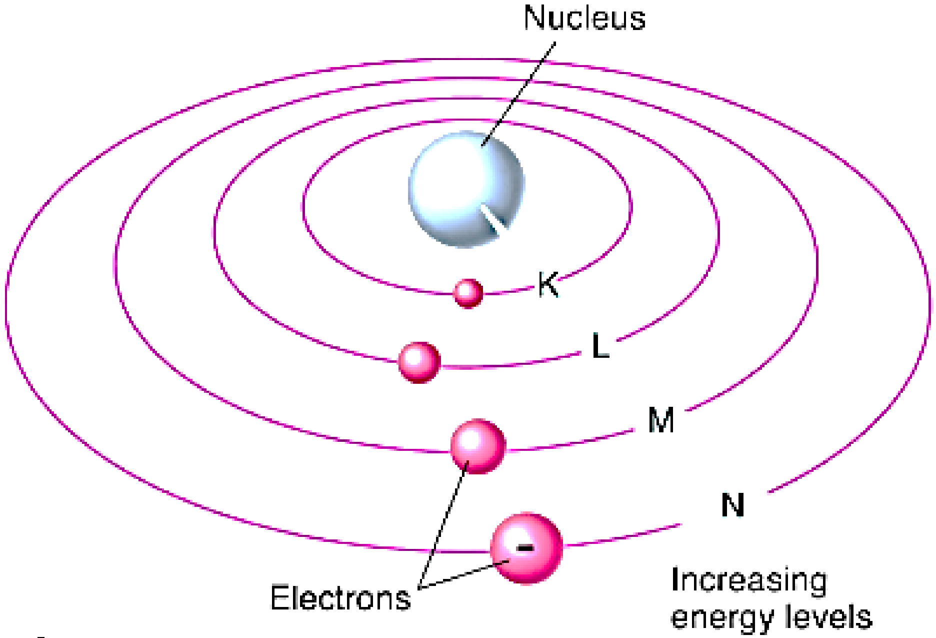
i. Electrons occupy only specific **discrete orbits** inside the atom.

ii. While revolving in discrete orbits the electrons **do not radiate energy.**

These orbits or shells are called **energy levels.**

They are represented by the letters **K, L, M, N,** or the numbers, **n=1, 2, 3, 4, ….**

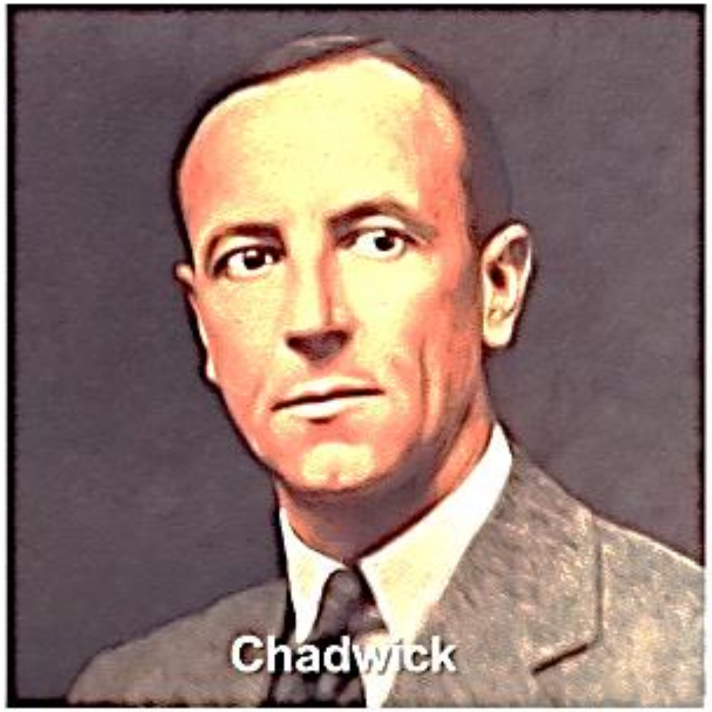


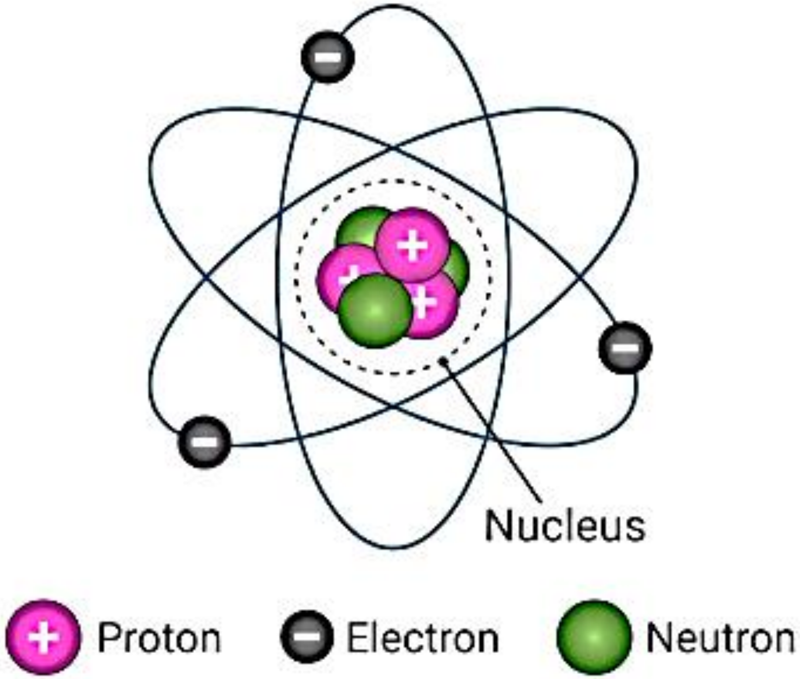


A few energy levels in an atom

THE STRUCTURE OF AN ATOM — NEUTRONS

- **Neutron (n)** is a subatomic particle discovered by **J. Chadwick** (1932). It has **no charge.**
- They are seen in the **nucleus of all atoms except hydrogen.**
- Neutron has a mass nearly equal to that of a proton. So, the **mass of an atom is the sum of the masses of protons and neutrons** in the nucleus.





Mass of protons

+

Mass of neutrons

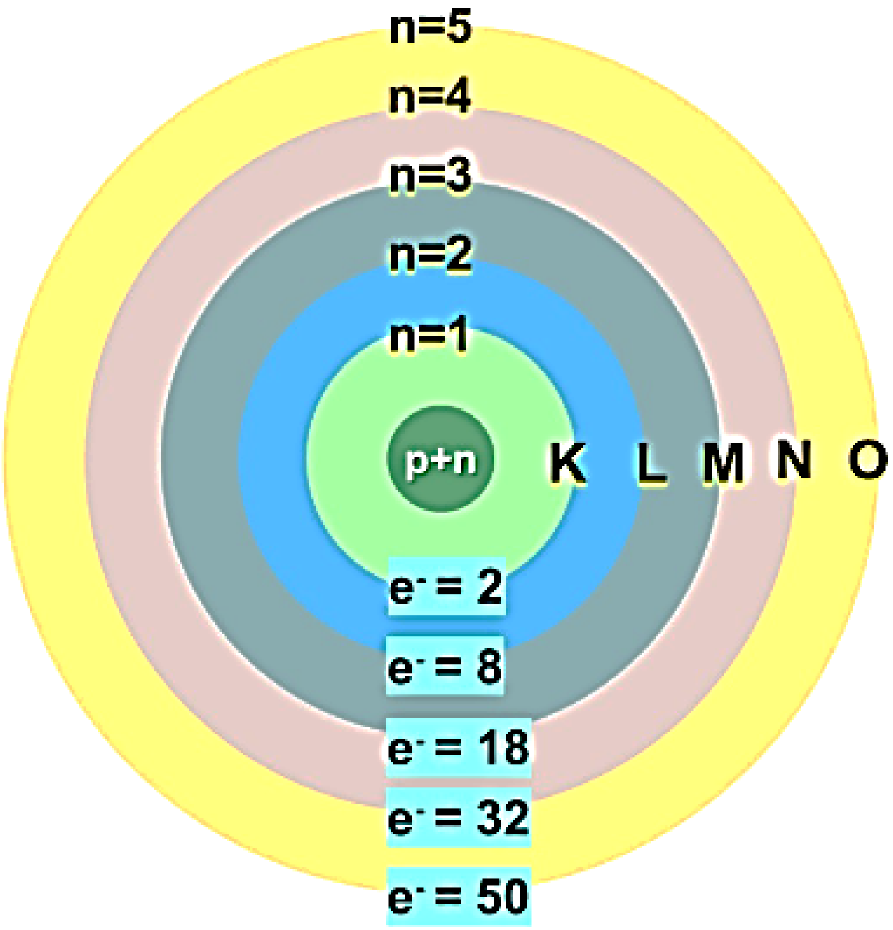
↓

Mass of an atom

HOW ARE ELECTRONS DISTRIBUTED IN DIFFERENT ORBITS (SHELLS)?

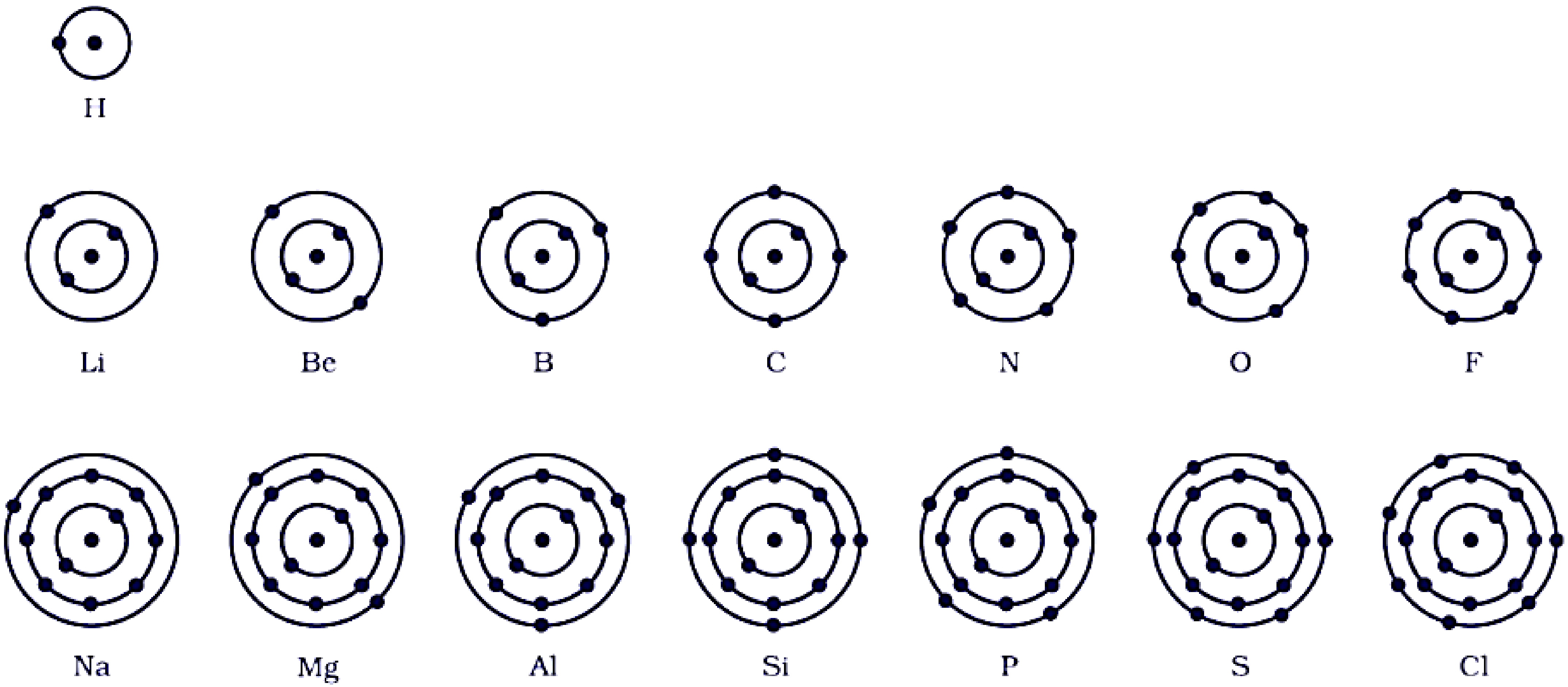
Bohr and **Bury** proposed the following rules for the **distribution of electrons** in an atom's orbits:

- Maximum number of electrons in a shell is determined by the formula **$2n^2$** (n = orbit number or energy level index).
  - **K-shell (1st orbit):** $2 \times 1^2 = 2$ electrons
  - **L-shell (2nd orbit):** $2 \times 2^2 = 8$ electrons
  - **M-shell (3rd orbit):** $2 \times 3^2 = 18$ electrons
  - **N-shell (4th orbit):** $2 \times 4^2 = 32$ and so on.
- The **outermost shell** can accommodate a maximum of **8 electrons.**
- Electrons fill inner shells before moving to outer shells. That is, the shells are filled in a step-wise manner.



HOW ARE ELECTRONS DISTRIBUTED IN DIFFERENT ORBITS (SHELLS)?

Schematic atomic structure of the first eighteen elements



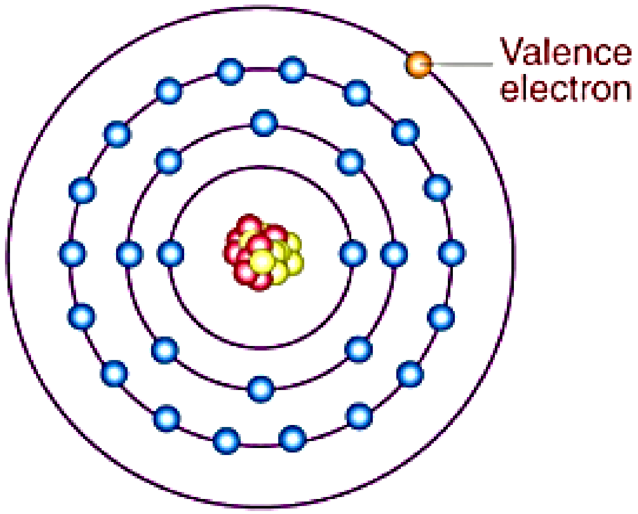
HOW ARE ELECTRONS DISTRIBUTED IN DIFFERENT ORBITS (SHELLS)?

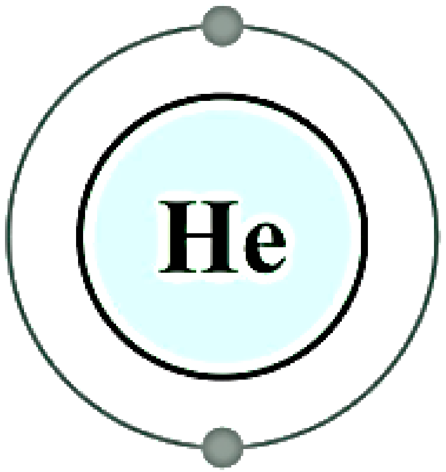
Composition of Atoms of the First Eighteen Elements with Electron Distribution in Various Shells

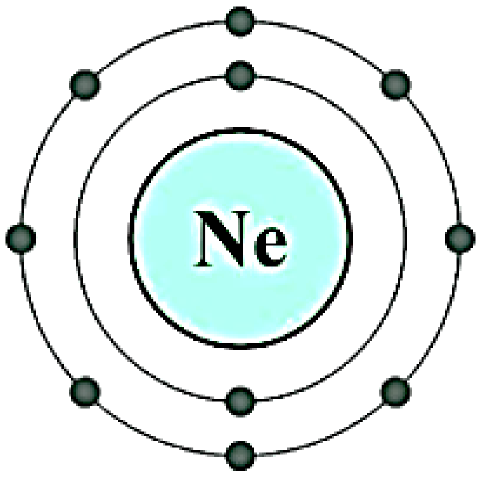
Name of Element	Symbol	Atomic Number	Number of Protons	Number of Neutrons	Number of Electrons	Distribution of electrons				Valency
						K	L	M	N	
Hydrogen	H	1	1	-	1	1	-	-	-	1
Helium	He	2	2	2	2	2	-	-	-	0
Lithium	Li	3	3	4	3	2	1	-	-	1
Beryllium	Be	4	4	5	4	2	2	-	-	2
Boron	B	5	5	6	5	2	3	-	-	3
Carbon	C	6	6	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

VALENCY

- The **electrons** present in the **outermost shell** of an atom are called the **valence electrons.**
- The **combining capacity of an atom** of each element is called its **valency.** i.e., it is the **tendency to react** and form molecules with atoms of the same or different elements.
- Atoms of elements, completely filled with **8 electrons** in the outermost shell show little chemical activity. They are called **inert elements.** So, their **valency is zero.**
- Among inert elements, the **helium (He)** atom has **2 electrons** in its outermost shell. Other inert elements have **8 electrons** in their outermost shell.



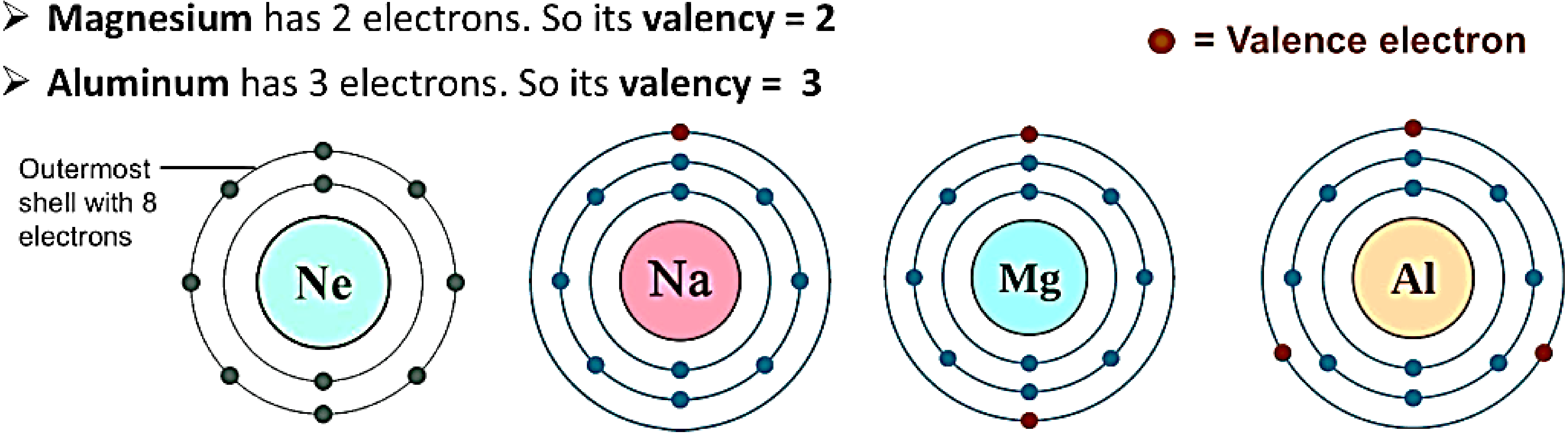




Thus the **valency** of an atom is an **attempt to attain a fully-filled outermost shell.**

VALENCY

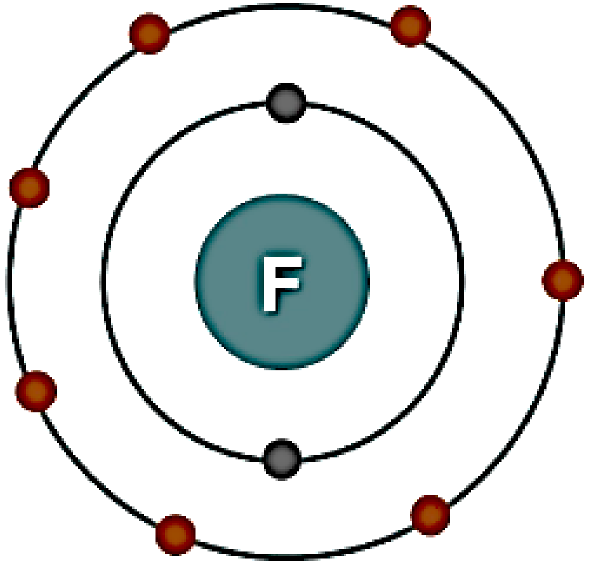
- An outermost shell with 8 electrons is termed as **octet.**
- Atoms react to achieve octet by sharing, gaining, or losing electrons. The number of electrons gained, lost, or shared to complete the octet directly indicates an element's valency. E.g.,
  - **Hydrogen/lithium/sodium** atoms have one electron in their outermost shell and can lose that one electron. So its **valency = 1.**
  - **Magnesium** has 2 electrons. So its **valency = 2**
  - **Aluminum** has 3 electrons. So its **valency = 3**

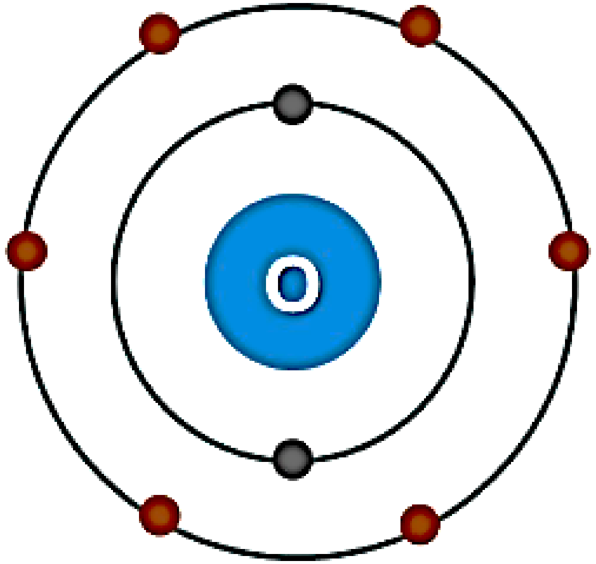


VALENCY

If an atom's outermost shell is nearly full, its valency is calculated differently. E.g.,

- **Fluorine (F)** has **7 electrons** in the outermost shell. But it is easier to gain one electron instead of losing 7 electrons. Hence, its valency is 8 – 7 = **1.**
- **Oxygen (O)** atom has **6 electrons** in the outermost shell. It gains 2 electrons instead of losing 6 electrons. Hence its valency is 8 – 6 = **2.**





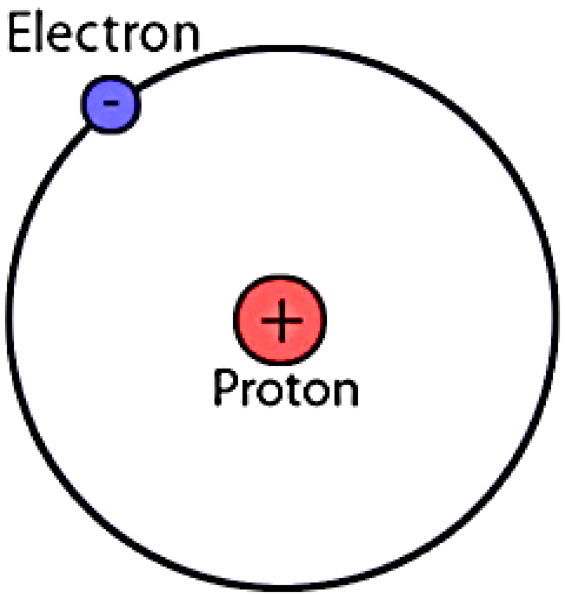
ATOMIC NUMBER AND MASS NUMBER

ATOMIC NUMBER (Z)

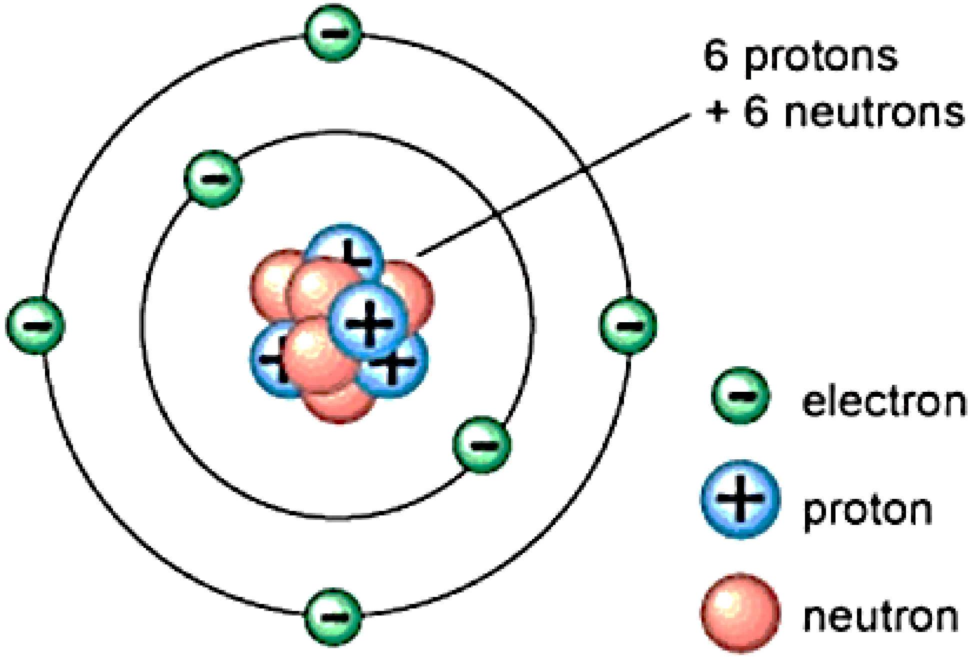
- It is the **total number of protons** present in the nucleus of an atom.
- All atoms of an element have same atomic number (Z).

Elements are defined by the number of protons they possess. E.g.,

- **Z= 1** for **hydrogen** (only one proton).
- **Z = 6** for **carbon** (6 protons).



Hydrogen atom

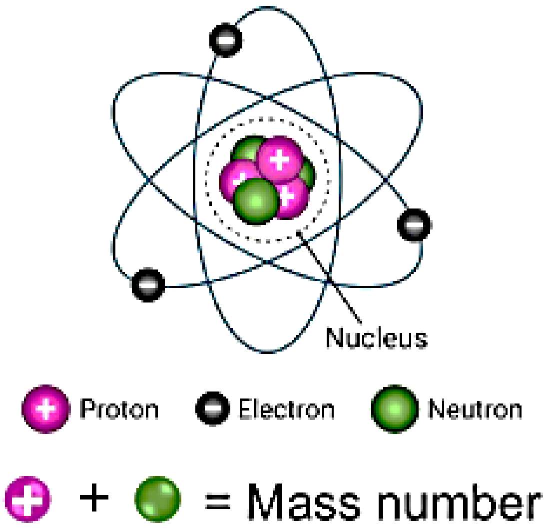


Carbon atom

ATOMIC NUMBER AND MASS NUMBER

MASS NUMBER (A)

- It is the sum of the **total number of protons and neutrons** present in the nucleus of an atom.
- Mass of an atom is practically due to protons & neutrons. Being present in the nucleus, they are also called **nucleons.** i.e., the mass of an atom resides in its nucleus. E.g.,
  - Mass (A) of **carbon** is **12 u** because it has **6 protons** and **6 neutrons** (6 u + 6 u = 12 u).
  - Mass of **aluminium** is **27 u** (13 protons + 14 neutrons).



In the notation for an atom, the atomic number, mass number and symbol of the element are written as:

Mass Number A

Symbol of element X

Atomic Number Z

E.g., nitrogen is written as $^{14}_{7}N$

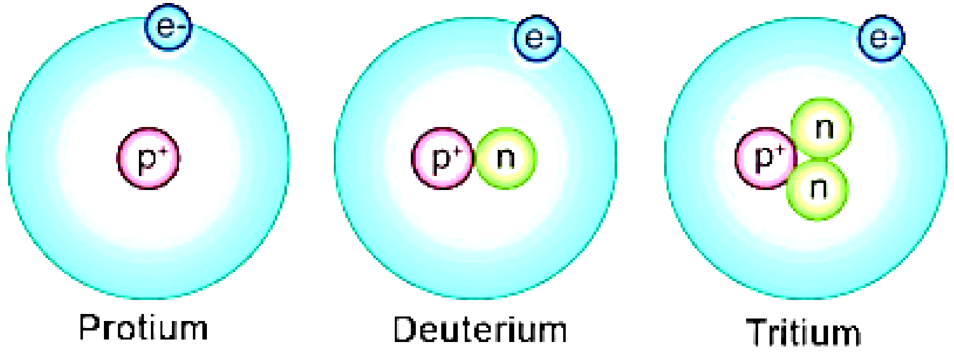
$^{14}_{7}N$ $^{27}_{13}Al$

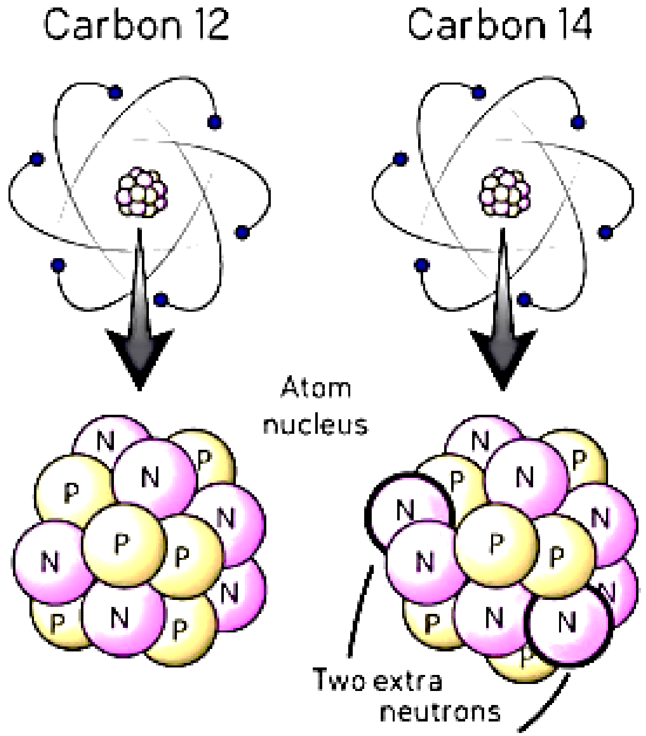
ISOTOPES

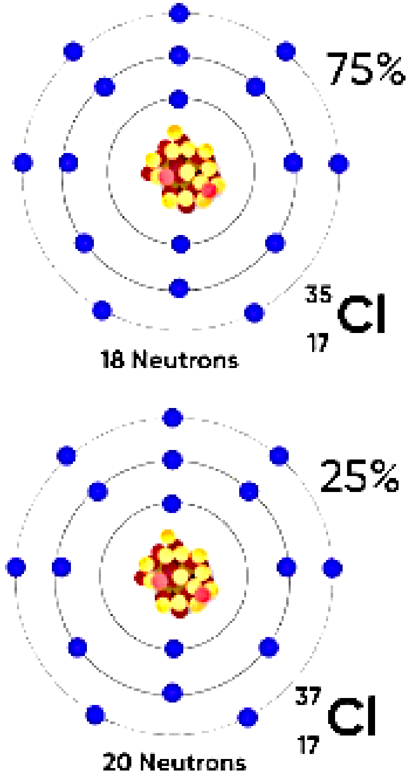
Isotopes are the atoms of the same element, having the **same atomic number** but **different mass numbers.** E.g.,

- **Hydrogen** atom has 3 isotopes: **Protium ($^{1}_{1}$H), deuterium ($^{2}_{1}$H or D)** and **tritium ($^{3}_{1}$H or T).**

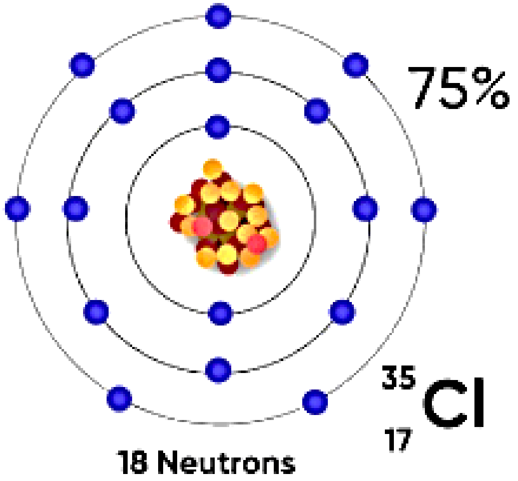
  They have same atomic number (Z=1) but the mass number is 1, 2 & 3 respectively.
- **Carbon:** $^{12}_{6}$C and $^{14}_{6}$C.
- **Chlorine:** $^{35}_{17}$Cl and $^{37}_{17}$Cl.



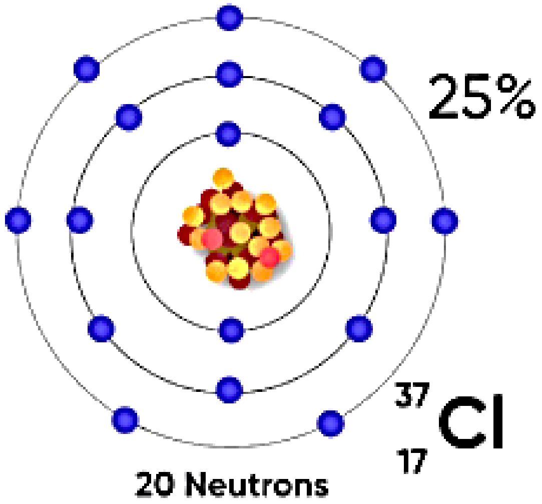




ISOTOPES



- Many elements consist of a mixture of isotopes. Each isotope of an element is a pure substance. Isotopes have **similar chemical properties** but **different physical properties.**
- The mass of an atom of a natural element is taken as the average mass of all the naturally occurring atoms of that element.
- If an element has no isotopes, its atomic mass equals the sum of its protons and neutrons. But if an element has isotopic forms, its average mass is calculated based on the percentage of each isotope. E.g., **Chlorine** has **2 natural isotopes** with masses **35 u** and **37 u** in the ratio of 3:1. So the average atomic mass is



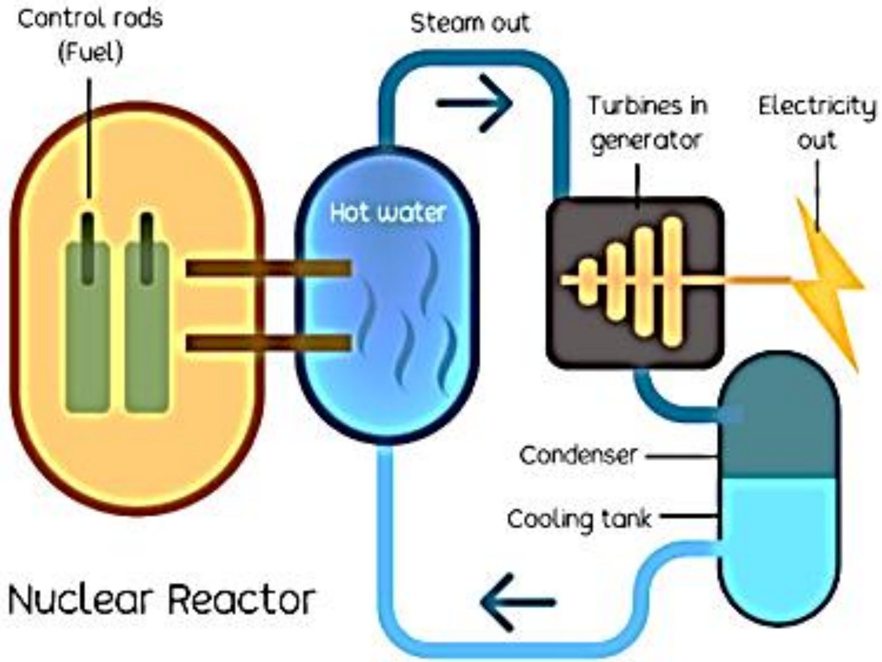
$$\left(35 \times \frac{75}{100} + 37 \times \frac{25}{100}\right) = \left(\frac{105}{4} + \frac{37}{4}\right) = \frac{142}{4} = 35.5\,\text{u}$$

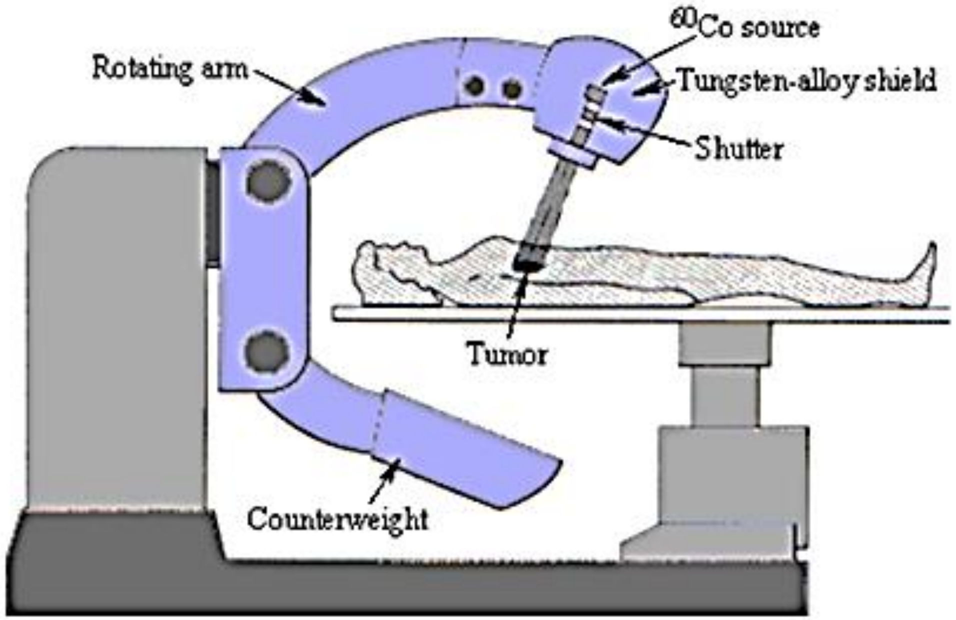
Since isotopes of an element share same chemical properties, using a mixture is not a concern.

ISOTOPES

Applications of some isotopes

- An isotope of **uranium** is used as **fuel in nuclear reactors.**
- An isotope of **cobalt** is used in **cancer treatment.**
- An isotope of **iodine** is used in **treatment of goitre.**

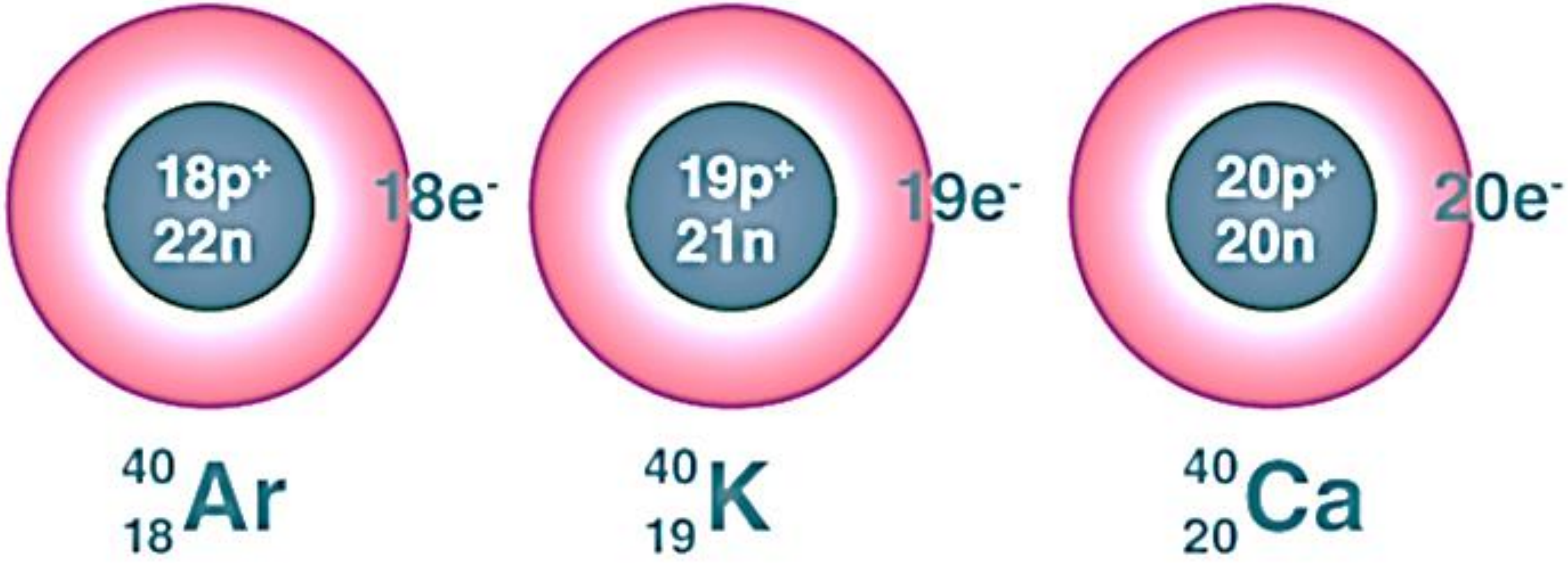




ISOTOPES

ISOBARS

- These are atoms of different elements that have **different atomic numbers** but the **same mass number.**
- E.g., calcium (Z= 20) and argon (Z= 18). They have different number of protons, but the mass number is 40. i.e., total number of nucleons is the same in them.




thank you