STRUCTURE OF THE ATOM

CBSE CLASS 9 SCIENCE • CHAPTER 4 • COMPREHENSIVE STUDY & REVISION GUIDE

1. Introduction & Fundamental Subatomic Particles

While early Daltonian models asserted that atoms were basic, indivisible structures, breakthrough experiments in late 19th and early 20th centuries revealed that atoms are composed of smaller, individual **subatomic particles**: Electrons, Protons, and Neutrons.

Particle Name	Symbol	Relative Charge	Relative Mass	Discoverer
Electron	e^-	-1	$\approx \frac{1}{2000} \text{ u}$ (Negligible)	J.J. Thomson (1897)
Proton	p^+	$+1$	1 u	E. Goldstein / Rutherford
Neutron	n^0	0 (Neutral)	1 u	James Chadwick (1932)

2. Early Atomic Models & Breakthrough Experiments

A. Thomson's Christmas Pudding Model

J.J. Thomson proposed that an atom resembles a **Plum Pudding** or a **Watermelon**:

- An atom is structured as a uniform, positively charged sphere.
- Negatively charged electrons are embedded directly within it, like raisins in a pudding or seeds inside a watermelon.
- *Limitation:* Though it correctly recognized overall electrical neutrality, it failed completely to explain later alpha-particle scattering discoveries.

B. Rutherford's Gold Foil Scattering Experiment

Ernest Rutherford directed fast-moving, high-energy **alpha particles (α-particles / He^{2+})** toward an ultra-thin gold foil sheet.

Crucial Observations:

- Most α-particles passed directly through the gold foil completely undeflected.
- A small fraction of particles experienced minor spatial deflections.
- Incredibly, 1 out of every 12,000 particles completely bounced back (180°).

Structural Conclusions:

- Most of the interior space within an atom is entirely empty.
- The positive charge and nearly all atomic mass are concentrated into an incredibly tiny space.
- This dense central core is called the **nucleus**.

Rutherford's Limitation: According to classical electromagnetic theory, an electron revolving in a circular orbit must undergo acceleration, radiate energy continuously, and eventually collapse directly into the nucleus. This would make atoms inherently unstable, which contradicts reality.

C. Bohr's Postulates of the Atomic Model

Niels Bohr resolved Rutherford's stability paradox by introducing quantized energy concepts:

- Electrons revolve around the central nucleus only within specific, non-radiating paths called **discrete orbits** or **energy shells**.
- While moving within these specific discrete orbits, electrons do not lose or radiate any energy.
- These definitive configurations are labeled as the **K, L, M, N...** shells, corresponding to principal quantum values $n = 1, 2, 3, 4...$.

```
                    [ Electron Shell Structure ]
                                  ○ (Electron)
                             /────────────┐
                      /      L Shell │ (n = 2)
                         /     ┌──────────┼┐
                 │       │ K Shell ││ (n = 1)
                          │    │    ┌───┐   ││
 │     │    │ ⊕ │ ││ ─── Nucleus (Protons + Neutrons)
                          │    │    └───┘   ││
                          │    └──────────┘│
                           \───────────────/
```

3. Electronic Configuration & Bohr-Bury Rules

The systematic distribution of electrons across various atomic energy shells is governed explicitly by the **Bohr-Bury Scheme**:

1. The maximum capacity of any shell is mathematically computed using the formula:

   $$\text{Maximum Electrons in a Shell} = 2n^2$$

   Where n represents the specific shell index number.
   - **K-Shell ($n=1$):** $2(1)^2 = 2 \text{ electrons}$
   - **L-Shell ($n=2$):** $2(2)^2 = 8 \text{ electrons}$
   - **M-Shell ($n=3$):** $2(3)^2 = 18 \text{ electrons}$
   - **N-Shell ($n=4$):** $2(4)^2 = 32 \text{ electrons}$
2. The outermost shell can accommodate a maximum of **8 electrons** (octet rule), even if its total theoretical capacity is higher.
3. Electrons are not accommodated in a given shell unless the inner shells are completely filled (stepwise filling sequence).

Step-by-Step Electronic Configurations of Common Elements

Element Name	Atomic Number (Z)	K Shell ($n=1$)	L Shell ($n=2$)	M Shell ($n=3$)	Valency
Hydrogen	1	1	0	0	1
Helium	2	2 (Duplet Filled)	0	0	0

Element Name	Atomic Number (Z)	K Shell ($n=1$)	L Shell ($n=2$)	M Shell ($n=3$)	Valency
Carbon	6	2	4	0	4
Oxygen	8	2	6	0	2 ($8 - 6$)
Sodium	11	2	8	1	1
Argon	18	2	8	8 (Octet Filled)	0

4. Atomic Number, Mass Number, and Valency

- **Atomic Number (Z):** The total number of protons residing within the nucleus of an atom. For any neutral atom, this matches the number of orbiting electrons.

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$$Z = ext{Number of Protons} = ext{Number of Electrons (in neutral atom)}$$
```

- **Mass Number (A):** The total sum of nucleons (protons and neutrons combined) packed inside the central core.

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$$A = ext{Number of Protons} + ext{Number of Neutrons}$$
```

- **Calculating Neutrons (N):** Computed by finding the mathematical difference between mass and atomic numbers:

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$$N = A - Z$$
```

- **Valency:** The combining capacity of an atom, determined by its valence electrons (outermost shell). If valence electrons ≤ 4, Valency = Valence Electrons. If valence electrons > 4, Valency = $8 - ext{Valence Electrons}$.

5. Isotopes vs. Isobars

Isotopes

Atoms of the **same chemical element** that possess the **same atomic number (Z)** but completely **different mass numbers (A)**.

Examples of Hydrogen Isotopes:

- Protium: $_1^1 ext{H}$ (0 Neutrons)
- Deuterium: $_1^2 ext{H}$ (1 Neutron)
- Tritium: $_1^3 ext{H}$ (2 Neutrons)

Key Note: Isotopes exhibit identical chemical properties but show variation in physical properties.

Isobars

Atoms belonging to **different chemical elements** that share the **same mass number (A)** but have **different atomic numbers (Z)**.

Standard Example:

- Calcium: $_{20}^{40} ext{Ca}$
- Argon: $_{18}^{40} ext{Ar}$

Both possess a matching mass number ($A = 40$) but have distinct elemental configurations and completely different chemical behaviors.

High-Yield Medical & Industrial Applications of Isotopes:

- An isotope of **Uranium ($^{235} ext{U}$)** serves as a fundamental fuel source in nuclear energy power plants.
- An isotope of **Cobalt ($^{60} ext{Co}$)** is used worldwide in radiation therapies to treat cancer.
- An isotope of **Iodine ($^{131} ext{I}$)** is critical in medical procedures to diagnose and treat Goitre.

6. Chapter Summary & Core Keywords

Summary: Atoms consist of a dense, positively charged nucleus containing protons and neutrons, discovered through Rutherford's alpha scattering experiment. Electrons orbit this nucleus in specific, non-radiating energy shells (Bohr model). Elements can be identified by their atomic number (Z) and mass number (A), with isotopes varying in neutron count and isobars varying in proton count.

Essential Exam Keywords:

`Subatomic Particles` `Alpha Scattering` `Atomic Nucleus` `Discrete Energy Shells` `Bohr-Bury Scheme` `Octet Config` `Valency Capacity` `Isotope Applications`