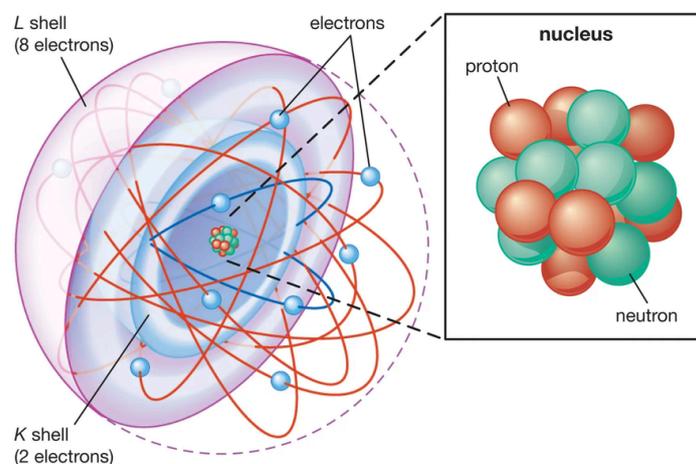


Atomic Physics & Nuclear Science

Core Concepts



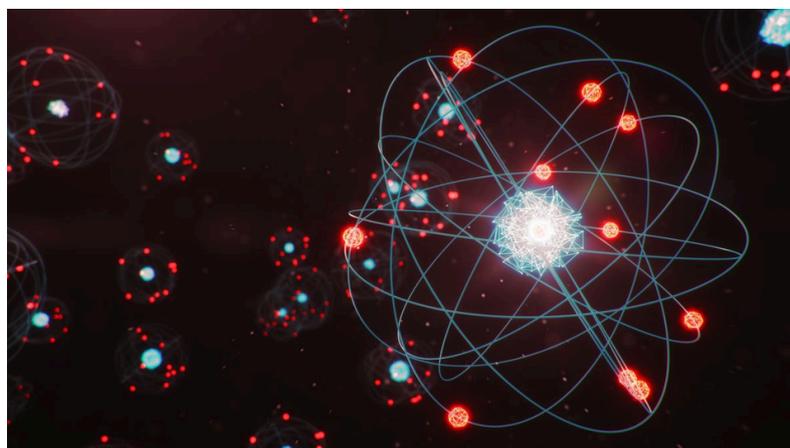
Big Idea: Matter is made of tiny particles, and the nucleus at its centre holds enormous energy. By studying atomic physics, we understand radiation, nuclear processes, and the fundamental building blocks of the universe.



Real-Life Connection: From medical imaging and cancer treatment to smoke detectors, nuclear power plants, and space exploration—atomic physics shapes modern technology and global challenges.

Key Concepts:

- Atoms are mostly empty space, with a dense nucleus.
- Radiation changes nuclei and can be both useful and dangerous.
- Fundamental particles and forces build all matter.



IB Key Concept: Nuclear change affects energy, matter, and even the universe's evolution.

Core Physics Summary

⚙️ 1. Atomic Structure & Subatomic Particles

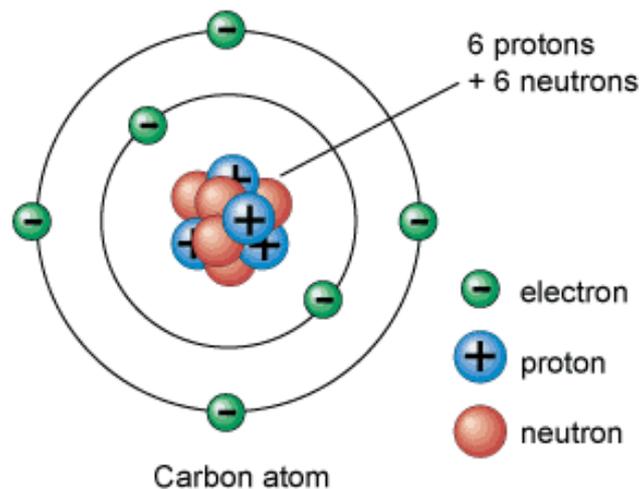
Atoms consist of:

- Protons: +1 charge, mass 1 u
- Neutrons: 0 charge, mass 1 u
- Electrons: -1 charge, very small mass

Key definitions:

- Atomic number (Z): number of protons
- Mass number (A): protons + neutrons
- Isotopes: same element, different neutrons

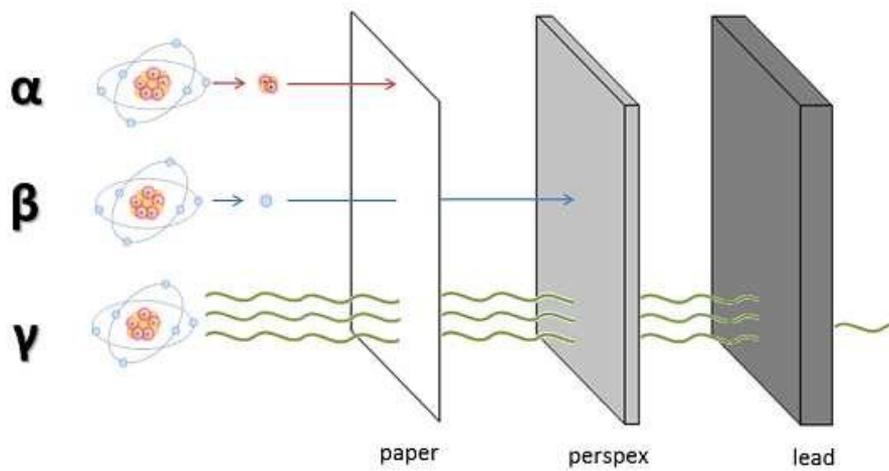
Electrons orbit the nucleus in energy levels.



⚙️ 2. Nuclear Radiation: Alpha, Beta, Gamma

Types of radiation:

- **Alpha (α):** 2 protons + 2 neutrons
 - Highly ionising
 - Low penetration (stopped by paper)
- **Beta (β):** Electron emitted when neutron \rightarrow proton
 - Medium ionising
 - Penetrates aluminium
- **Gamma (γ):** High-energy electromagnetic wave
 - Weak ionising
 - Strong penetration (lead needed)



⚙️ 3. Detection of Radiation

Methods for detecting radiation:

- **GM (Geiger-Müller) Tube:**
 - Detects ionising radiation as clicks
 - Used for measuring count rates
- **Cloud Chamber:**
 - Tracks charged particles as vapour trails
- **Photographic Film:**
 - Darkens when exposed to radiation
 - Used in medical dosimeters.

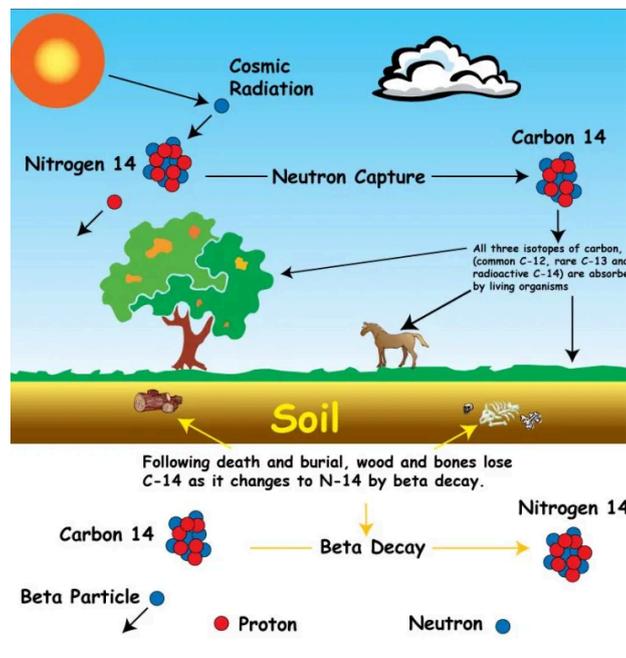


⚙️ 4. Half-Life & Radioactive Decay

- Radioactive decay is random and spontaneous.
- Half-life: time for half the nuclei to decay
- Graph: exponential decrease
- Formula for remaining activity: $A = A_0 \left(\frac{1}{2}\right)^n$, where n = number of half-lives elapsed.

Applications:

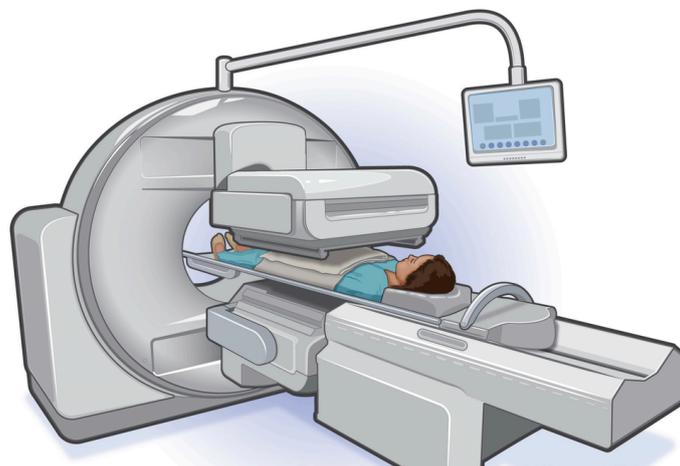
Used in dating fossils, medical tracers, nuclear waste management.



⚙️ 5. Uses of Radioactivity

Various applications of radioactivity:

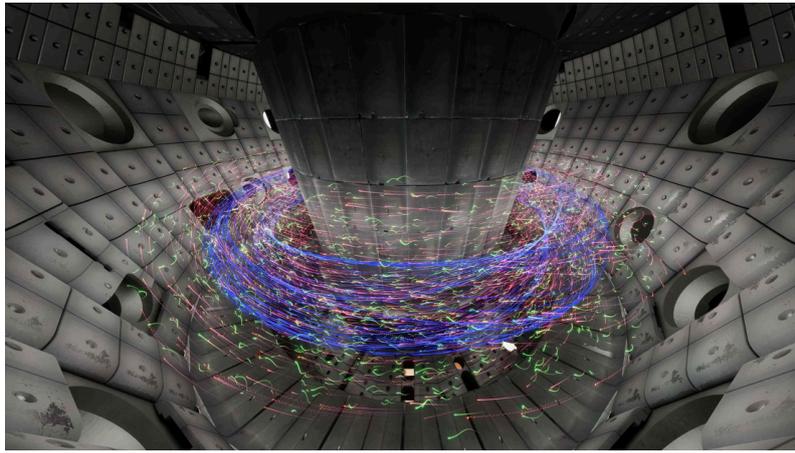
- **Tracers:** Radioactive isotopes track flow in medicine and industry.
- **Radiotherapy:** Gamma rays kill cancer cells. Highly targeted → reduced damage to healthy tissue
- **Thickness Monitoring:** Beta radiation checks thickness in paper/foil manufacturing
- **Smoke Detectors:** Americium-241 emits alpha particles.



⚙️ 6. Nuclear Reactions: Fission & Fusion

- **Fission:** Heavy nuclei (e.g., uranium-235) split into smaller nuclei.
 - Releases large energy and neutrons.
 - Used in nuclear reactors and weapons.
 - Chain reactions controlled using moderators and control rods.
- **Fusion:** Light nuclei (hydrogen isotopes) fuse to form helium.
 - Occurs in stars.
 - Releases more energy than fission.
 - Requires extremely high temperatures and pressures.

- Future goal for clean energy (tokamaks, stellarators).

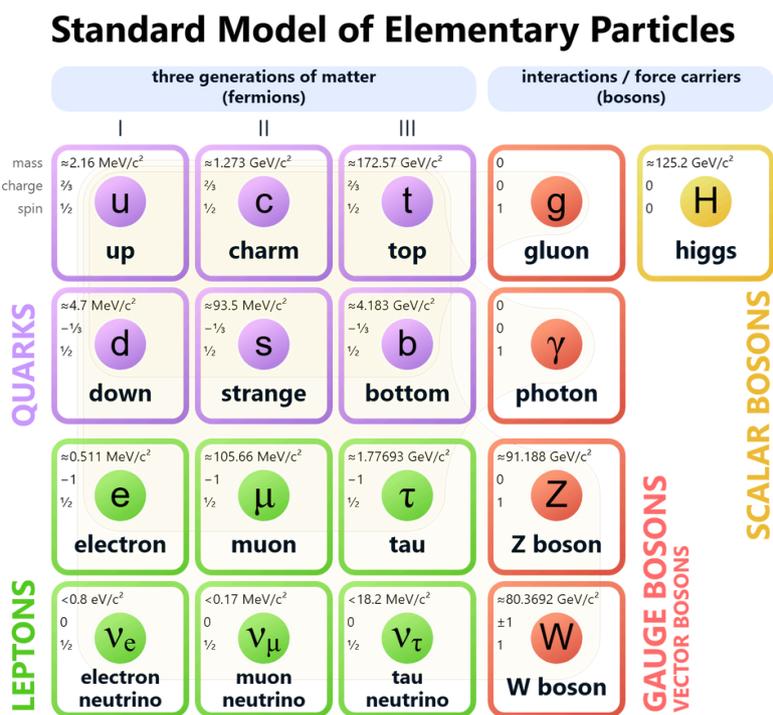


⚙️ 7. The Standard Model

Framework describing fundamental particles:

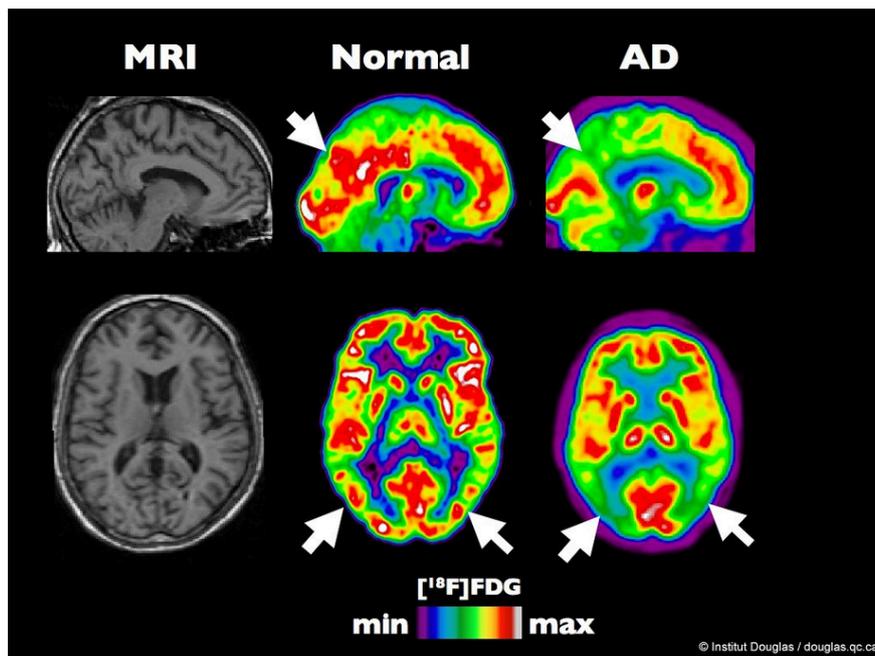
- **Quarks:** Up, down, strange, charm, top, bottom. Combine to form hadrons. Proton = uud. Neutron = udd.
- **Leptons:** Electron, muon, tau + their neutrinos.
- **Exchange Particles (Force Carriers):**
 - Photon → electromagnetic force.
 - Gluon → strong nuclear force.
 - W^+ / W^- / Z → weak nuclear force.
 - Graviton (hypothetical) → gravity.

This model explains most observed particle interactions.



🌱 **Everyday Example:** When a doctor uses a radioactive tracer to monitor organ function, a small amount of gamma-emitting isotope travels through the body. Detectors track the radiation, forming

images, an application of radioactive decay, detection, and medical physics combined.



Think & Reflect:

- Why is gamma radiation both useful for treatment and potentially dangerous?
- If fusion creates more energy than fission, why is it still not the world's main energy source?

Summary: Atomic physics reveals the hidden structure of matter and the powerful processes inside nuclei. Radiation, nuclear reactions, and fundamental particles help explain technologies from medical imaging to nuclear reactors and give insight into the forces shaping the universe. Understanding these ideas prepares students for deeper scientific inquiry and global decision-making.

Next Step: To explore nuclear equations, decay calculations, and exam-style particle physics problems, check LumiKnow Premium Physics Notes.