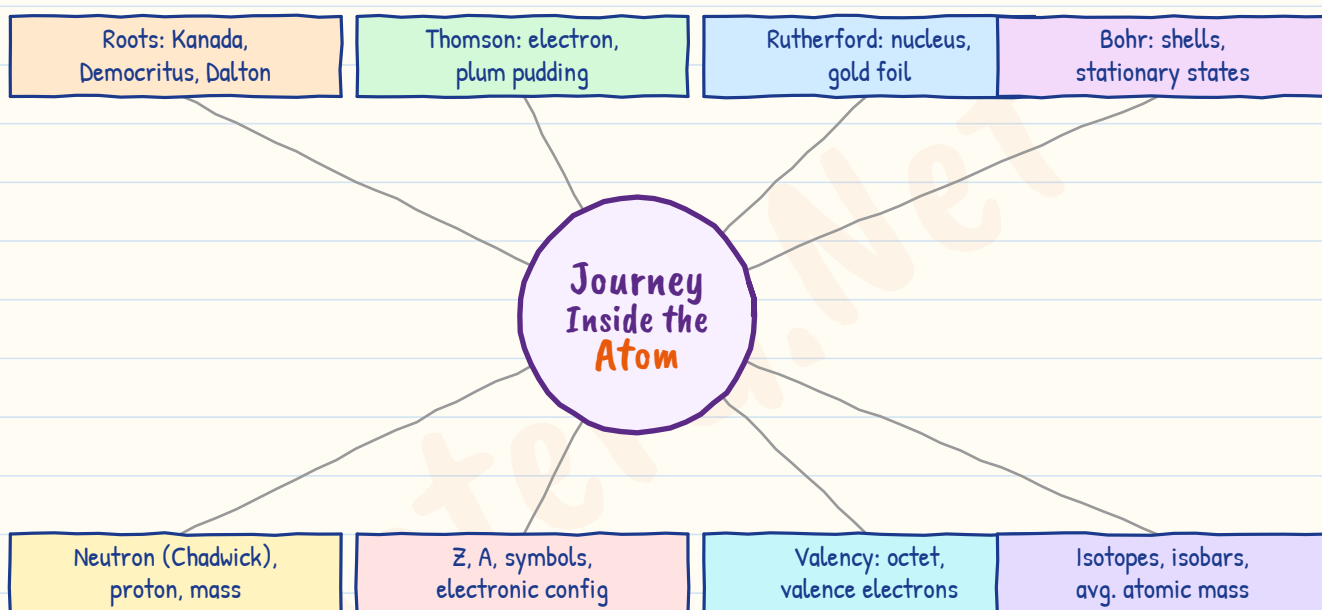


MasterG.Net CBSE Coaching Classes

# Journey Inside the Atom

Class 9 Science (Exploration) | NCERT Chapter 8

Handwritten Notes + In-between Q&amp;As + Extras + Most Important Questions



Roadmap of the chapter: one look and you know the whole journey!

## How to read these notes

[Textbook] = straight from NCERT [Extra] = beyond the book, good for understanding [★]

Most Imp] = exam favourite, revise twice!

Red highlighted words = **key terms**. Green words = **examples / answers**. Blue = normal ink.

## 8.0 Atoms: The Big Question

- Everything we see or feel is **matter**, and matter is made of tiny particles called **atoms** (too small to see with the naked eye).
- Both living things (human body) and non-living things (house) are made of atoms: human body → organ → tissue → cell → protein → atoms; house → room → wall → brick → silicates → atoms.
- Big question: is the atom really the smallest, indivisible unit? If not, what is inside it and how is it arranged?

### Think It Over: Dekhe Kya Seekha Tumne? (answers at the end of the journey)

**Q1.** Are atoms the smallest indivisible particles? [Textbook]

**Ans.** No. Atoms are made of smaller **subatomic particles**: electrons, protons and neutrons.

**Q2.** Why do electrons not fall into the nucleus although protons attract them? [Textbook]

**Ans.** In Bohr's model electrons move in fixed-energy circular paths (**stationary states**) and do not lose energy while in them, so they never spiral in.

**Q3.** Why did scientists keep modifying atomic models? [Textbook]

**Ans.** Every model explained the experiments known at that time. When a new experiment gave a result the model could not explain, a better model was needed. Science moves one step at a time.

## 8.1 Roots of Atomic Theory

Journey back more than **2,000 years** to ancient India and ancient Greece. Two very different civilisations asked the same question: "**What is everything made up of?**"

| Thinker                  | Where / When                                          | Idea                                                                                                                                                                                                            | Basis                   |
|--------------------------|-------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|
| Acharya Kanada           | India (about 2000+ years ago); text: Vaisesika Sutras | Divide matter (dravya) again and again → you reach smallest particles that cannot be divided: <b>parmanu</b> . Combinations form dyads (2 parmanus), triads (3 parmanus)... and these build the whole universe. | Philosophical reasoning |
| Leucippus and Democritus | Ancient Greece                                        | Indivisible particles called <b>atomos</b> (Greek: atomos = indivisible)                                                                                                                                        | Philosophical reasoning |
| John Dalton              | 1808, England                                         | All matter is made of indivisible particles called atoms. First <b>scientific</b> description of matter.                                                                                                        | Experiments of his time |

- ✦ A parmanu is infinitely small and cannot be perceived by the senses. Kanada's description did not tell the **proportions** in which parmanus combine.
- ✦ Remember: the concept of the 'atom' began as an **imaginary idea**, not from experiments. Dalton made it scientific.
- ✦ After Dalton, scientists asked: (1) What are atoms made of? (2) What would atoms look like if we could see them? (3) What makes atoms of one element different from another?

### Dalton's Atomic Theory (1808): Extra but Most Important ★

- ✦ All matter is made of very small indivisible particles called **atoms**.
- ✦ Atoms of the **same element** are identical in mass and properties; atoms of **different elements** differ.
- ✦ Atoms combine in **simple whole-number ratios** to form compounds.
- ✦ Atoms can neither be created nor destroyed in a chemical reaction (they only rearrange).
- ✦ In 1803 Dalton also gave the first **pictorial symbols** for elements (see 8.4).

### Limitations of Dalton's theory (Extra)

- ✦ Atoms are NOT indivisible: electrons, protons, neutrons were discovered inside them.
- ✦ Atoms of the same element are NOT always identical in mass → **isotopes** (e.g. C-12, C-13, C-14).
- ✦ Atoms of different elements can have the same mass number → **isobars** (e.g. Ar-40, K-40, Ca-40).

### Kuch Mazedaar Questions

**Q1.** Who was Acharya Kanada? What did he propose and where is it recorded? [Textbook]

**Ans.** An ancient Indian thinker. He said that dividing matter repeatedly leads to smallest particles called **parmanus**; recorded in the Sanskrit text **Vaisesika Sutras**.

**Q2.** What does 'atomos' mean? Who used the term? [Textbook]

**Ans.** 'Atomos' means **indivisible** (Greek). Leucippus and Democritus used it.

**Q3.** Why is Dalton's atomic theory called the first scientific description of matter? [Textbook ★ Most Imp]

**Ans.** Because it was based on **scientific experiments** of his time, unlike the earlier ideas that were based only on thinking and reasoning.

**Q4.** Write any three postulates of Dalton's atomic theory. Which of them are not correct today? [Extra ★ Most Imp]

**Ans.** Postulates: matter is made of indivisible atoms; atoms of an element are identical; atoms combine in simple whole-number ratios; atoms are not created/destroyed in reactions.

- Not correct today: (i) atoms are indivisible (they have subatomic particles) and (ii) all atoms of an element are identical (isotopes exist).

**Q5.** Name the Sanskrit text in which Kanada's ideas appear. [Extra]

**Ans.** Vaishesika Sutras.

## 8.2 A Short Historical Journey Through Atomic Models

Early models were simple guesses that were improved as new evidence arrived. They are still important because they show how science moves forward: **curiosity** → **questioning** → **experimentation**.

### Atoms ARE divisible: Radioactivity

- ✦ Until the late 19th century atoms were thought to be the smallest, indivisible units.
- ✦ Then scientists found that some elements emit invisible energy and particles called **radiation**. This phenomenon is **radioactivity** (discovered by Henri Becquerel in 1896: Extra).
- ✦ Conclusion: atoms must contain smaller particles → they are NOT indivisible.

### 8.2.1 J. J. Thomson and the Electron

- ✦ **1897**: J. J. Thomson passed electric current through a gas at **very low pressure** in a glass tube with two electrodes and applied a high voltage.
- ✦ Rays moved from the **cathode (-)** to the **anode (+)**: called **cathode rays**.
- ✦ In electric and magnetic fields these rays bent → they are streams of **negatively charged particles** with mass much smaller than atoms → named **electrons**.
- ✦ Nature of cathode rays was **independent** of the cathode material and the gas used → electrons are a fundamental part of **every atom**.
- ✦ Charge of an electron =  $-1.602 \times 10^{-19}$  C, taken as **-1** by convention and convenience.

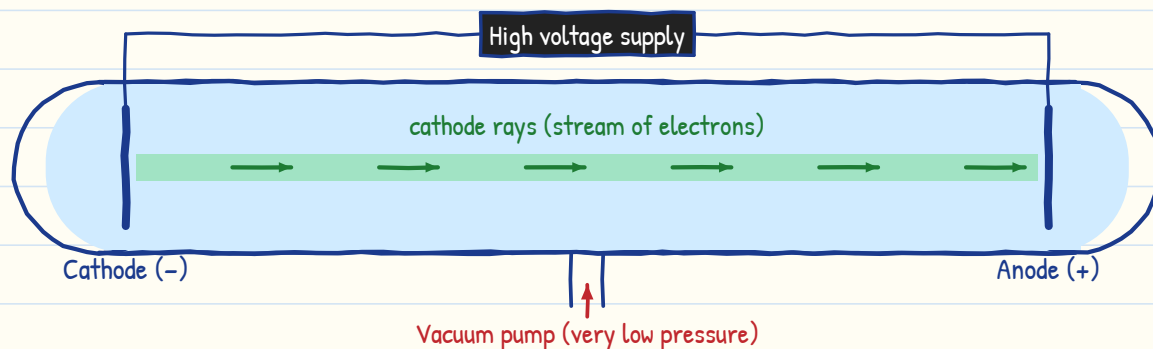


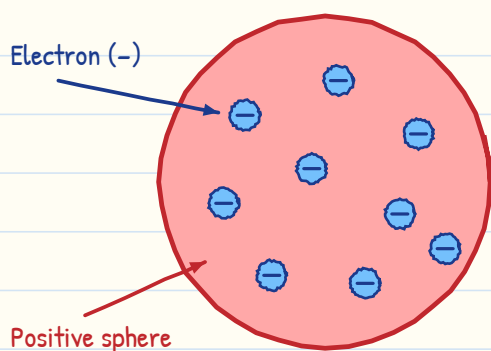
Fig. 8.1: Cathode ray tube (line diagram)

### Extra: Properties of cathode rays

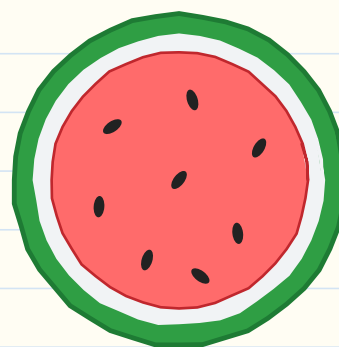
- ✦ Travel in straight lines; cast sharp shadows of objects placed in their path.
- ✦ Deflected by electric field towards the positive plate and also by a magnetic field → carry negative charge.
- ✦ Can turn a tiny paddle wheel → they have mass and momentum (particles).
- ✦ Mass of an electron  $\approx 9.1 \times 10^{-31}$  kg  $\approx 1/1836$  of a proton. Thomson got the Nobel Prize in Physics in **1906** and headed the Cavendish Laboratory, Cambridge (Rutherford was guided by him).

### ➤ Thomson's model of the atom (Plum pudding / Watermelon model, 1904: Extra)

- ✦ Puzzle: electrons are negative but atoms are **neutral** → where is the positive charge?
- ✦ Thomson: atom = a **sphere of positive charge** with electrons **embedded throughout** it, like plums in a pudding or seeds in a watermelon (red pulp = positive matter).
- ✦ First genuine attempt to show how positive and negative charges balance inside an atom.
- ✦ Limitation: could not explain the result of the gold foil experiment (large-angle scattering); it had no nucleus.



Thomson model (plum pudding)



Watermelon: red pulp = (+), seeds = electrons

Fig. 8.2 / 8.3: Thomson's model and the watermelon picture

**Pause and Ponder: Chalo, Dimaag Lagayein!**

**Q1.** Clay (positive) and beads (electrons) atom: what if (i) positive charge on clay is less than the total negative charge of beads? (ii) the clay itself carries a bit of negative charge?

[Textbook]

**Ans.** (i) The model would carry a **net negative charge** → it behaves like a negative ion, not a neutral atom.

➤ (ii) Then the total charge is even more negative; it would **not** represent a neutral atom. For neutrality, positive charge must exactly equal the total negative charge.

**Q2.** Could an orange or lemon (seeds in soft pulp) be a good comparison for Thomson's model?

[Textbook]

**Ans.** Matches: seeds spread through the pulp ≈ electrons spread through the positive sphere.

➤ Falls short: pulp and seeds carry no charge; seeds are big, few and not equal in number to any charge; real atoms are billions of times smaller.

**Q3.** Why did Thomson conclude that electrons are present in all atoms? [Textbook ★ Most Imp]

**Ans.** Cathode rays (electrons) behaved the **same way whatever the cathode material or gas** used. So electrons must be a common part of all atoms.

**Q4.** Who discovered the electron and in which year? Name the first subatomic particle discovered. [Extra]

**Ans.** J. J. Thomson, 1897; the electron.

**Q5.** What problem did Thomson face after discovering electrons and how did he solve it? [Extra ★ Most Imp]

**Ans.** Atoms are neutral, so positive charge had to exist. He proposed a sphere of positive charge with electrons embedded in it (plum pudding model).

## 8.2.2 Testing Thomson: The Gold Foil Experiment

- ✦ **1911** (NCERT): Geiger and Marsden, working under **Ernest Rutherford**, aimed a narrow beam of  **$\alpha$ -particles** at an extremely thin **gold foil**. (Extra: actual experiments were done in 1908–09, model proposed 1911. Write 1911 in exams.)
- ✦  **$\alpha$ -particle** = tiny, positively charged particle from radioactive elements; it is the nucleus of a helium atom: **2 protons + 2 neutrons** (charge +2, mass  $\approx 4$  u: Extra).
- ✦ Thomson's model predicted:  $\alpha$ -particles pass straight or deflect only slightly (positive charge spread evenly).
- ✦ Deflection from the straight path = **scattering**; so it is also called the  **$\alpha$ -ray scattering experiment**.

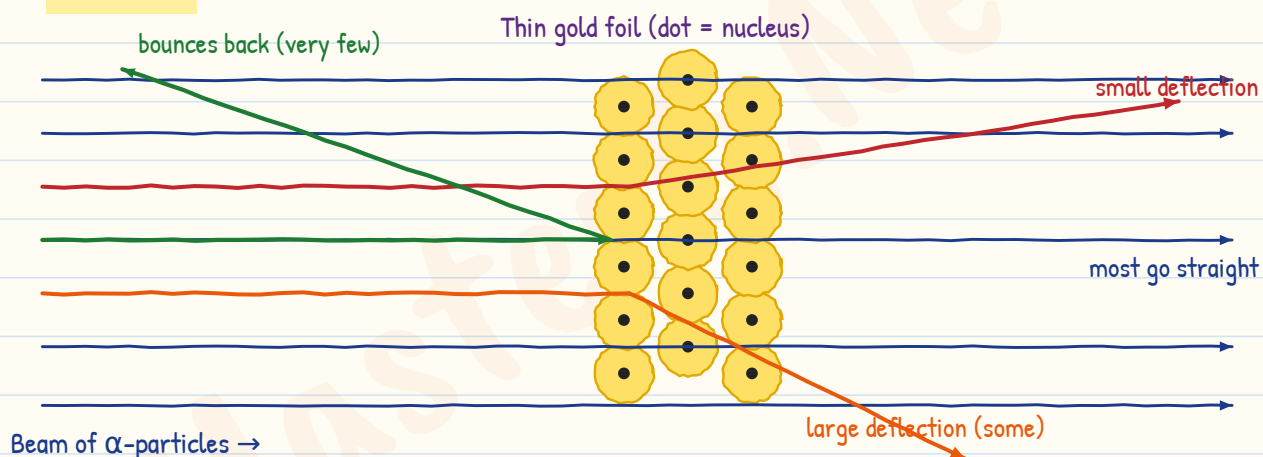


Fig. 8.4: Schematic view of the gold foil experiment

| Observation                                                         | Conclusion (Most Important ★)                                                                |
|---------------------------------------------------------------------|----------------------------------------------------------------------------------------------|
| Most $\alpha$ -particles passed straight through undeflected        | Most of the atom is <b>empty space</b>                                                       |
| Some $\alpha$ -particles were deflected by small/large angles       | Positive charge is concentrated at one place and repels the (+) $\alpha$ -particles          |
| A very few (about 1 in 8000: Extra) bounced back almost $180^\circ$ | The positive charge and most of the mass are packed in a <b>tiny, dense centre = nucleus</b> |

### Extra: Why gold foil? Why so thin?

- ✦ Gold is highly malleable: it can be beaten into a foil only a few hundred atoms ( $\approx 100$  nm) thick.
- ✦ Thin foil means each  $\alpha$ -particle meets very few atoms; so the deflection seen is due to a **single atom's nucleus**, not many collisions.
- ✦ Gold nuclei are heavy and strongly positive  $\rightarrow$  strong, easily seen deflections.

### ➤ A. Rutherford's model of the atom (1911) — planetary model

- ✦ The positive charge is not spread out; it is concentrated in an extremely small region called the **nucleus**.
- ✦ Most of the atom is **empty space** (most  $\alpha$  passed through).
- ✦ The nucleus is **dense**; it contains all the positive charge and most of the mass.
- ✦ Electrons **revolve around the nucleus** like planets around the Sun → **planetary model**.
- ✦ Sizes: atom  $\approx 10^{-10}$  m; nucleus  $\approx 10^{-15}$  m → nucleus is about  **$10^5$  (one lakh) times smaller** than the atom.
- ✦ Imagine: atom = cricket ground ( $\approx 100$  m across) → nucleus = a tiny **black pepper grain** (few mm) at the centre!

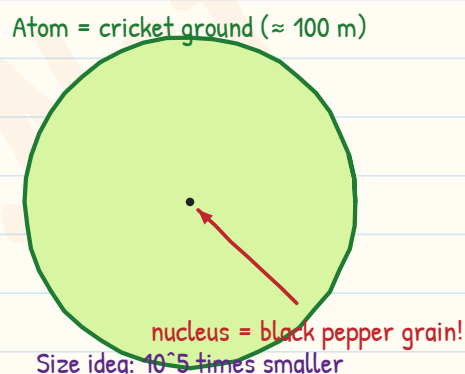
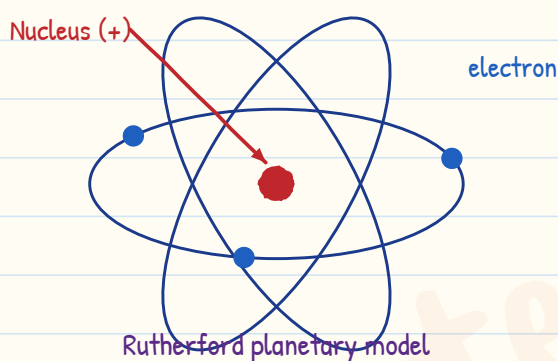


Fig. 8.5: Planetary model suggested by Rutherford

### Ready to Go Beyond: How many atoms make a paper sheet?

- ✦ Thickness of paper =  $0.1 \text{ mm} = 10^{-4} \text{ m}$ ; diameter of one atom  $\approx 10^{-10} \text{ m}$ .
- ✦ Number of atoms stacked  $\approx 10^{-4} \div 10^{-10} = \mathbf{10^6 \text{ (one million)}}$ . A simple sheet is a vast assembly of tiny building blocks!

### Think as a Scientist: thicker gold foil?

- ✦ A thick foil has many layers of atoms → each  $\alpha$ -particle has a **much greater chance of hitting a nucleus** (or being scattered many times).
- ✦ Prediction: fewer  $\alpha$ -particles pass straight; **more are deflected** and more bounce back; many may even be stopped. (Draw: same beam, thick foil, fewer straight arrows, more bent/returning arrows.)

### ➤ B. Limitations of Rutherford's model

- ✦ Could not explain the **stability** of the atom.
- ✦ An electron moving on a circular path keeps changing direction → it is **accelerating** (Chapter 4: motion).

- ✦ An accelerating charged particle should **lose energy** → spiral inward → fall into the nucleus → atoms would **collapse** and matter would not exist! But atoms are stable. So a new explanation was needed.

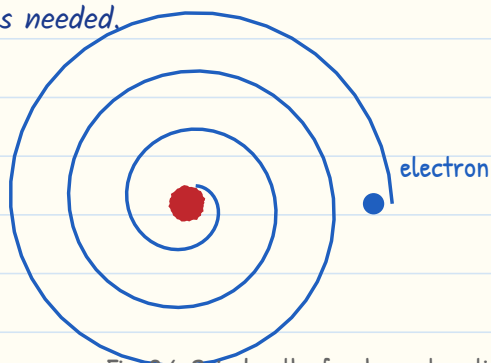


Fig. 8.6: Spiral path of a charged particle on losing energy

Circular motion = acceleration

→ electron radiates (loses) energy

→ spirals into nucleus

→ atom would **COLLAPSE!** (but it does not)

### ➤ C. Discovery of the proton

- ✦ Rutherford showed that the nucleus carries positive charge due to particles called **protons** (he discovered and named them; Extra: Goldstein saw canal rays in 1886, and Rutherford identified the proton ~1919).
- ✦ Protons are much heavier than electrons; charge equal and opposite (+1).
- ✦ Atom is neutral → **number of protons = number of electrons**. Examples: helium (2 p, 2 e), sodium (11 p, 11 e).
- ✦ Meet a Scientist: Rutherford (born in New Zealand) → "Father of Nuclear Physics"; Nobel Prize in Chemistry **1908**; his portrait is on New Zealand's \$100 note.

### Pause and Ponder: Yeh Zaroor Aayega!

**Q1.** What would happen if  $\alpha$ -particles were replaced by negatively charged particles in Rutherford's experiment? [Textbook]

**Ans.** Negative particles would be **attracted** by the positive nucleus (not repelled), so they would bend towards the nucleus (opposite sense of bending).

- Those passing near the nucleus could be pulled in; most would still go straight since the atom is mostly empty space. (Electrons in the atom would also repel them a little.)

**Q2.** A few  $\alpha$ -particles bounced back sharply. How does this single result rule out Thomson's plum pudding model? [Textbook ★ Most Imp]

**Ans.** In Thomson's model positive charge is spread evenly and weakly, so it cannot turn a fast, heavy  $\alpha$ -particle back. A bounce-back needs a **very small, dense, strongly positive centre**. (Rutherford: like a shell bouncing back off tissue paper!)

**Q3.** If you could ask Rutherford one question, what would it be? [Textbook]

**Ans.** Open-ended. Example: "If electrons orbit the nucleus, why do they not lose energy and fall into it?"

**Q4.** Assertion (A): Rutherford concluded that most of the mass of an atom is concentrated in a small central region (nucleus). Reason (R): According to Thomson's model electrons are embedded in a uniformly distributed positive sphere. [Textbook ★ Most Imp]

**Ans.** Answer: (ii) Both A and R are true, but R is not the correct explanation of A.

- A is Rutherford's conclusion from the experiment. R is true about Thomson's model, but it does not explain why Rutherford reached A.

**Q5.** State the postulates (conclusions) of Rutherford's nuclear model. [Extra ★ Most Imp]

**Ans.** Positive charge and most of the mass in a tiny dense nucleus; most of the atom is empty; electrons revolve around the nucleus in circular paths; atom is neutral ( $p = e$ ).

**Q6.** Write the drawbacks of Rutherford's model. [Extra ★ Most Imp]

**Ans.** It could not explain stability: a revolving electron is accelerated and would radiate energy, spiral into the nucleus and the atom would collapse. It also did not explain how electrons are arranged.

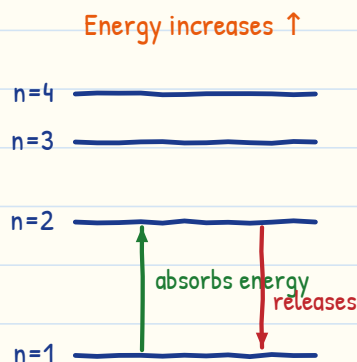
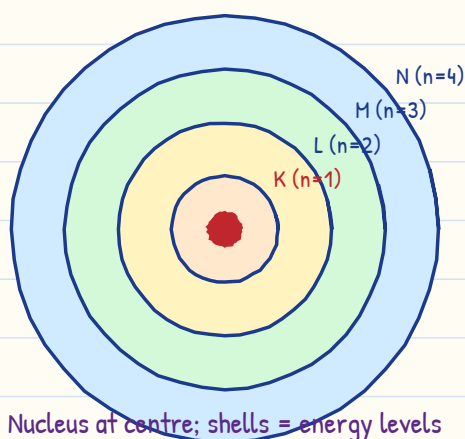
**Q7.** Why did most  $\alpha$ -particles pass straight through the gold foil? [Extra]

**Ans.** Because most of the atom is **empty space**; the nucleus occupies a tiny fraction of the volume.

## 8.2.3 Bohr's Model of the Atom

To explain why atoms are stable, **Niels Bohr** proposed a new model in **1913**. According to Bohr:

- ✦ Electrons do not move randomly; they follow fixed circular paths called **stationary states, orbits or shells**. Each shell has a definite energy → also called **energy levels**.
- ✦ Shells are named **K, L, M, N...** or  **$n = 1, 2, 3, 4...$**
- ✦ Electrons revolve only in these allowed shells, **not in between**. While in a fixed shell an electron does **not lose energy**.
- ✦ K ( $n = 1$ ) is closest to the nucleus and has the **least energy**; energy increases outwards ( $L > K, M > L...$ ).
- ✦ An electron jumps to another shell by **absorbing or releasing** a fixed amount of energy = difference between the two energy levels ( $\Delta E = E_2 - E_1$ ).
- ✦ Each shell can hold only a certain number of electrons.



$$\Delta E = E(\text{final}) - E(\text{initial})$$

Fig. 8.7: Energy Levels in an atom (left) and the energy ladder (right)

### How does Bohr's model explain stability?

- ✦ Electrons still move in circular paths around the nucleus, but Bohr made a **postulate**: in a **stationary state** the energy of the electron stays constant even though it is moving.
- ✦ So the electron does not radiate energy and does not spiral into the nucleus → atom is stable.

### Threads of Curiosity: why K, L, M, N... and not A, B, C, D?

- ✦ Charles Barkla named the first X-ray line he observed "K". He did not start from A to leave room for a possible earlier series (none was ever found). Bohr adopted the same letters for shells.

### Extra: Limitations of Bohr's model

- ✦ Works well for hydrogen (one electron) but fails for atoms with many electrons.
- ✦ Electrons do not really follow well-defined paths; we can only say where they are **most likely** to be.
- ✦ Modern view: **quantum mechanical model** (1920s) → electrons exist as **electron clouds**.  
(Next Level Up: higher classes.)

### ➤ Atomic models at a glance (comparison: Extra but Most Important ★)

| Feature           | Thomson                                 | Rutherford                                      | Bohr                                       |
|-------------------|-----------------------------------------|-------------------------------------------------|--------------------------------------------|
| Year              | 1897 ( $e^-$ ); model 1904              | 1911                                            | 1913                                       |
| Picture           | Positive sphere with embedded electrons | Tiny dense nucleus; electrons revolve around it | Nucleus + electrons in fixed energy shells |
| Based on          | Cathode rays                            | Gold foil ( $\alpha$ -scattering)               | Stability + energy levels                  |
| Failed to explain | Gold foil result                        | Stability of atom                               | Multi-electron atoms; exact electron paths |

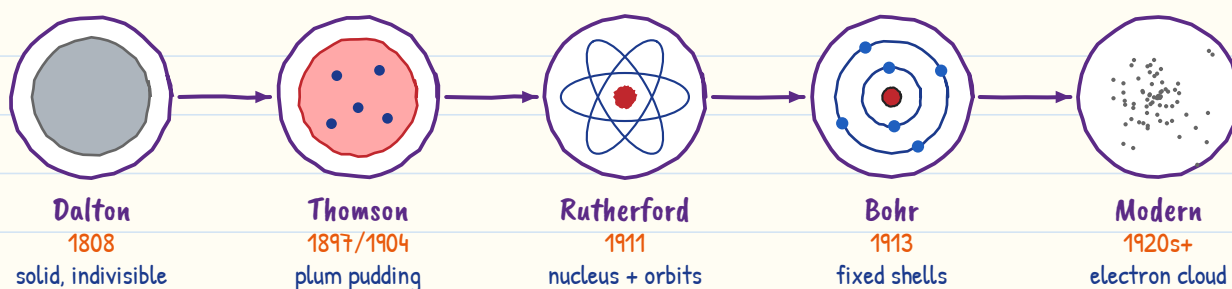


Fig. 8.16: Journey of the development of atomic models (and it is still being discovered!)

### Quick Check: Ho Jaye?

**Q1.** Which of the following are correct/incorrect according to Bohr's model? (i) Electrons lose energy in fixed orbits and slowly fall in. (ii) Electrons can exist anywhere with no fixed energy. (iii) Electrons revolve in orbits of fixed energy without losing energy. (iv) Electrons can be found between energy levels. [Textbook ★ Most Imp]

**Ans.** (i) Incorrect: in stationary orbits electrons do NOT lose energy.

- (ii) Incorrect: electrons stay only in allowed shells having fixed energies.
- (iii) **Correct**: this is Bohr's main postulate.
- (iv) Incorrect: electrons cannot be found between allowed energy levels; they jump from one to another.

**Q2.** State the postulates of Bohr's model of the atom. [Extra ★ Most Imp]

**Ans.** Fixed circular orbits (stationary states) with definite energy; no energy loss in an orbit; energy increases with distance from nucleus; jump between orbits by absorbing/releasing energy equal to the energy difference; each shell holds a limited number of electrons.

**Q3.** Both Rutherford's and Bohr's models have electrons orbiting. Why did Rutherford's fail to explain stability but Bohr's succeeded? [Textbook]

**Ans.** Rutherford's revolving electrons would radiate energy and collapse into the nucleus. Bohr **postulated** stationary states where the energy stays constant, so no energy is lost.

**Q4.** When does an electron move from a lower to a higher shell? [Extra]

**Ans.** When it **absorbs** energy exactly equal to the difference of the two energy levels. It returns to lower shell by releasing the same energy.

## 8.3 What Contributes to the Mass of an Atom?

- ✦ Rutherford: most of the mass is in the nucleus; electrons are so light their mass can be **ignored**.
- ✦ Puzzle: hydrogen has 1 proton, helium has 2 protons, yet helium's mass is about **4 times** hydrogen's (not 2 times)! Something else in the nucleus adds mass but no charge.

### 8.3.1 Discovery of the Neutron

- ✦ **1932: James Chadwick** (student of Rutherford, Cavendish Laboratory) discovered a particle with mass nearly equal to a proton and **no charge** → **neutron**, symbol  $n$ .
- ✦ Neutrons are found in the nucleus of **all atoms except hydrogen** (ordinary hydrogen, protium).
- ✦ Mass of an atom comes mainly from **protons + neutrons** packed in the nucleus (nucleons).  
Chadwick: Nobel Prize in Physics 1935.

| Particle | Symbol | Relative charge | Mass (Extra)                                                    | Location                 | Discovered by         |
|----------|--------|-----------------|-----------------------------------------------------------------|--------------------------|-----------------------|
| Electron | $e^-$  | -1              | $\approx 1/1836 \text{ u}$ ( $9.1 \times 10^{-31} \text{ kg}$ ) | Outside nucleus (shells) | J. J. Thomson (1897)  |
| Proton   | $p^+$  | +1              | $\approx 1 \text{ u}$ ( $1.67 \times 10^{-27} \text{ kg}$ )     | Nucleus                  | Rutherford            |
| Neutron  | $n^0$  | 0               | $\approx 1 \text{ u}$ ( $1.675 \times 10^{-27} \text{ kg}$ )    | Nucleus                  | James Chadwick (1932) |

### Threads of Curiosity: why do protons not push each other apart?

- ✦ Protons repel each other (like charges), but neutrons act as spacers **increasing the distance** and strengthen the **nuclear force** that binds particles together.
- ✦ Light atoms have about equal  $p$  and  $n$  (C: 6  $p$ , 6  $n$ ; O: 8  $p$ , 8  $n$ ). Heavier atoms need many more neutrons: Iron 26  $p$  + 30  $n$ ; Uranium 92  $p$  + 146  $n$ .

### Ready to Go Beyond + What if...

- ✦ Neutrons are uncharged so they penetrate nuclei easily → artificial radioactive elements, splitting of uranium → the **atomic age** (nuclear power and nuclear weapons).
- ✦ What if an atom had no empty space? Atoms would shrink enormously (nucleus  $\approx 10^5$  times smaller), so objects would become unimaginably small and dense: a teaspoon of such matter would weigh millions of tonnes!

## India's Scientific Contributions

- ✦ **BARC** (Bhabha Atomic Research Centre), Mumbai, runs neutron-scattering experiments using reactors like **Dhruva**, revealing the structure of superconductors, battery electrodes and drug molecules → better medicines, energy storage and alloys.
- ✦ **Homi Jehangir Bhabha**: father of the Indian nuclear programme; founded TIFR and BARC for peaceful uses of atomic energy.
- ✦ By 1869 about 69 elements were known; today **118** elements are known (some artificially made).

## Kuch Mazedaar Questions

**Q1.** Why is helium's mass about four times (and not two times) that of hydrogen? [Textbook ★

Most Imp]

**Ans.** Helium has 2 protons AND 2 neutrons in its nucleus; each of the 4 nucleons weighs about 1 u. Hydrogen has just 1 proton. So 4 : 1.

**Q2.** Who discovered the neutron, in which year, and what are its properties? [Textbook]

**Ans.** James Chadwick, 1932. Mass  $\approx$  proton, charge zero, found in the nucleus.

**Q3.** Which atom has no neutron? [Extra]

**Ans.** Ordinary hydrogen (protium,  $^1\text{H}$ ): 1 proton and no neutron.

**Q4.** Why can the mass of electrons be ignored while calculating an atom's mass? [Textbook]

**Ans.** An electron is about 1/1836 as heavy as a proton, so its contribution is negligible.

**Q5.** Why do heavier nuclei need more neutrons than protons? [Extra ★ Most Imp]

**Ans.** Many protons repel strongly. Extra neutrons increase the distance between protons and strengthen the nuclear force, keeping the nucleus bound.

## 8.4 Symbols of Elements

- ✦ **1803**: Dalton introduced the first **pictorial symbols** (e.g. a dot in a circle for hydrogen) to make chemistry easier.
- ✦ **1813**: **Berzelius** suggested symbols derived from **Latin names** → alphabetic chemical symbols.
- ✦ Today **IUPAC** (International Union of Pure and Applied Chemistry) approves the names and symbols of elements.

### Rules for writing symbols

- ✦ Many symbols = first letter or first two letters of the name: H, He, Al.
- ✦ First letter is **CAPITAL**, second (if any) is **small**: Al (not AL), Co (not CO).
- ✦ Some use first letter + another letter: Chlorine Cl, Zinc Zn.
- ✦ Some come from Latin/Greek/German names: Iron Fe (ferrum), Mercury Hg (hydrargyros: Greek), Tungsten W (wolfram: German).

| Element   | Symbol | Element         | Symbol | Element            | Symbol |
|-----------|--------|-----------------|--------|--------------------|--------|
| Aluminium | Al     | Copper (Cuprum) | Cu     | Nitrogen           | N      |
| Argon     | Ar     | Fluorine        | F      | Oxygen             | O      |
| Barium    | Ba     | Gold (Aurum)    | Au     | Potassium (Kalium) | K      |
| Boron     | B      | Hydrogen        | H      | Silicon            | Si     |
| Bromine   | Br     | Iodine          | I      | Silver (Argentum)  | Ag     |
| Calcium   | Ca     | Iron (Ferrum)   | Fe     | Sodium (Natrium)   | Na     |
| Carbon    | C      | Lead (Plumbum)  | Pb     | Sulfur             | S      |
| Chlorine  | Cl     | Magnesium       | Mg     | Uranium            | U      |
| Cobalt    | Co     | Neon            | Ne     | Zinc               | Zn     |

Table 8.2: Names and symbols of some common elements

Why symbols? They are **internationally recognised** so scientists everywhere can communicate clearly, whatever their language. **Memory trick (Extra)**: Na, K, Fe, Cu, Ag, Au, Pb, Hg, W are the "odd" ones: learn them from their old names!

### Pause and Ponder: Thoda Practice Ho Jaye

**Q1.** You discover a new element and name it after yourself. Justify that the symbol follows IUPAC rules. [Textbook]

**Ans.** Example: element named **Riyum**, symbol **Ri**: (i) 1st letter capital, 2nd small; (ii) letters come from the name; (iii) symbol not already used by another element. IUPAC must approve it.

**Q2.** What problems could arise if every scientist used different symbols for the same element?

[Textbook]

**Ans.** Confusion, wrong communication, mistakes in experiments/formulae, difficulty in sharing and checking research across countries; possible safety risks.

**Q3.** Which is correct: CO or Co for cobalt? Why? [Extra]

**Ans.** Co: only the first letter is capital. (CO = carbon monoxide, a compound of C and O.)

**Q4.** Give the symbols of: sodium, potassium, iron, silver, gold, lead, mercury, tungsten. [Extra]

**Ans.** Na, K, Fe, Ag, Au, Pb, Hg, W.

## 8.5 Atomic Number (Z)

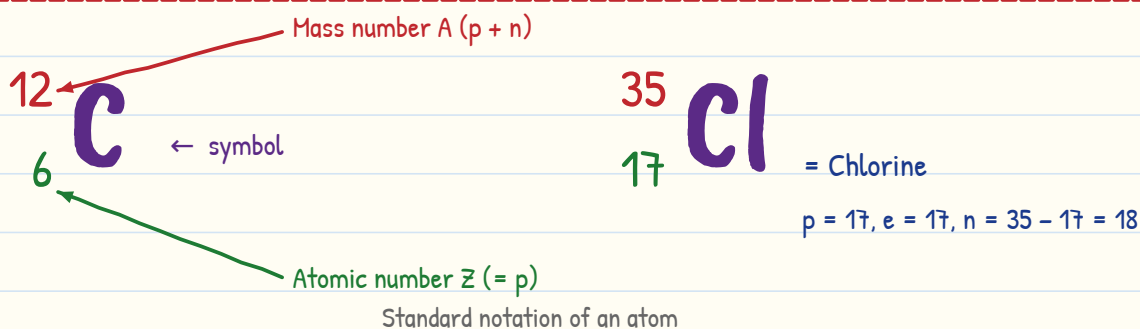
- Atoms of one element are alike but differ from atoms of other elements in the number of protons and electrons.
- Atomic number  $Z$**  = number of protons in the nucleus. It decides the **identity** of the element and its chemical behaviour.
- Neutral atom:  $Z = p = e$ . Hydrogen:  $Z = 1$  (1 p, 1 e). Helium:  $Z = 2$  (2 p, 2 e). Lithium:  $Z = 3$ , 3 p, 4 n, 3 e.

## 8.6 Mass Number (A)

- Mass number  $A$**  = total number of protons + neutrons in the nucleus. Protons and neutrons together are called **nucleons**.
- Electron mass is negligible so it is ignored.

### Formulas to remember ★

- $A = p + n \rightarrow n = A - Z \rightarrow Z = p = e$  (neutral atom)
- Standard notation: mass number written top-left, atomic number bottom-left of the symbol, e.g. C-12 with  $A = 12$ ,  $Z = 6$ .



| Element  | Protons ( $p^+$ ) | Neutrons ( $n^0$ ) | Mass number (A) |
|----------|-------------------|--------------------|-----------------|
| Hydrogen | 1                 | 0                  | 1               |
| Helium   | 2                 | 2                  | 4               |
| Lithium  | 3                 | 4                  | 7               |

Table 8.3: Mass number of different elements

### Pause and Ponder: Numericals

**Q1.** An atom with atomic number 26 has 56 nucleons. Find electrons, protons and neutrons.

[Textbook ★ Most Imp]

**Ans.**  $Z = 26 \rightarrow p = 26, e = 26$ . Nucleons  $A = 56 \rightarrow n = 56 - 26 = 30$  (iron).

**Q2.** The nucleus of an atom has 20 protons and mass number 41. Find the neutrons. [Textbook ★ Most Imp]

**Ans.**  $n = A - p = 41 - 20 = 21$ .

**Q3.** An atom has 18 neutrons and atomic number 17. What is its mass number? [Textbook ★ Most Imp]

**Ans.**  $A = p + n = 17 + 18 = 35$  (chlorine-35).

**Q4.** An atom with mass number 23 has 11 electrons. Find the neutrons. [Textbook ★ Most Imp]

**Ans.**  $e = 11 \rightarrow Z = 11, n = 23 - 11 = 12$  (sodium).

**Q5.** How many protons, neutrons and what atomic number does lithium have (Fig. 8.10)? [Textbook]

**Ans.** 3 protons, 4 neutrons, atomic number = 3.

**Q6.** Find  $p, n, e$  in calcium-40 ( $Z = 20$ ). [Extra]

**Ans.**  $p = 20, e = 20, n = 40 - 20 = 20$ .

## 8.7 How Are Electrons Distributed in Energy Levels?

Rules suggested by **Bohr and Bury**:

- Maximum electrons in a shell =  $2n^2$  ( $n$  = shell number): K ( $n=1$ ) = 2; L ( $n=2$ ) = 8; M ( $n=3$ ) = 18; N ( $n=4$ ) = 32.
- Maximum electrons in the **outermost shell** = 8 (for the first shell it is 2).
- Shells are filled **stepwise** from the nearest to the nucleus: K  $\rightarrow$  L  $\rightarrow$  M  $\rightarrow$  N. L fills only after K is complete.

| Shell                | K                  | L                  | M                   | N                   |
|----------------------|--------------------|--------------------|---------------------|---------------------|
| $n$                  | 1                  | 2                  | 3                   | 4                   |
| Max electrons $2n^2$ | $2 \times 1^2 = 2$ | $2 \times 2^2 = 8$ | $2 \times 3^2 = 18$ | $2 \times 4^2 = 32$ |

### 8.7.1 Building Up Atoms

Add one electron each time the atomic number increases by 1. The distribution of electrons among shells is the **electronic configuration**. Written as K, L, M: e.g. Na = 2, 8, 1.

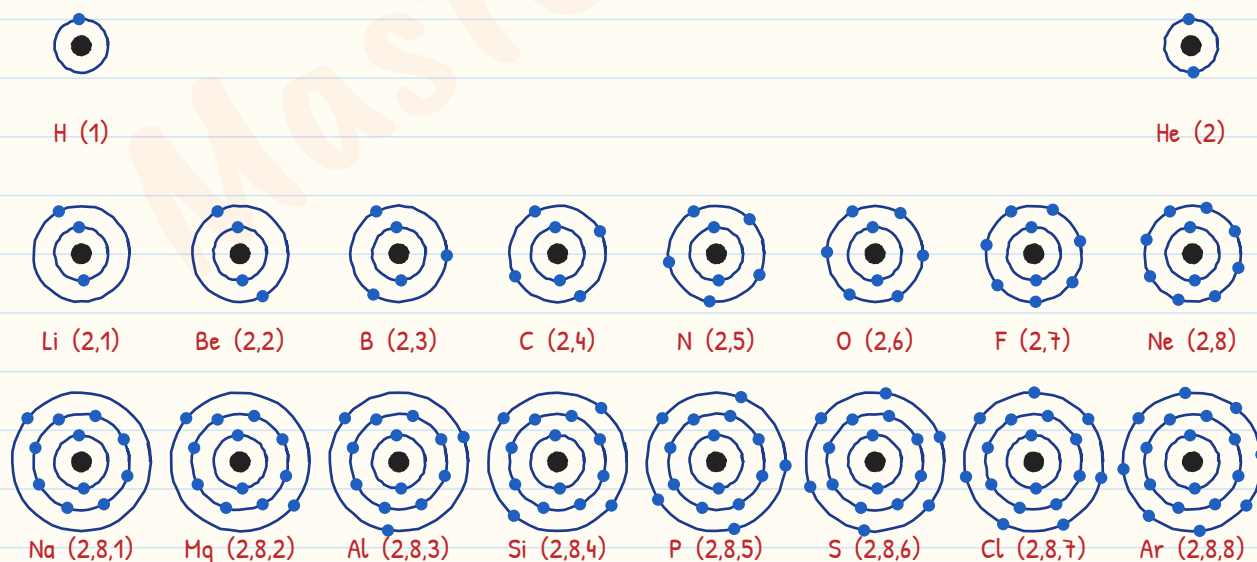


Fig. 8.11: Atomic structure of the first 18 elements (K, L, M shells)

### Extra (Most Important ★): beyond $Z = 18$

- Potassium ( $Z = 19$ ) = 2, 8, 8, 1 and Calcium ( $Z = 20$ ) = 2, 8, 8, 2, because the outermost shell cannot hold more than 8 electrons.

Table 8.4 (with extra column: valency, as the textbook asks you to add):

| Element    | Sym | Z  | p  | n  | e  | K | L | M | 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       |
| Sulfur     | 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: lose/gain/share to reach 8 (or 2). Noble gases He, Ne, Ar → valency 0

### Pause and Ponder: Chalokhe

**Q1.** Outermost-shell electrons of (i) C-12 (ii) F-19 (iii) Si-28? [Textbook ★ Most Imp]

**Ans.** (i) C:  $Z = 6 \rightarrow 2, 4 \rightarrow 4$

➤ (ii) F:  $Z = 9 \rightarrow 2, 7 \rightarrow 7$

➤ (iii) Si:  $Z = 14 \rightarrow 2, 8, 4 \rightarrow 4$

**Q2.** Electronic configuration of elements with  $Z = 12, 16, 18$ . [Textbook ★ Most Imp]

**Ans.**  $12 \rightarrow 2, 8, 2$  (Mg);  $16 \rightarrow 2, 8, 6$  (S);  $18 \rightarrow 2, 8, 8$  (Ar).

**Q3.** Riddle: mass number 23, 11 protons, soft metal that reacts vigorously with water. Who am I and how many neutrons? [Textbook ★ Most Imp]

**Ans.**  $Z = 11 \rightarrow$  Sodium (Na); neutrons =  $23 - 11 = 12$ . Configuration 2, 8, 1.

**Q4.** Why can the K shell hold only 2 electrons? [Extra]

**Ans.** Formula  $2n^2$ ; for  $n = 1, 2 \times 1^2 = 2$ .

**Q5.** Write the electronic configuration of K ( $Z = 19$ ) and Ca ( $Z = 20$ ). [Extra]

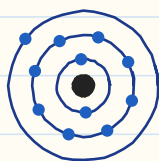
**Ans.** K: 2, 8, 8, 1; Ca: 2, 8, 8, 2 (outer shell never exceeds 8).

## 8.8 Combining Capacity of an Atom: Valency

- ✦ **Combining capacity** = number of H (or Cl) atoms with which one atom of an element combines. Water  $H_2O$ : O combines with 2 H  $\rightarrow$  capacity 2.  $NH_3 \rightarrow$  N has **3**;  $MgCl_2 \rightarrow$  Mg has **2**.
- ✦ Outermost shell containing electrons = **valence shell**; its electrons = **valence electrons**.
- ✦ Outer shell with **8 electrons = octet** (or 2 in He = duplet)  $\rightarrow$  atom is stable and largely **unreactive**.
- ✦ Atoms with incomplete valence shell are reactive: they **lose, gain or share** electrons to complete the octet.
- ✦ **Valency** = number of electrons gained, lost or shared to complete the octet.

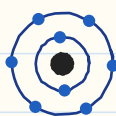
### Quick rule for valency ★

- ✦ Valence electrons **less than 4**  $\rightarrow$  atom **loses** them  $\rightarrow$  valency = number of valence electrons (Na: 2,8,1  $\rightarrow$  valency 1).
- ✦ Valence electrons **more than 4**  $\rightarrow$  atom **gains** electrons  $\rightarrow$  valency =  $8 - \text{valence electrons}$  (O: 2,6  $\rightarrow$  valency 2).
- ✦ Exactly **4** valence electrons  $\rightarrow$  **shares** 4 (Carbon: 2,4  $\rightarrow$  valency 4).
- ✦ Octet complete (Ne: 2,8; Ar: 2,8,8) or He (2)  $\rightarrow$  valency **0** (inert).



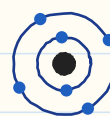
Na (2,8,1)

loses  $1e^- \rightarrow$  valency 1



O (2,6)

gains  $2e^- \rightarrow$  valency 2



C (2,4)

shares  $4e^- \rightarrow$  valency 4

Valency from electronic configuration

### Kuch Mazedaar Questions

**Q1.** Define valency. How is it linked to the electronic configuration? [Textbook ★ Most Imp]

**Ans.** Valency is the number of electrons an atom gains, loses or shares to attain a stable octet (duplet for He). It depends on the number of valence electrons.

**Q2.** Valency of Mg, Al, S, Cl, Ne? [Textbook ★ Most Imp]

**Ans.** Mg (2,8,2) = 2; Al (2,8,3) = 3; S (2,8,6) = 2; Cl (2,8,7) = 1; Ne (2,8) = 0.

**Q3.** Will atoms with 8 electrons in the outermost shell try to lose or gain electrons? [Textbook]

**Ans.** No. They already have a stable octet, are largely unreactive; their valency is zero (e.g. neon, argon).

**Q4.** Difference between valence electrons and valency? [Extra ★ Most Imp]

**Ans.** Valence electrons = electrons present in the outermost shell (e.g. 6 in oxygen). Valency = electrons gained/lost/shared to reach an octet (2 for oxygen).

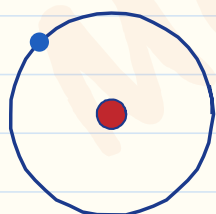
**Q5.** Why does carbon share electrons instead of losing/gaining? [Extra]

**Ans.** It has 4 valence electrons: too many to lose, too many to gain easily, so it shares four.

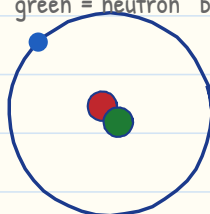
## 8.9 A Deeper Look: Isotopes

- ✦ Dalton said all atoms of an element are identical in mass, but atoms of the same element can have the **same Z, different number of neutrons** → different mass numbers.
- ✦ **Isotopes** = atoms of the same element with the **same atomic number but different mass numbers** ("twin atoms").
- ✦ Hydrogen occurs naturally as a mixture of 3 isotopes: protium ( ${}^1\text{H}$ , 0 n, ~99.98%), deuterium ( ${}^2\text{H}$ , 1 n, ~0.015%) and tritium ( ${}^3\text{H}$ , 2 n, traces). All have 1 proton and 1 electron.

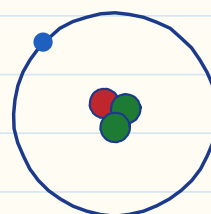
red = proton green = neutron blue = electron



Protium (H-1)



Deuterium (H-2)



Tritium (H-3)

Fig. 8.12: Isotopes of hydrogen

| Isotope   | Symbol | p | n | e | A  |
|-----------|--------|---|---|---|----|
| Protium   | H-1    | 1 | 0 | 1 | 1  |
| Deuterium | H-2    | 1 | 1 | 1 | 2  |
| Tritium   | H-3    | 1 | 2 | 1 | 3  |
| Carbon-12 | C-12   | 6 | 6 | 6 | 12 |
| Carbon-13 | C-13   | 6 | 7 | 6 | 13 |
| Carbon-14 | C-14   | 6 | 8 | 6 | 14 |

Isotopes of hydrogen and carbon (C-12 is the most abundant)

### Properties of isotopes ★

- ✦ **Chemical properties are the same:** same number of electrons and same electronic configuration (same valence electrons).
- ✦ **Physical properties differ:** mass, density, melting and boiling points.

### Bridging Science and Society: uses of isotopes

- ✦ **U-235:** fuel in nuclear reactors (electricity).
- ✦ **Co-60:** radiation treatment of cancer.
- ✦ **I-131:** treats goitre and thyroid cancer.
- ✦ **C-14:** age of ancient fossils and artefacts (carbon dating; Extra: half-life  $\approx$  5730 years).

### Ready to Go Beyond: atomic mass unit

- ✦ Atoms are too tiny to weigh in kg, so the **unified atomic mass unit (u)** is used (earlier amu). (Extra:  $1\text{ u} = 1/12$  of the mass of a C-12 atom  $\approx 1.66 \times 10^{-27}$  kg.)

#### ➤ A. Average atomic mass (Chlorine example, Most Important ★)

- ✦ Chlorine has two isotopes: Cl-35 (mass 35 u,  $\sim 75\%$ ) and Cl-37 (mass 37 u,  $\sim 25\%$ ), ratio 3 : 1.
- ✦ Simple average =  $(35 + 37) / 2 = 36\text{ u}$ : **wrong**, because it ignores abundance.
- ✦ **Weighted average** =  $35 \times 75/100 + 37 \times 25/100 = 26.25 + 9.25 = 35.5\text{ u}$ .
- ✦ No single atom weighs 35.5 u. In 1 million Cl atoms: 7.5 lakh are Cl-35 and 2.5 lakh are Cl-37.

### Formula

- ✦ Average atomic mass =  $\Sigma (\text{isotopic mass} \times \% \text{ abundance} / 100)$

#### ➤ B. Isobars

Atoms of **different elements** with the **same mass number but different atomic numbers**: Argon ( $Z = 18$ ), Potassium ( $Z = 19$ ), Calcium ( $Z = 20$ ): all  $A = 40$ . **Memory trick (Extra):** iso = same; topos = place (same place in periodic table = same  $Z$ ); baros = weight (same mass).

| Point             | Isotopes     | Isobars            |
|-------------------|--------------|--------------------|
| Atomic number (Z) | Same         | Different          |
| Mass number (A)   | Different    | Same               |
| Element           | Same element | Different elements |

| Point               | Isotopes         | Isobars            |
|---------------------|------------------|--------------------|
| Neutrons            | Different        | Usually different  |
| Chemical properties | Same             | Different          |
| Example             | C-12, C-13, C-14 | Ar-40, K-40, Ca-40 |

### Extra (Next Level Up): isotones and the modern model

- ✦ **Isotones** = atoms with the same number of neutrons (C-14 and N-15 both have 8 n).
- ✦ Today electrons are known to exist as **electron clouds**, not fixed orbits. STM and TEM microscopes can image atoms. The journey is far from over!

### Pause and Ponder: Chalo Calculate

**Q1.** Two atoms have 11 protons each; one has 12 neutrons and the other 13. Compare their atomic numbers and mass numbers. Same element? [Textbook ★ Most Imp]

**Ans.** Atomic number: same (11). Mass number: 23 and 24. **Same element** (sodium), they are isotopes.

**Q2.** Bromine: Br-79 (49.7%) and Br-81 (50.3%). Calculate average atomic mass. [Textbook ★ Most Imp]

**Ans.**  $= 79 \times 49.7/100 + 81 \times 50.3/100$   
 $\rightarrow = 39.263 + 40.743 = 80.006 \approx \mathbf{80.0\ u}$

**Q3.** Boron: B-10 (20%) and B-11 (80%). Average atomic mass? [Extra ★ Most Imp]

**Ans.**  $10 \times 0.20 + 11 \times 0.80 = 2 + 8.8 = \mathbf{10.8\ u}$ .

**Q4.** Copper: Cu-63 (69%), Cu-65 (31%). Average atomic mass? [Extra ★ Most Imp]

**Ans.**  $63 \times 0.69 + 65 \times 0.31 = 43.47 + 20.15 = \mathbf{63.62\ u}$ .

**Q5.** Why do isotopes have the same chemical properties but different physical properties? [Extra ★ Most Imp]

**Ans.** Same electrons and same electronic configuration (chemical behaviour depends on valence electrons) but different masses because of different neutrons.

**Q6.** Give one use each: U-235, Co-60, I-131, C-14. [Extra]

**Ans.** Nuclear fuel; cancer radiotherapy; goitre/thyroid cancer; dating fossils.

## 8.10 At a Glance + Who Discovered What

### At a Glance

- ✦ Atoms are the building blocks of matter. Thomson: electrons embedded in a positive sphere. Rutherford: mostly empty space, dense (+) nucleus, electrons orbit. Bohr: electrons in fixed energy levels (K, L, M, N...).
- ✦ Chadwick discovered neutrons. Three subatomic particles: **electrons, protons, neutrons**.
- ✦ Octet (2 for He) → stable, largely unreactive. **Valency** = electrons gained, lost or shared.
- ✦  $Z$  = protons;  $A$  = nucleons. **Isotopes**: same  $Z$ , different  $A$ . **Isobars**: different  $Z$ , same  $A$ . Average atomic mass uses relative abundance.

| Scientist                            | Year        | Contribution                                                        |
|--------------------------------------|-------------|---------------------------------------------------------------------|
| Acharya Kanada / Democritus          | Ancient     | Parmanu / atomos: indivisible particles (ideas)                     |
| John Dalton                          | 1803 / 1808 | First pictorial symbols; first scientific atomic theory             |
| Berzelius                            | 1813        | Alphabetic symbols from Latin names                                 |
| J. J. Thomson                        | 1897 / 1904 | Electron (cathode rays); plum pudding model; Nobel 1906             |
| Rutherford (with Geiger and Marsden) | 1911        | Gold foil; nucleus; planetary model; proton; Nobel (Chemistry) 1908 |
| Niels Bohr                           | 1913        | Energy levels / stationary states; Nobel 1922                       |
| Bohr and Bury                        | —           | Rules for distribution of electrons in shells                       |
| James Chadwick                       | 1932        | Neutron; Nobel 1935                                                 |
| Homi J. Bhabha                       | —           | Father of the Indian nuclear programme (TIFR, BARC)                 |

## 8.11 Revise, Reflect, Refine: Solved

### Textbook Exercise Solutions (Part 1)

**Q1.** Gold foil experiment: choose the correct options and give reasons. (i) showed neutrons in the nucleus (ii) disproved plum pudding and led to nucleus idea (iii) large deflection of few  $\alpha$  showed mass and positive charge packed in tiny centre (iv) deflection showed electrons move around nucleus. [Textbook ★ Most Imp]

**Ans.** Correct: (ii) and (iii).

- (i) Wrong: neutrons were discovered by Chadwick in 1932, after this experiment.
- (ii) Right: uniform positive sphere could not give large deflections.
- (iii) Right: bounce-back needs a small, heavy, positive centre.
- (iv) Wrong: scattering of  $\alpha$  shows the nucleus, not the motion of electrons.

**Q2.** Bohr's model: correct or incorrect? (i)–(iv) [Textbook ★ Most Imp]

**Ans.** Only (iii) is correct. (i), (ii) and (iv) are incorrect (see the Bohr Q&A above for reasons).

**Q3.** Nuclei X (18 p, 19 n), Y (17 p, 18 n), Z (17 p, 20 n). Relation between (i) Y and Z, (ii) Z and X? [Textbook ★ Most Imp]

**Ans.** A:  $X = 37$ ,  $Y = 35$ ,  $Z = 37$ .

- (i) Y and Z: same  $Z = 17$ , different  $A$  (35, 37) → **isotopes** (chlorine-35, chlorine-37).
- (ii) Z and X: same  $A = 37$ , different  $Z$  (17, 18) → **isobars**.

**Q4.** Conclusion of Rutherford from the few  $\alpha$  that bounced back or deflected at large angles? [Textbook ★ Most Imp]

**Ans.** Positive charge of the atom is concentrated in a very small, dense central region (nucleus) which contains most of the atom's mass; it repels the  $\alpha$ -particles strongly.

**Q5.** Arrange chronologically: Bohr, Thomson, Rutherford, Dalton. [Textbook ★ Most Imp]

**Ans.** Order: (iv) Dalton → (ii) Thomson → (iii) Rutherford → (i) Bohr.

- Indivisible atom → plum pudding → nucleus → fixed energy shells.

**Q6.** Why do electrons not fly away from the atom? [Textbook]

**Ans.** The negatively charged electrons are held by the **electrostatic force of attraction** of the positively charged nucleus.

**Q7.** Assertion: The discovery of subatomic particles helped in understanding atomic structure.

Reason: Number of electrons = number of protons. [Textbook ★ Most Imp]

**Ans.** Answer (ii). Both are true but R does not explain A (R explains neutrality, not why discovery helped).

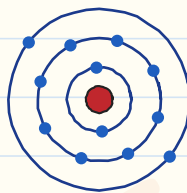
### Textbook Exercise Solutions (Part 2)

**Q8.** Magnesium:  $A = 24$ ,  $Z = 12$ . Find protons, neutrons, electrons; illustrate arrangement.

[Textbook ★ Most Imp]

**Ans.**  $p = 12$ ;  $n = 24 - 12 = 12$ ;  $e = 12$ . Configuration **2, 8, 2** ( $K = 2$ ,  $L = 8$ ,  $M = 2$ ).

12 p, 12 n



$K = 2$

$L = 8$

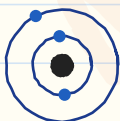
$M = 2$

Magnesium atom (2, 8, 2)

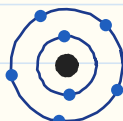
### Textbook Exercise Solutions (Part 3): Fig. 8.17

**Q9.** Fig. 8.17 atoms (a)–(d): find name, symbol, total electrons, valence electrons, valency, protons, atomic number. (Count the dots on each shell.) [Textbook ★ Most Imp]

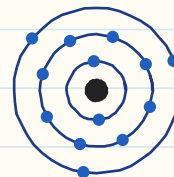
**Ans.** Using the figure: (a)  $2 + 1 = 3$  e; (b)  $2 + 5 = 7$  e; (c)  $2 + 8 + 3 = 13$  e; (d)  $2 + 7 = 9$  e. See table below.



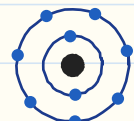
(a)



(b)



(c)



(d)

|                         | (a)         | (b)         | (c)           | (d)         |
|-------------------------|-------------|-------------|---------------|-------------|
| Element / Symbol        | Lithium, Li | Nitrogen, N | Aluminium, Al | Fluorine, F |
| Total electrons         | 3           | 7           | 13            | 9           |
| Configuration           | 2, 1        | 2, 5        | 2, 8, 3       | 2, 7        |
| Valence electrons       | 1           | 5           | 3             | 7           |
| Valency                 | 1           | 3           | 3             | 1           |
| Protons = atomic number | 3           | 7           | 13            | 9           |

## Textbook Exercise Solutions (Part 4)

**Q10.** Why did Rutherford's model fail to explain atomic stability while Bohr's succeeded? [Textbook

★ Most Imp]

**Ans.** Revolving electrons would lose energy and collapse (Rutherford); Bohr's stationary states have fixed energy so electrons do not lose energy.

**Q11.** An atom  $^{70}\text{X}$  has 31 electrons. Neutrons? [Textbook ★ Most Imp]

**Ans.**  $Z = 31$ ;  $n = 70 - 31 = 39$  (gallium).

**Q12.** Atom has 79 protons and mass number 197. Find (i) neutrons (ii) electrons. [Textbook ★ Most Imp]

**Ans.** (i)  $n = 197 - 79 = 118$ ; (ii)  $e = 79$  (gold).

**Q13.** Complete Table 8.5. [Textbook ★ Most Imp]

**Ans.** See the table below.

| Atomic no. | Mass no. | Neutrons | Protons | Electrons | Element    |
|------------|----------|----------|---------|-----------|------------|
| 5          | 11       | 6        | 5       | 5         | Boron      |
| 7          | 14       | 7        | 7       | 7         | Nitrogen   |
| 12         | 24       | 12       | 12      | 12        | Magnesium  |
| 15         | 31       | 16       | 15      | 15        | Phosphorus |
| 1          | 1        | 0        | 1       | 1         | Hydrogen   |

Table 8.5 (answers)

## Textbook Exercise Solutions (Part 5)

**Q14.** Element X: mass number 35, 18 neutrons. (i) electrons and protons (ii) atomic number (iii) identify (iv) configuration (v) valence electrons (vi) mass number if 2 neutrons added (vii) relation with new atom. [Textbook ★ Most Imp]

**Ans.** (i)  $p = 35 - 18 = 17$ ,  $e = 17$

➤ (ii)  $Z = 17$

➤ (iii) Chlorine (Cl)

➤ (iv) 2, 8, 7

➤ (v) 7

➤ (vi)  $A = 35 + 2 = 37$

➤ (vii) Same  $Z = 17$ , different  $A \rightarrow$  they are **isotopes** (Cl-35 and Cl-37).

**Q15.** Atom: 12 p and 12 n. Electrons replaced by hypothetical particles with the same charge but 500 times heavier. Effect on (i) atomic number (ii) atomic mass (iii) mass number (iv) overall charge? [Textbook ★ Most Imp]

**Ans.** (i) Atomic number: **unchanged** (12), it counts protons.

- (ii) Atomic mass: **increases**. 12 particles  $\times$  500  $\approx$  6000 electron masses  $\approx$   $6000/1836 \approx 3.3$  u extra (about 24 u  $\rightarrow$  27 u).
- (iii) Mass number: **unchanged** (24), it counts only nucleons.
- (iv) Overall charge: **unchanged** (still neutral), as the charge is the same as an electron's.

**8.12 Most Important Extra Practice****Section A: MCQs (Quick Check — Ho Jaye?)**

1. Who proposed the idea of 'parmanu'?

(a) Democritus (b) Acharya Kanada (c) Dalton (d) Thomson

2. The nucleus of ordinary hydrogen (protium) contains:

(a) 1 p + 1 n (b) 1 proton only (c) 1 neutron only (d) 1 p + 1 e

3. Cathode rays are streams of:

(a) protons (b) neutrons (c) electrons (d)  $\alpha$ -particles

4. Most  $\alpha$ -particles passed undeflected through gold foil because:

(a) nucleus is negative (b) most of the atom is empty space (c) gold has no electrons (d)  $\alpha$ -particles are neutral

5. The neutron was discovered by:

(a) Rutherford (b) Bohr (c) Chadwick (d) Thomson

6. Maximum electrons in the M shell:

(a) 8 (b) 2 (c) 32 (d) 18

7. Valency of an element with configuration 2, 8, 6:

(a) 6 (b) 2 (c) 8 (d) 4

8. An atom with  $Z = 17$  and  $A = 37$  has how many neutrons?

(a) 17 (b) 18 (c) 20 (d) 37

9. Isotopes have the same:

(a) mass number (b) atomic number (c) neutrons (d) physical properties

10. Which pair are isobars?

(a) Cl-35, Cl-37 (b) Ar-40, Ca-40 (c) C-12, C-14 (d) H-1, H-2

11. Which is NOT true for Bohr's model?

(a) fixed orbits (b) no energy loss in an orbit (c) electrons can stay between orbits (d) energy increases outwards

12. Symbol of potassium:

(a) P (b) Po (c) K (d) Pt

13. Average atomic mass of chlorine is 35.5 u because:

(a) one isotope weighs 35.5 u (b) it is the weighted average of Cl-35 and Cl-37 (c) it is a simple average (d) neutrons weigh 0.5 u

14. An element with configuration 2, 8, 8 is:

(a) very reactive metal (b) very reactive non-metal (c) chemically inert (d) a radioactive element

15. Nobel Prize 1922 for the structure of the atom:

(a) Rutherford (b) Bohr (c) Thomson (d) Chadwick

Answer key: 1-b 2-b 3-c 4-b 5-c 6-d 7-b 8-c 9-b 10-b 11-c 12-c 13-b 14-c 15-b

### Section B: Assertion-Reason (options: (i) both true, R explains A; (ii) both true, R does not explain A; (iii) A true, R false; (iv) A false, R true)

Q1. A: Atoms are electrically neutral. R: Number of protons equals number of electrons. [Extra ★ Most Imp]

Ans. Answer (i): both true, R explains A.

Q2. A: Most  $\alpha$ -particles went straight through the gold foil. R: The atom is mostly empty space. [Extra ★ Most Imp]

Ans. Answer (i).

Q3. A: Isotopes have similar chemical properties. R: Isotopes have the same number of neutrons. [Extra ★ Most Imp]

Ans. Answer (iii): A true, R false (they have the same number of electrons, not neutrons).

Q4. A: Neon is chemically inert. R: Neon has a complete octet in its outermost shell. [Extra ★ Most Imp]

Ans. Answer (i).

Q5. A: Rutherford's model could not explain atomic stability. R: An electron revolving in a circle would continuously radiate energy. [Extra ★ Most Imp]

Ans. Answer (i).

### Section C: Short and Long Answer (Yeh Zaroor Aayega!)

Q1. Describe Rutherford's gold foil experiment: setup, observations and conclusions. Draw a labelled diagram. [Extra ★ Most Imp]

Ans. Setup: narrow beam of  $\alpha$ -particles on very thin gold foil (screen to detect).

- Observations: most passed straight; some deflected; very few bounced back.
- Conclusions: atom mostly empty; positive charge and mass in tiny dense nucleus; electrons revolve outside.

Q2. Distinguish between isotopes and isobars with examples. [Extra ★ Most Imp]

Ans. See the comparison table in 8.9 (same Z, different A: C-12/C-14; same A, different Z: Ar-40/Ca-40).

**Q3.** Compare Thomson's and Rutherford's models. [Extra ★ Most Imp]

**Ans.** Thomson: positive charge spread, electrons embedded, no nucleus. Rutherford: tiny dense nucleus with all (+) charge and most mass, electrons orbit, mostly empty space.

**Q4.** Give reasons: (a) atom is electrically neutral, (b) isotopes show the same chemical properties, (c) noble gases are unreactive. [Extra ★ Most Imp]

**Ans.** (a)  $p = e$  so charges cancel.

- (b) Same electronic configuration (same valence electrons).
- (c) Outer shell is already a complete octet (duplet for He), so valency is zero.

**Q5.** Why are protons not seen to repel each other and break the nucleus? [Extra]

**Ans.** Neutrons separate protons and the strong nuclear force binds all nucleons.

### Section D: Numericals (Thoda Practice Ho Jaye)

**Q1.** Atom has configuration 2, 8, 3 and mass number 27. Find protons, neutrons, name and valency. [Extra ★ Most Imp]

**Ans.**  $e = 13 = p$ ;  $n = 27 - 13 = 14$ ; Aluminium; valency 3.

**Q2.** Element with  $Z = 16$  and  $A = 32$ :  $n$ , configuration, valency? [Extra ★ Most Imp]

**Ans.**  $n = 16$ ; 2, 8, 6; valency 2 (sulfur).

**Q3.** An atom has  $A = 14$  and 8 neutrons. Identify it. [Extra ★ Most Imp]

**Ans.**  $p = 14 - 8 = 6 \rightarrow Z = 6 \rightarrow$  Carbon-14.

**Q4.** Neon: Ne-20 (90%) and Ne-22 (10%): average atomic mass? [Extra ★ Most Imp]

**Ans.**  $20 \times 0.9 + 22 \times 0.1 = 18 + 2.2 = 20.2 \text{ u}$ .

**Q5.** In 2000 chlorine atoms (75% Cl-35, 25% Cl-37), how many of each? [Extra ★ Most Imp]

**Ans.** Cl-35: 1500; Cl-37: 500.

**Q6.** Ar-40, K-40, Ca-40: number of neutrons in each? [Extra ★ Most Imp]

**Ans.** Ar:  $40 - 18 = 22$ ; K:  $40 - 19 = 21$ ; Ca:  $40 - 20 = 20$ .

### Section E: HOTS / Case-based

**Q1.** Table: A ( $Z = 11$ ,  $A = 23$ ), B ( $Z = 12$ ,  $A = 24$ ), C ( $Z = 17$ ,  $A = 35$ ), D ( $Z = 18$ ,  $A = 40$ ). Find (i) neutrons, (ii) names, (iii) valency, (iv) the inert element. [Extra ★ Most Imp]

**Ans.** (i) A: 12, B: 12, C: 18, D: 22.

- (ii) Sodium, Magnesium, Chlorine, Argon.
- (iii) 1, 2, 1, 0.
- (iv) **D (Argon)**: configuration 2, 8, 8.

**Q2.** Why did Rutherford use gold and not a light metal? [Extra ★ Most Imp]

**Ans.** Gold is malleable (very thin foil possible) and its nucleus is heavy and highly charged, so scattering is easily seen.

**Q3.** Why is most of the atom's mass in the nucleus although electrons occupy most of its volume? [Extra]

**Ans.** Protons and neutrons are each ~1836 times heavier than an electron, and they sit in the tiny nucleus.

### The Quest Continues...

- ♦ Is it possible to completely understand everything that happens inside an atom? Scientists keep discovering. Keep asking questions, keep experimenting!
- ♦ Explore: [phet.colorado.edu](http://phet.colorado.edu) simulations "Rutherford Scattering" and "Isotopes and Atomic Mass".