Atomic Models and Structure

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The Development of Atomic Models

Thomson's Model (1897), the "Plum Pudding"

J.J. Thomson discovered the electron. He proposed that an atom was a sphere of uniformly distributed positive charge with electrons embedded throughout it, like raisins in a pudding. This model predicted that alpha particles fired at atoms would pass through or be deflected by only small amounts.

The Geiger-Marsden Experiment (1909)

Rutherford directed Geiger and Marsden to fire alpha particles at a thin gold foil and detect where they landed:

- **Expected (if Thomson correct):** almost all particles pass straight through; minor small-angle scattering.
- **Observed:** most particles did pass straight through; but some were deflected through large angles, and a few bounced almost directly back.

Rutherford famously said it was "as if you fired a 15-inch shell at tissue paper and it came back and hit you."

Conclusion: most of the atom is empty space; positive charge and most of the mass are concentrated in a tiny, dense **nucleus**. Electrons orbit the nucleus in the surrounding empty space.

Rutherford's Nuclear Model (1911)

Rutherford proposed the atom as a miniature solar system: a tiny, dense, positively charged nucleus at the centre, with electrons orbiting it like planets around the Sun. The nucleus diameter is about

10^{-4} times the atom diameter.

Bohr's Model (1913)

Niels Bohr modified Rutherford's model by proposing that electrons occupy specific energy levels called **shells** or orbits. Electrons in a shell have a fixed energy and do not radiate energy as long as they remain in that shell. When an electron jumps to a lower shell, it emits energy as light of a specific frequency.

Chadwick's Discovery of the Neutron (1932)

James Chadwick confirmed the existence of the **neutron**, an uncharged particle with nearly the same mass as a proton, inside the nucleus. This explained why nuclear masses were always greater than the number of protons alone would predict.

Structure of the Atom

Particle	Charge	Relative mass	Location
Proton	+1	1	Nucleus
Neutron	0	1	Nucleus
Electron	−1	1/1836 (negligible)	Shells surrounding nucleus

The atom is electrically neutral: number of protons = number of electrons.

Nuclide Notation

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

where:

- X is the chemical symbol of the element.
- Z is the **atomic number** (proton number), number of protons.
- A is the **mass number** (nucleon number), total number of protons + neutrons.

Number of neutrons: $N = A - Z$.

Example: $^{40}_{20}\mathrm{Ca}$ has 20 protons, 20 neutrons, and (as a neutral atom) 20 electrons.

Nuclide structure (2024 Paper 02, Q6 and 2019 Paper 02, Q6)

Lithium-7($^{7}_{3}\mathrm{Li}$ **):**

- Protons: $Z = 3$
- Neutrons: $A - Z = 7 - 3 = 4$
- Electrons (neutral atom): 3

Radium-226($^{226}_{88}\mathrm{Ra}$ **):**

- Protons: 88
- Neutrons: $226 - 88 = 138$

Isotopes

Isotopesare atoms of the same element (same Z
) with different numbers of neutrons (different A
). Isotopes have identical chemical properties but different nuclear properties.

Examples:

- Hydrogen: $^{1}1\mathrm{H}$, $^{2}1\mathrm{H}$ (deuterium), $^{3}_{1}\mathrm{H}$ (tritium).
- Carbon: $^{12}6\mathrm{C}$ (stable), $^{14}6\mathrm{C}$ (radioactive, used in dating).
- Uranium: $^{235}92\mathrm{U}$ (fissile) and $^{238}92\mathrm{U}$.

The Electron Shell Model

Electrons are arranged in shells around the nucleus. Each shell can hold a maximum number of electrons:

Shell	Maximum electrons	Energy level
First (K)	2	Lowest
Second (L)	8	Second
Third (M)	18	Third

The first two shells give electronic configurations for elements up to calcium. For example, sodium (Na,
$Z = 11$): 2, 8, 1, the outermost electron is responsible for sodium's chemistry.

Electron shell diagram of sodium (Na, Z = 11) showing 2 electrons in the first shell, 8 in the second shell, and 1 in the third shell, with the configuration 2,8,1 labelled

📝 **Exam Tip**

For any nuclide question: protons = Z (bottom number), neutrons = A − Z, electrons = Z (for a neutral atom). Mass number (A) is always the top number.

Isotopes have the same Z (same element) but different A (different neutron count). They behave identically chemically.