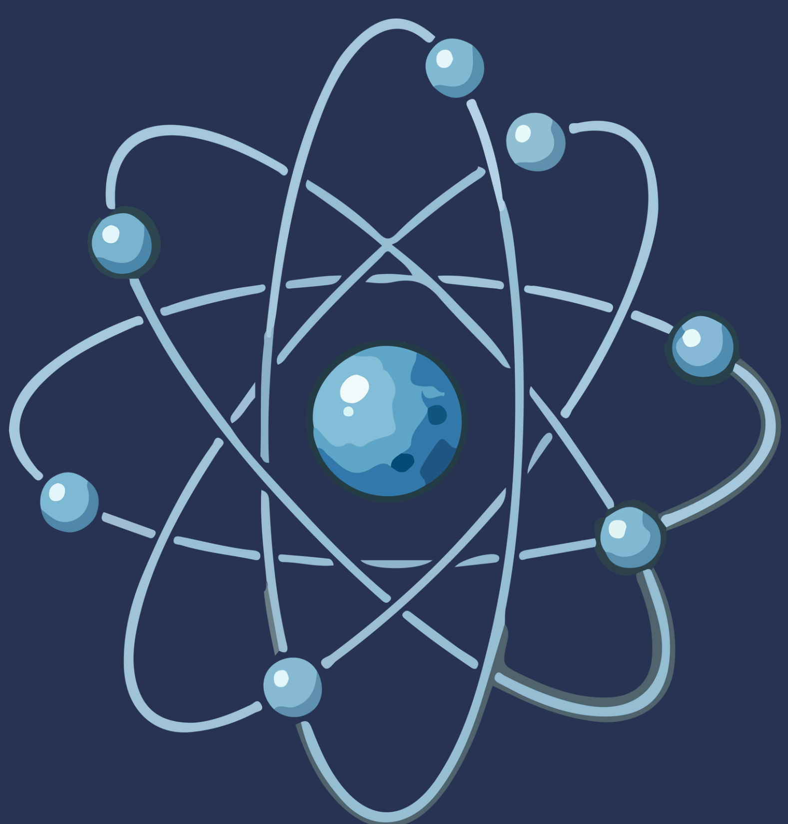
Educate Cloud

GCSE PHYSICS

ATOMIC STRUCTURE



CHECKLIST

4.4 Atomic Structure

4.4.1 Atoms and Isotopes				
Topic	**Success Criteria**	**Progress**		
The Structure of an Atom	I can state the radius of an atom.			
	I can describe how the radius of a nucleus compares to the radius of an atom.			
	I can describe the basic structure of an atom.			
	I can state the charge of the nucleus of an atom.			
	I can state the charge of an electron.			
	I can describe how electrons are arranged in atoms.			
	I can describe how electron arrangements may change with the absorption of electromagnetic radiation.			
	I can describe how electron arrangements may change with the emission of electromagnetic radiation.			
Mass Number, Atomic Number and Isotopes	I can describe how the number of electrons in an atom relates to the number of protons in the nucleus.			
	I can explain why atoms have no overall electrical charge.			
	I can describe how the number of protons in an atom of an element relates to its atomic number.			
	I can describe how the number of protons and neutrons in an atom relates to its mass number.			
	I can give a definition for the term 'isotope'.			
	I can explain how atoms turn into positive ions.			
	I can identify the difference between isotopes given appropriate information.			
The Development of the Model of the Atom	I can describe what atoms were thought to be like before the discovery of the electron.			
	I can describe the difference between the plum pudding model of the atom and the nuclear model of the atom.			
	I can describe how the results from the alpha particle scattering experiment led to the nuclear model.			
	I can describe how Niels Bohr adapted the nuclear model.			
	I can describe how developments in scientific methods led to the discovery of protons and neutrons.			
	I can describe how the experimental work of James Chadwick led to the development of the nuclear model.			

CHECKLIST

4.4.2 Atoms and Nuclear Radiation				
Topic	**Success Criteria**	**Progress**		
Radioactive Decay and Nuclear Radiation	I can describe what is meant by radioactive decay.			
	I can describe what is meant by the activity of an unstable nuclei.			
	I can describe what is meant by the count-rate of an unstable nuclei.			
	I can describe four types of nuclear radiation.			
	I can describe the penetration of alpha, beta and gamma radiation through materials.			
	I can describe the range of alpha, beta and gamma radiation in air.			
	I can describe the ionising power of alpha, beta and gamma radiation.			
	I can evaluate the best sources of radiation to use in a given situation.			
Nuclear Equations	I can represent alpha radiation in a nuclear equation.			
	I can represent beta radiation in a nuclear equation.			
	I can describe how alpha decay affects the mass and charge of the nucleus.			
	I can describe how beta decay affects the mass and charge of the nucleus.			
	I can describe how gamma decay affects the mass and charge of the nucleus.			
	I can balance the atomic numbers and mass numbers in nuclear equations to show single alpha and beta decay.			
Half-Lives and the Random Nature of Radioactive Decay	I know that radioactive decay is random.			
	I can give a definition for half-life in terms of number of nuclei or the count-rate.			
	I can explain the concept of half-life and how it is related to the random nature of radioactive decay.			
	I can determine the half-life of a radioactive isotope from given information.			
	(HT only) I can calculate the net decline, expressed as a ratio, in a radioactive emission after a given number of half-lives.			

CHECKLIST

Topic	Success Criteria	Progress		
Radioactive Contamination	I can describe what is meant by radioactive contamination.			
	I can explain what is meant by irradiation.			
	I can compare the hazards associated with contamination and irradiation.			
	I can suggest how to manage the use of radioactive sources during irradiation to protect against hazards.			
	I can explain why the findings of studies into the effects of radiation on humans should be published and shared with other scientists.			

4.4.3 Hazards and Uses of Radioactive Emissions and of Background Radiation

Topic	Success Criteria	Progress		
Background Radiation	I can state some natural sources of background radiation.			
	I can state some man-made sources of background radiation.			
	I can state some factors that affect the level of background radiation and radiation dose.			
Different Half-Lives of Radioactive Isotopes	I know that radioactive isotopes have a very wide range of half-life values.			
	I can explain why the hazards associated with radioactive material differ according to the half-life involved.			
	I can use data presented in standard form.			
Uses of Nuclear Radiation	I can state some uses of nuclear radiations in medicine.			
	I can describe and evaluate these uses of nuclear radiations.			
	I can evaluate the perceived risks of using nuclear radiations in relation to given data and consequences.			

CHECKLIST

4.4.4 Nuclear Fission and Fusion				
Topic	**Success Criteria**	**Progress**		
Nuclear Fission	I can give a definition for nuclear fission.			
	I can describe what must happen for fission to occur.			
	I can describe what happens in a fission reaction.			
	I can explain what happens in a chain reaction.			
	I can explain how a chain reaction is controlled.			
	I can draw and interpret diagrams representing nuclear fission and chain reactions.			
Nuclear Fusion	I can give a definition for nuclear fusion.			
	I can describe what happens in a fusion reaction.			

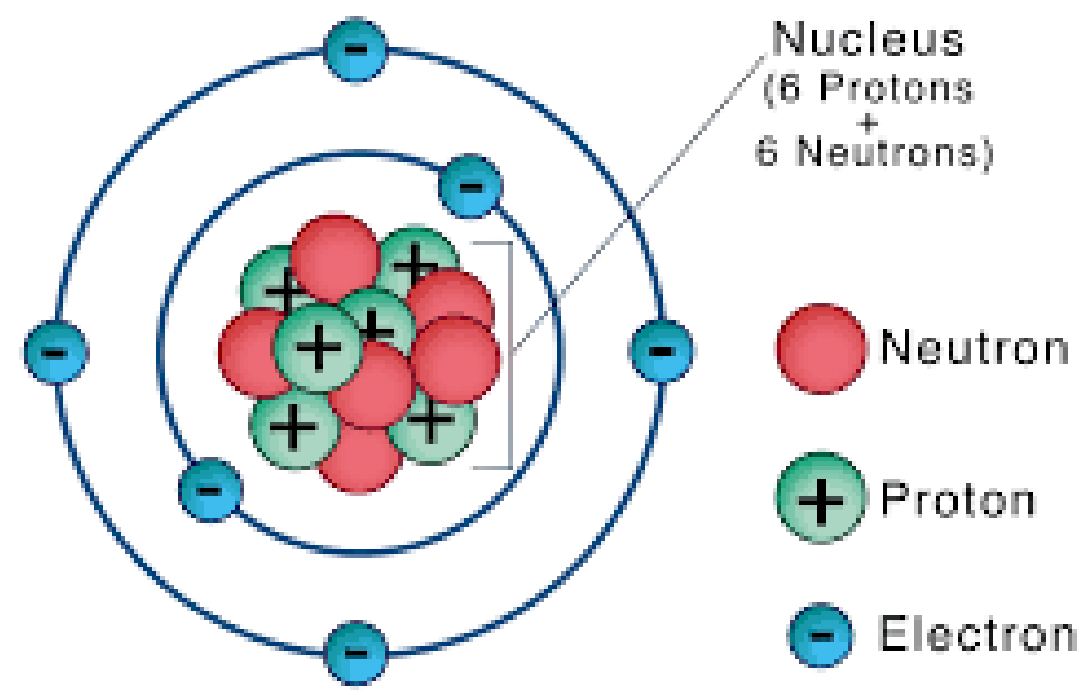
ATOMIC STRUCTURE

Atomic structure is the arrangement of particles inside an atom. An atom has a central nucleus containing protons and neutrons and electrons moving around the nucleus in regions called energy levels (shells).
The nucleus is extremely small compared with the size of the atom, so most of the atom is empty space.

Atom = Nucleus (protons + neutrons) + Electrons

Example:

- A carbon atom contains 6 protons and 6 neutrons in its nucleus, with 6 electrons around it.



Carbon Atom

SUB-ATOMIC PARTICLES

Subatomic particles are the smaller particles that make up an atom. The three key subatomic particles are:

- **Protons (p^+):** positively charged particles found in the nucleus
- **Neutrons (n^0)**: neutral particles found in the nucleus
- **Electrons (e^-):** negatively charged particles that move around the nucleus in energy levels (shells)

Key idea:

- The nucleus contains protons + neutrons and holds almost all the mass of the atom.
- Electrons have very small mass but are essential for charge, electricity, and chemical behaviour.

ATOMIC NUMBER (Z)

The atomic number is the number of protons in the nucleus. It identifies the element because changing the number of protons changes the element.

Formula(s):

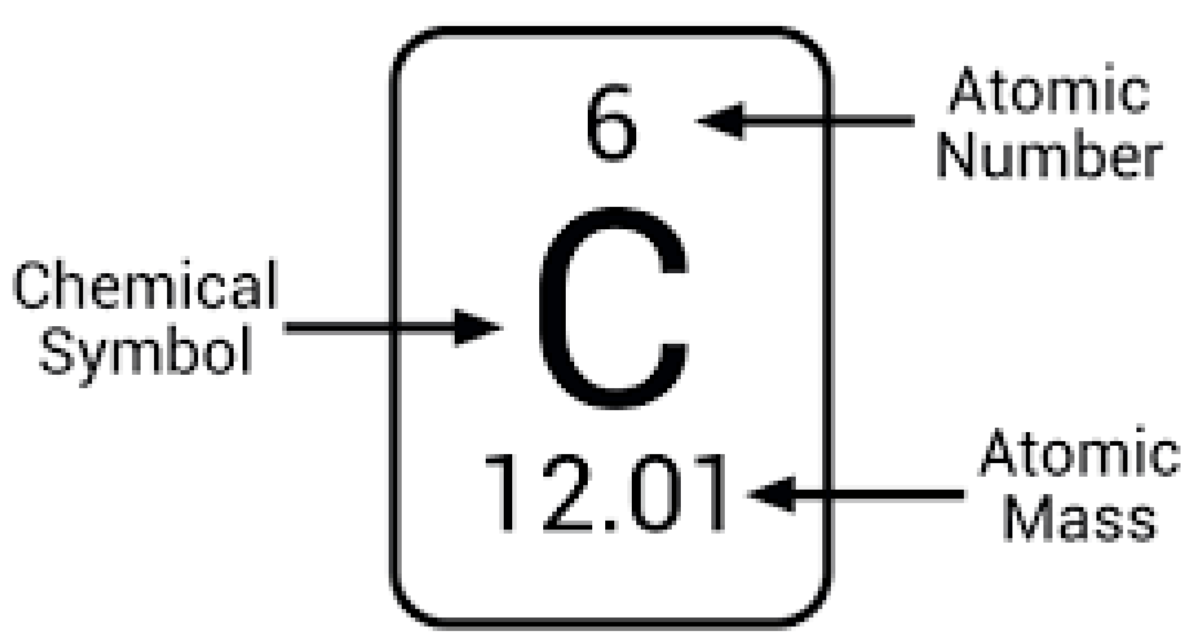
- Z = number of protons
- In a neutral atom: number of electrons = Z

Examples:

- Oxygen has Z = 8 → 8 protons → it is oxygen.
- Sodium has Z = 11 → 11 protons → it must be sodium.

Uses / Significance:

- Used to identify elements in the periodic table.
- Used in nuclear equations: atomic number must balance on both sides.
- Helps determine electron arrangements (since electrons = protons in neutral atoms).



MASS NUMBER (A)

The mass number is the total number of nucleons (particles in the nucleus): protons + neutrons. It shows how heavy the nucleus is (approximately).

Formula(s):

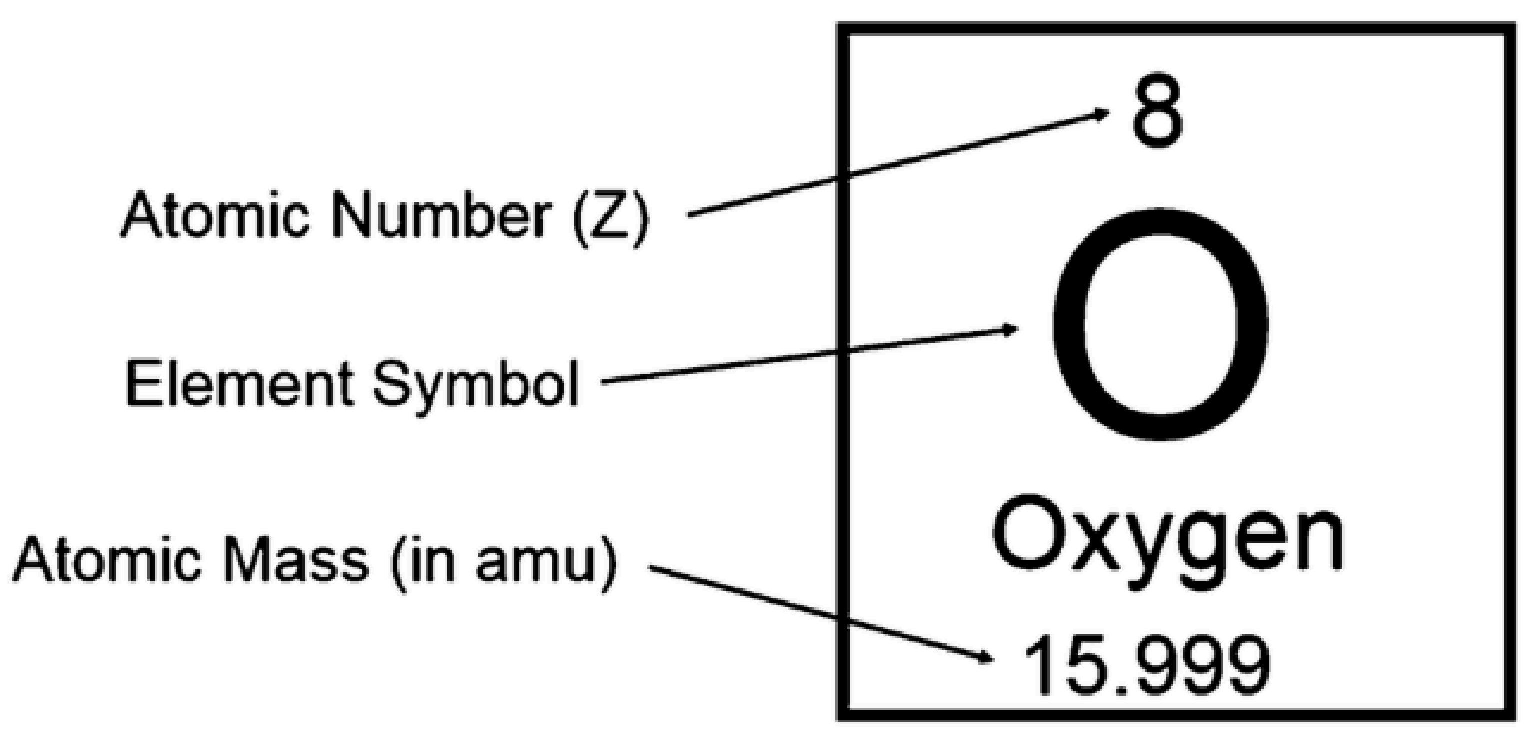
- A = protons + neutrons
- neutrons = A − Z

Examples to find the number of neutrons -

- Sodium-23: A = 23, Z = 11 → neutrons = 23 − 11 = 12
- Carbon-14: A = 14, Z = 6 → neutrons = 8

Usage of the mass number-

- Used to identify isotopes (same Z, different A).
- Needed in nuclear decay and reaction equations: mass number must balance.
- Helps explain nuclear stability (some combinations of neutrons/protons are unstable).



ISOTOPES

Isotopes are atoms of the same element with the same number of protons but different numbers of neutrons. That means isotopes have the same atomic number but different mass numbers.

Formula(s):

- Isotopes: same Z, different A
- neutrons = A − Z

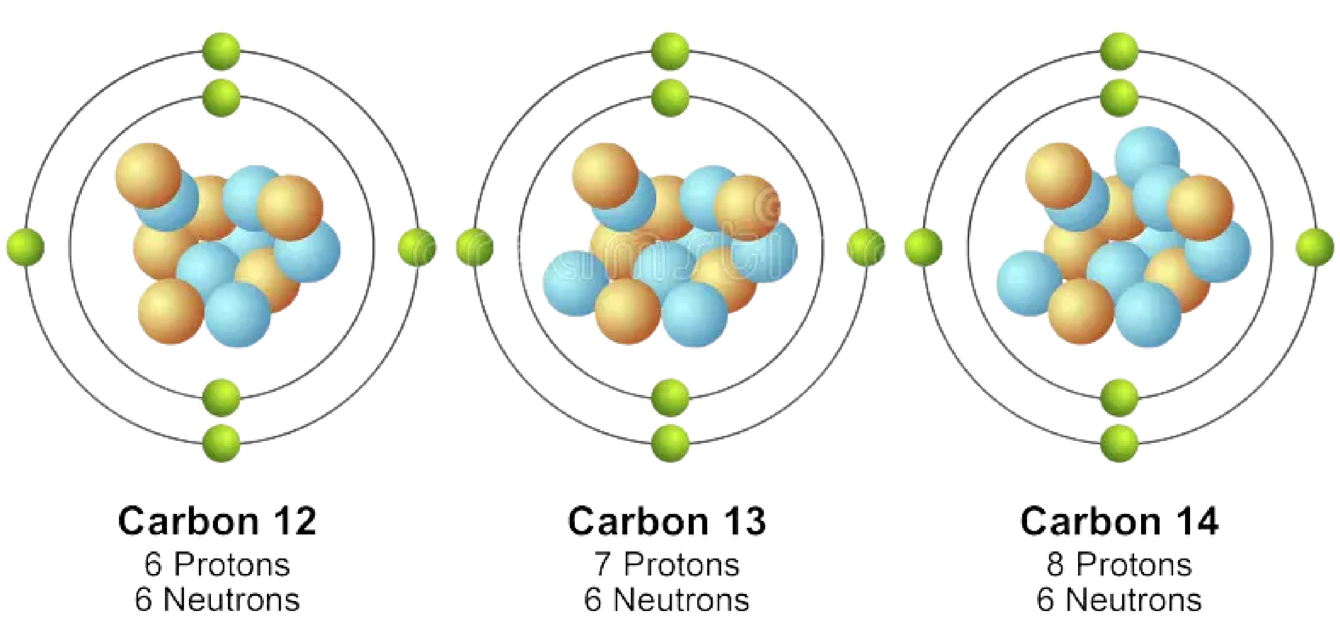
Examples:

- Carbon-12: 6p, 6n
- Carbon-14: 6p, 8n (unstable, radioactive)
- Chlorine-35 and Chlorine-37 are both chlorine, but have different neutrons.

Uses / Significance:

- Carbon-14 dating (estimating age of organic remains).
- Medical tracers (short half-life isotopes used for imaging).
- Understanding nuclear stability and radioactive decay (some isotopes are unstable).

ISOTOPES OF CARBON



ELECTRON ENERGY LEVELS (SHELLS)

Electrons exist in fixed energy levels called shells. Electrons cannot have any value of energy; they can only exist in certain allowed energy levels. Electrons in outer shells have higher energy and are less strongly attracted to the nucleus.

- 1st shell holds max 2 electrons
- 2nd shell holds max 8 electrons
- 3rd shell holds max 8 electrons
- (For GCSE, this simplified model is used.)

Examples:

- Sodium (Z = 11): electron arrangement = 2,8,1
- Magnesium (Z = 12): electron arrangement = 2,8,2
- Neon (Z = 10): electron arrangement = 2,8 (full outer shell → stable)

You must be able to explain

- Explain ion formation: atoms gain/lose electrons to get a full outer shell.
- Explain why some elements are reactive (one outer electron like sodium).
- Connect to Bohr model and to emission/absorption of light (electron transitions).

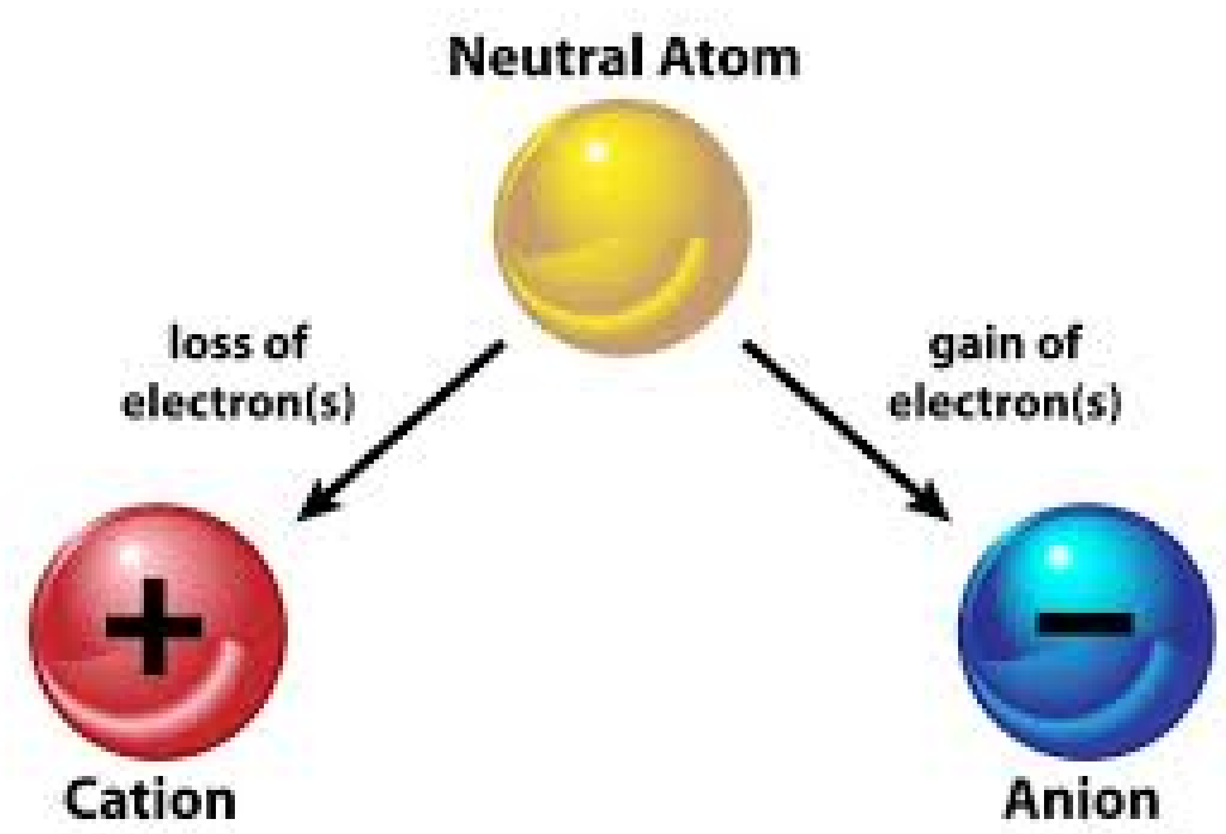
IONS

An ion is a charged atom (or group of atoms) formed when electrons are lost or gained. Protons do not change in ion formation; only the number of electrons changes.

- Charge = protons − electrons
- If electrons lost → positive ion called cation
- If electrons gained → negative ion called anion

Examples:

- Sodium loses 1 electron and becomes Na^{+}
- Magnesium forms Mg^{2+} by losing 2 electrons.



PLUM PUDDING MODEL

The Plum Pudding Model was an early scientific model of the atom proposed after the discovery of the electron by J. J. Thomson. It suggested that an atom is made of a uniform sphere of positive charge, with negative electrons embedded throughout this positive region.

The key idea was that:

- The positive charge is spread out evenly (not concentrated in one spot).
- The electrons are small particles “stuck inside” the positive charge.
- Overall, the atom is neutral because the total positive charge equals the total negative charge of the electrons.

In this model, the atom does not have a nucleus. Instead, it is like a “ball” of positive matter with electrons scattered inside it, similar to raisins or plums inside a pudding.

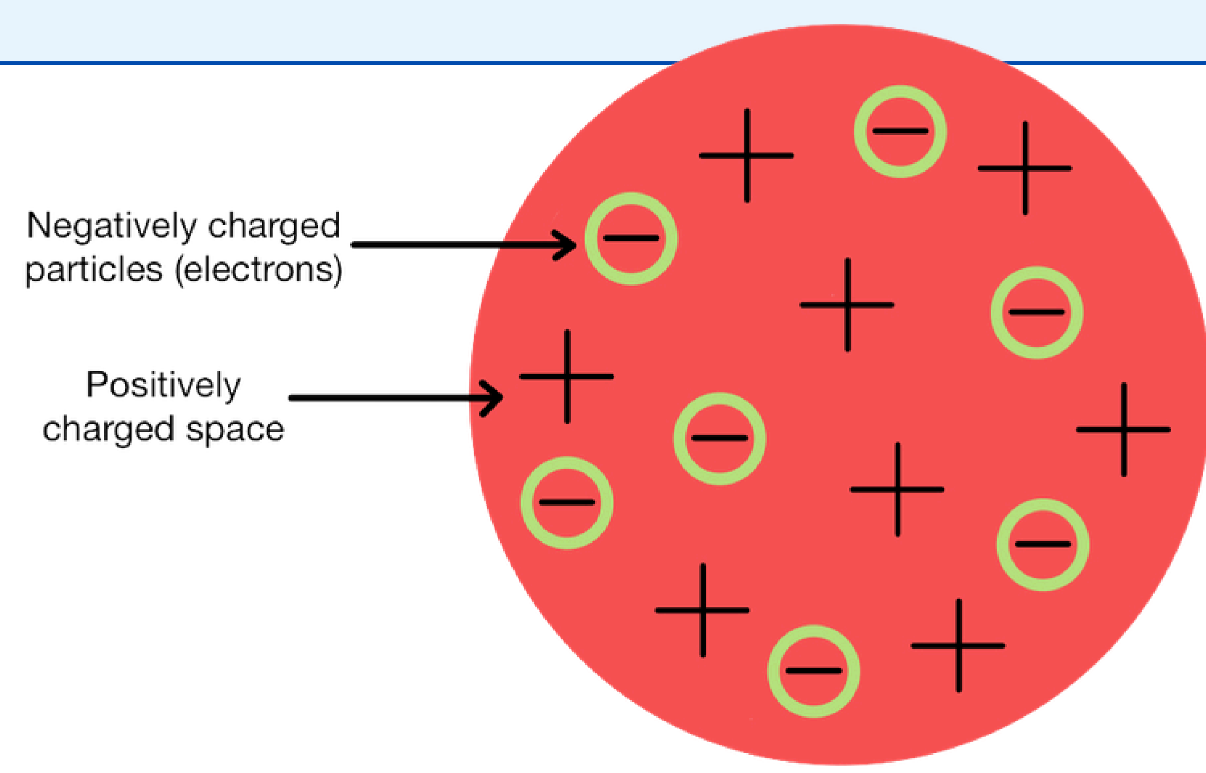
Why It Was Accepted Initially (important detail)

The Plum Pudding Model made sense at the time because:

- Electrons were known to exist and were much smaller than the atom.
- Scientists needed a way to explain how electrons fit into the atom.
- If electrons are negative, something else in the atom must be positive to balance the charge.

So the model attempted to explain two things:

1. The presence of electrons.
2. Why atoms are neutral overall.



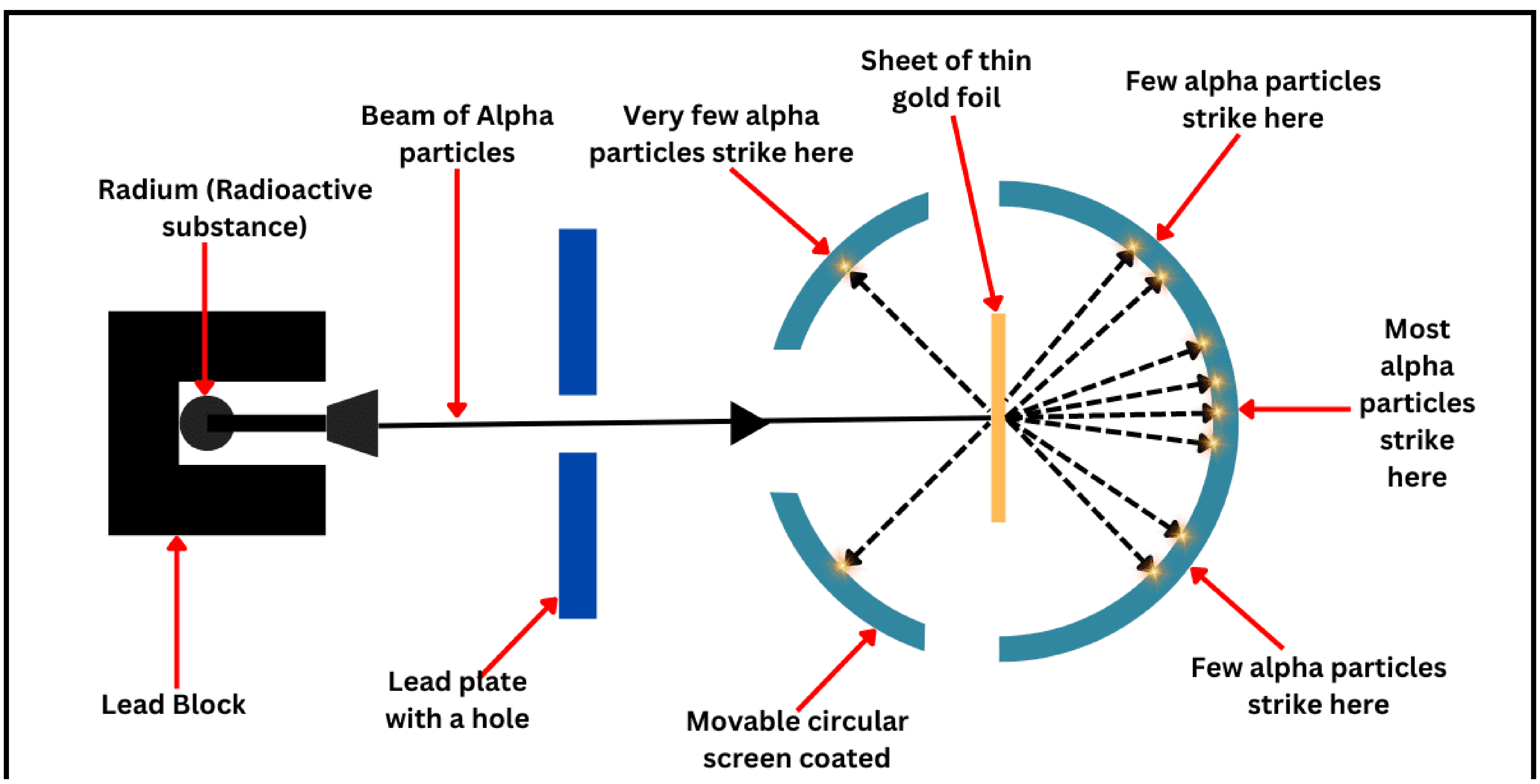
PLUM PUDDING MODEL

Why the Model Was Replaced by the ernest rutherford model of the atom?

The Plum Pudding Model was replaced after Ernest Rutherford's gold foil experiment results (1909) showed something unexpected:

- Some alpha particles were deflected at very large angles, and a few even bounced back.
- This could only happen if the atom's positive charge and mass were concentrated in a tiny, dense nucleus.

Since the Plum Pudding Model had no nucleus and spread charge evenly, it could not explain these results.



RUTHERFORD (NUCLEAR) MODEL OF THE ATOM

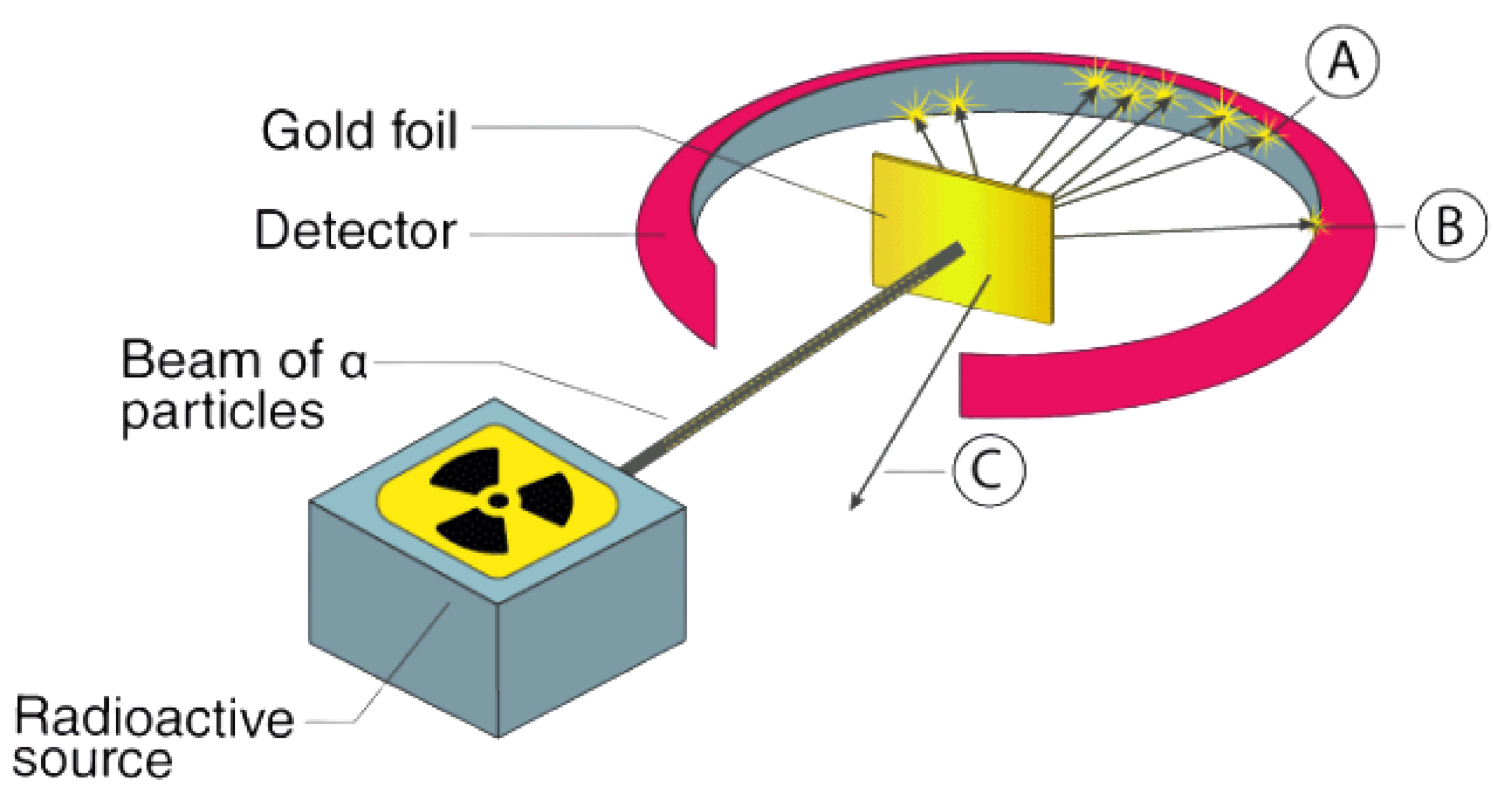
The Rutherford (nuclear) model states that an atom has:
A tiny, dense, positively charged nucleus at the centre, which contains almost all the mass of the atom and electrons moving around the nucleus
A crucial conclusion of this model is that:

- most of the atom is empty space, because the nucleus is extremely small compared with the whole atom.

This model replaced the older "positive sphere" idea because experiments showed that positive charge is not spread out; it is concentrated in a very small region (the nucleus).

There is no single "Rutherford formula" because it is a structural model. But you must apply these nuclear relationships with the nuclear model:

- Atomic number (Z) = number of protons
- Mass number (A) = protons + neutrons
- Neutrons = A − Z
- A neutral atom has equal protons and electrons, so overall charge is zero.



Rutherford's Experiment

RUTHERFORD (NUCLEAR) MODEL OF THE ATOM

Key Evidence
Rutherford Scattering: what was observed and what it meant

Rutherford's team fired alpha particles at thin metal foil and observed how they scattered. The results are explained by the nuclear model because:

1. **Most alpha particles passed straight through**

→ This suggests the atom is mostly empty space.

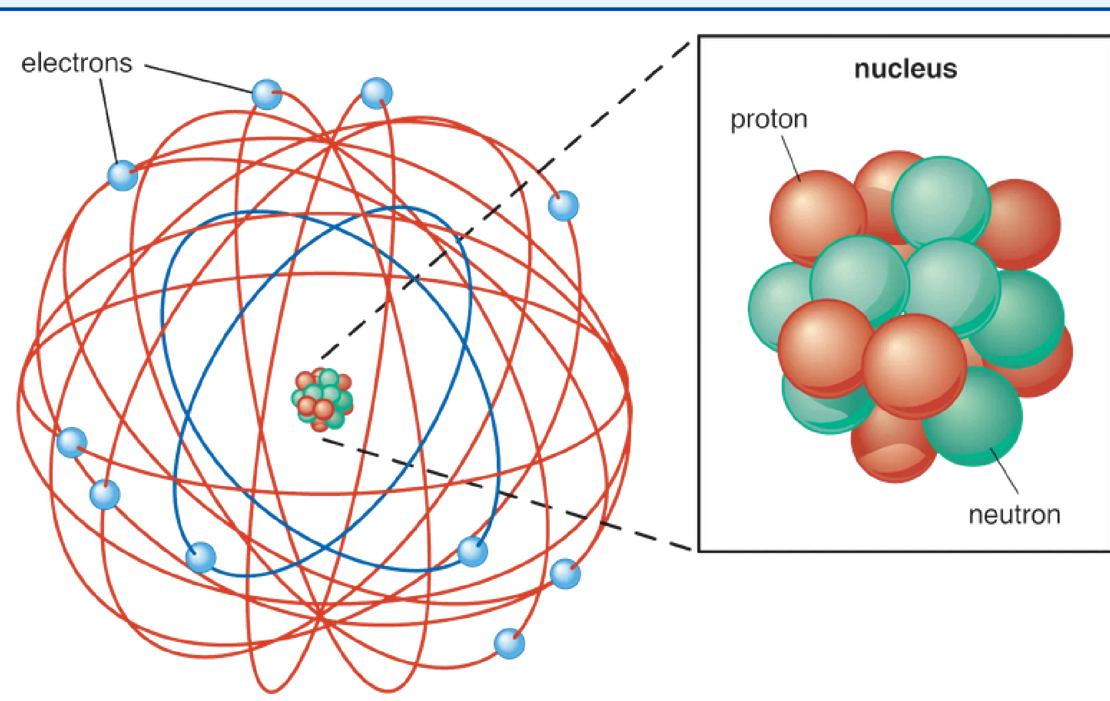
2. **Some alpha particles were deflected**

→ This implies there is a region of positive charge that can repel alpha particles (which are also positive).

3. **A tiny number were deflected by very large angles (even back)**
4.

→ This can only happen if the positive charge and mass are concentrated in a small, dense nucleus (a strong repulsion at close distance).

(In exams, you should link each observation to the conclusion: "straight through → empty space", "large deflection → small dense nucleus".)



BOHR'S MODEL OF THE ATOM

Bohr's model builds on the nuclear model by stating that electrons do not orbit at any random distance.

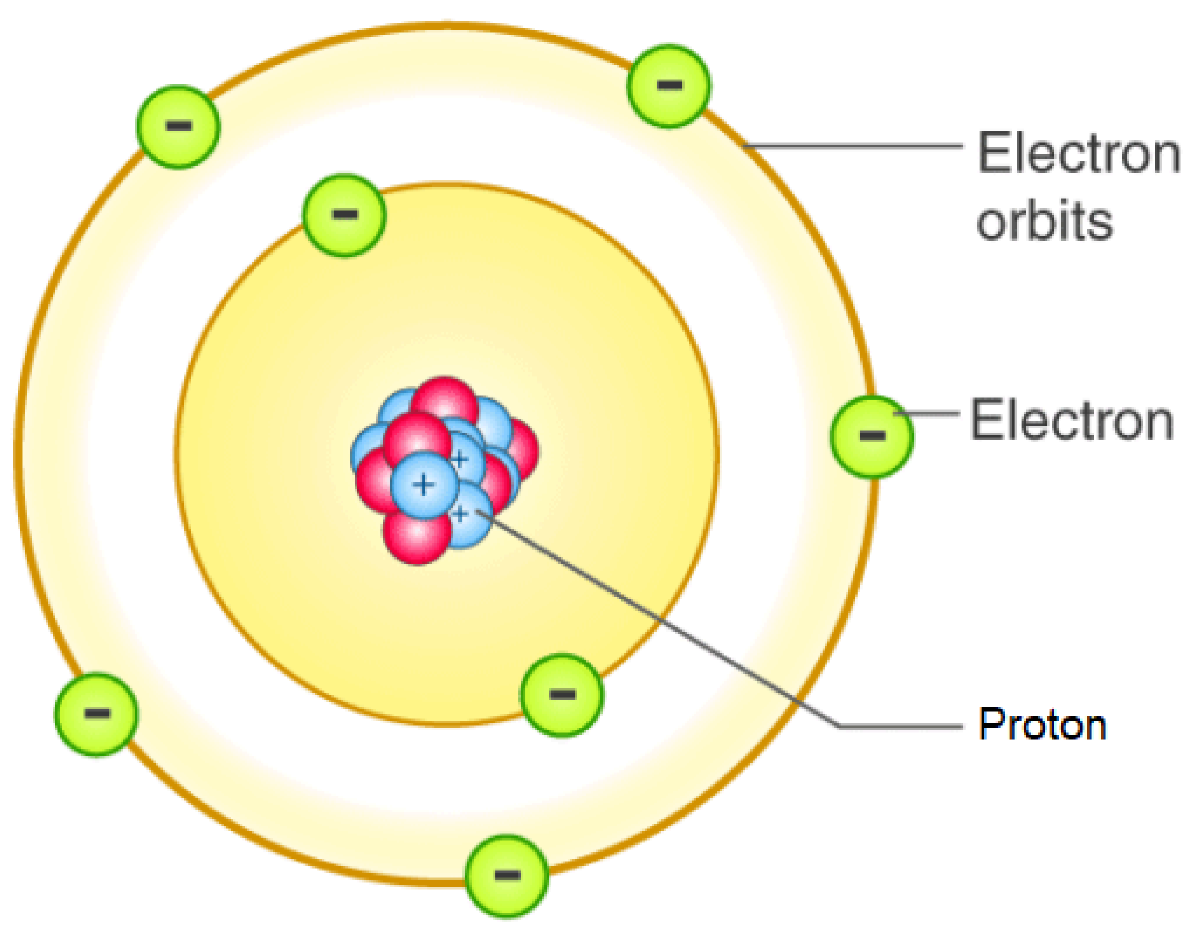
Instead:

- electrons move around the nucleus in fixed energy levels (also called shells), at specific distances from the nucleus.
- electrons in higher energy levels are further from the nucleus and have more energy.

Bohr's key improvement is that electrons can only exist in certain allowed levels, not in between.

Bohr's model is mainly explained through the fact that:

- Electrons are arranged in energy levels.
- Electrons can absorb electromagnetic radiation and move to a higher energy level.
- Electrons in higher levels are unstable and later fall back, emitting electromagnetic radiation.



Bohr atomic model of a Nitrogen atom

BOHR'S MODEL OF THE ATOM

How absorption and emission works (high-mark explanation)

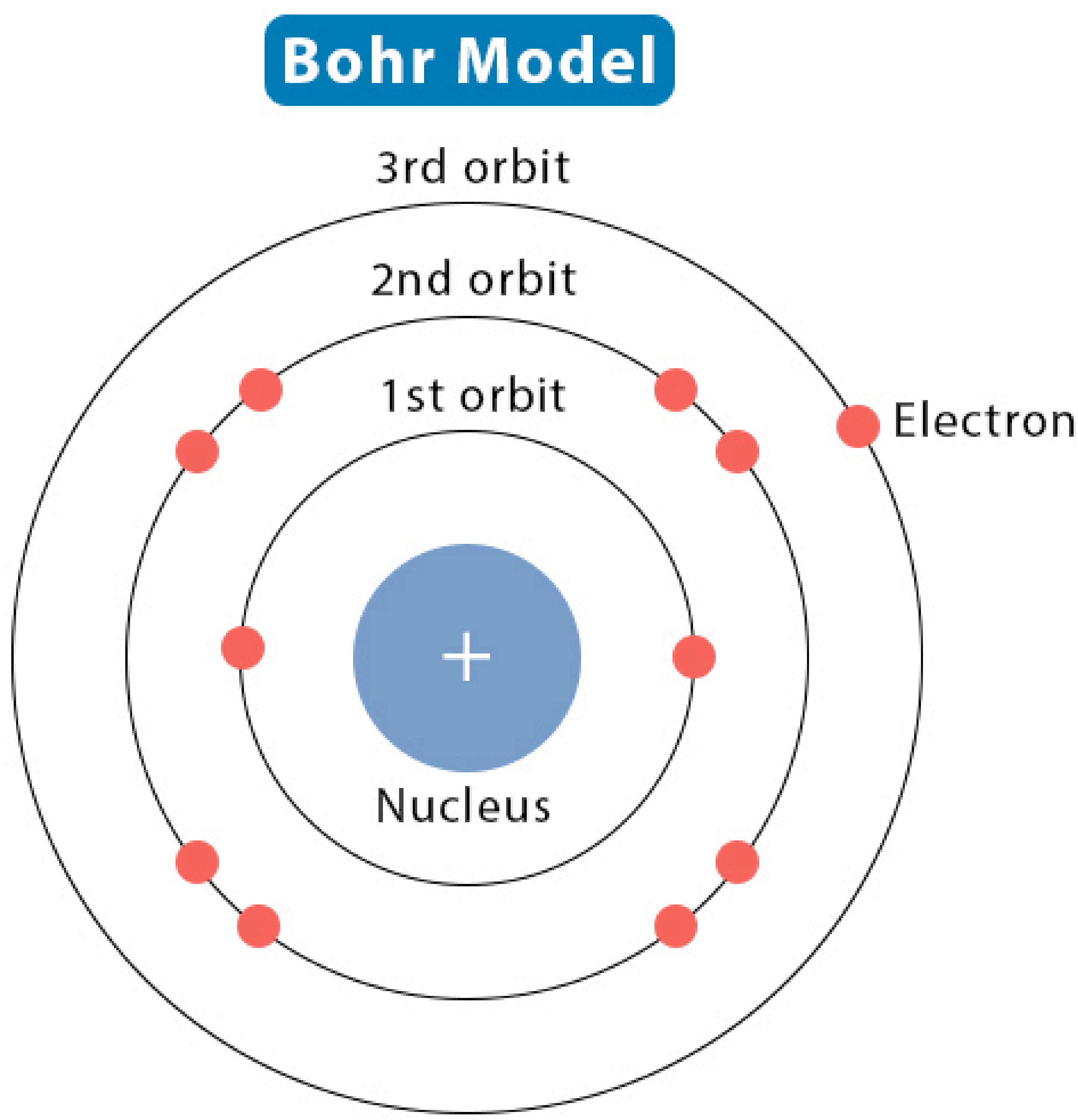
Absorption:

- Incoming electromagnetic waves (light/heat) can transfer energy to an electron.
- The electron absorbs energy and moves from a lower level to a higher level.

Emission:

- The electron in a higher energy level is unstable.
- It eventually drops to a lower energy level (closer to nucleus).
- When it drops, it emits electromagnetic radiation (light).

This is why atoms can produce visible light: different drops between levels produce different colours.



DISCOVERY OF PROTON

The proton is a positively charged particle found in the nucleus of the atom. The discovery of the proton came from experiments showing that atoms contain positive charge concentrated in a small central region (the nucleus). This explained why atoms are electrically neutral overall when electrons are included.

Formula(s):

- Atomic number (Z) = number of protons
- Charge of proton = +1
- Relative mass of proton ≈ 1

DISCOVERY OF NEUTRON

The neutron is a neutral particle found in the nucleus. It was discovered to explain why atomic nuclei have more mass than could be accounted for by protons alone, and to help explain nuclear stability.

Formula(s):

- Mass number (A) = protons + neutrons
- Neutrons = A − Z
- Charge of neutron = 0
- Relative mass of neutron ≈ 1

CHANGES IN THE ATOMIC MODEL

The atomic model changed as new experimental evidence became available. Each model attempted to better explain observations about atomic structure.

Models (in order):

- Plum pudding model: electrons embedded in positive charge.
- Rutherford (nuclear) model: small positive nucleus, electrons outside.
- Bohr model: electrons in fixed energy levels.

RADIOACTIVE DECAY

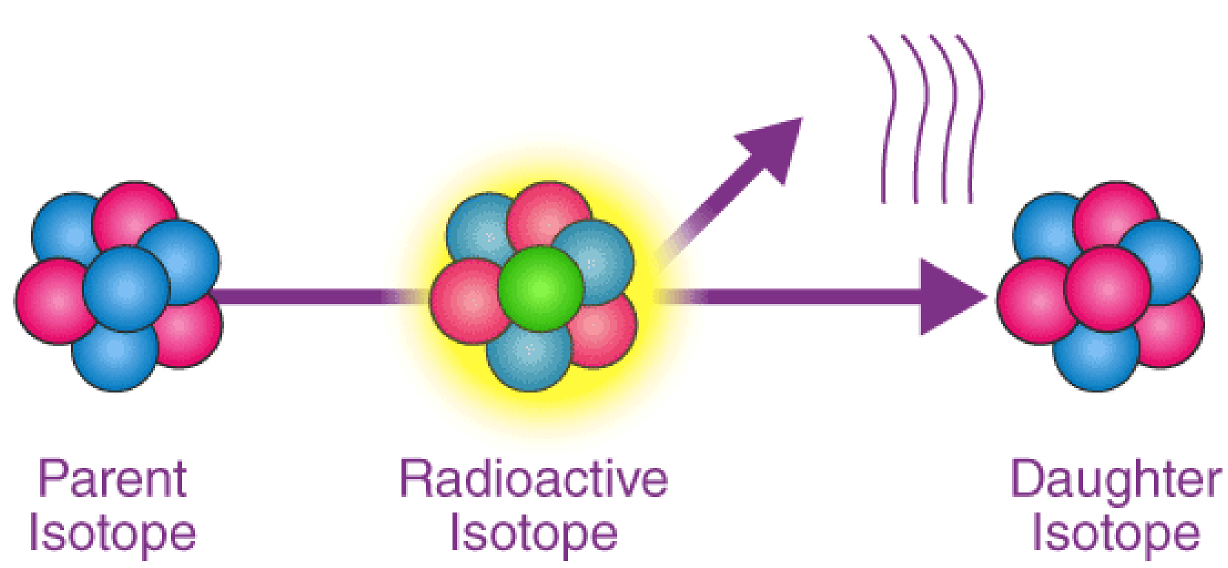
Radioactive decay is when an unstable nucleus emits radiation (particles or electromagnetic waves) to become more stable. This process happens because the nucleus has an imbalance (often too many/few neutrons or too large a nucleus).

Formula(s):

- Activity: A (Bq) = number of decays per second
- 1 Bq = 1 decay per second

Examples:

- Carbon-14 decays (beta decay) into nitrogen-14.
- Polonium-210 can undergo alpha decay.



TYPES OF RADIATION

Unstable nuclei emit alpha, beta, or gamma radiation to become more stable.

Key Properties:

- **Alpha (α)**: helium nucleus, charge +2, high ionisation, low penetration
- **Beta (β)**: fast electron, charge −1, medium penetration
- **Gamma (γ):** electromagnetic wave, no charge, high penetration

Examples:

- Alpha stopped by paper.
- Beta stopped by thin aluminium.
- Gamma reduced by thick lead.

USES OF RADIATION

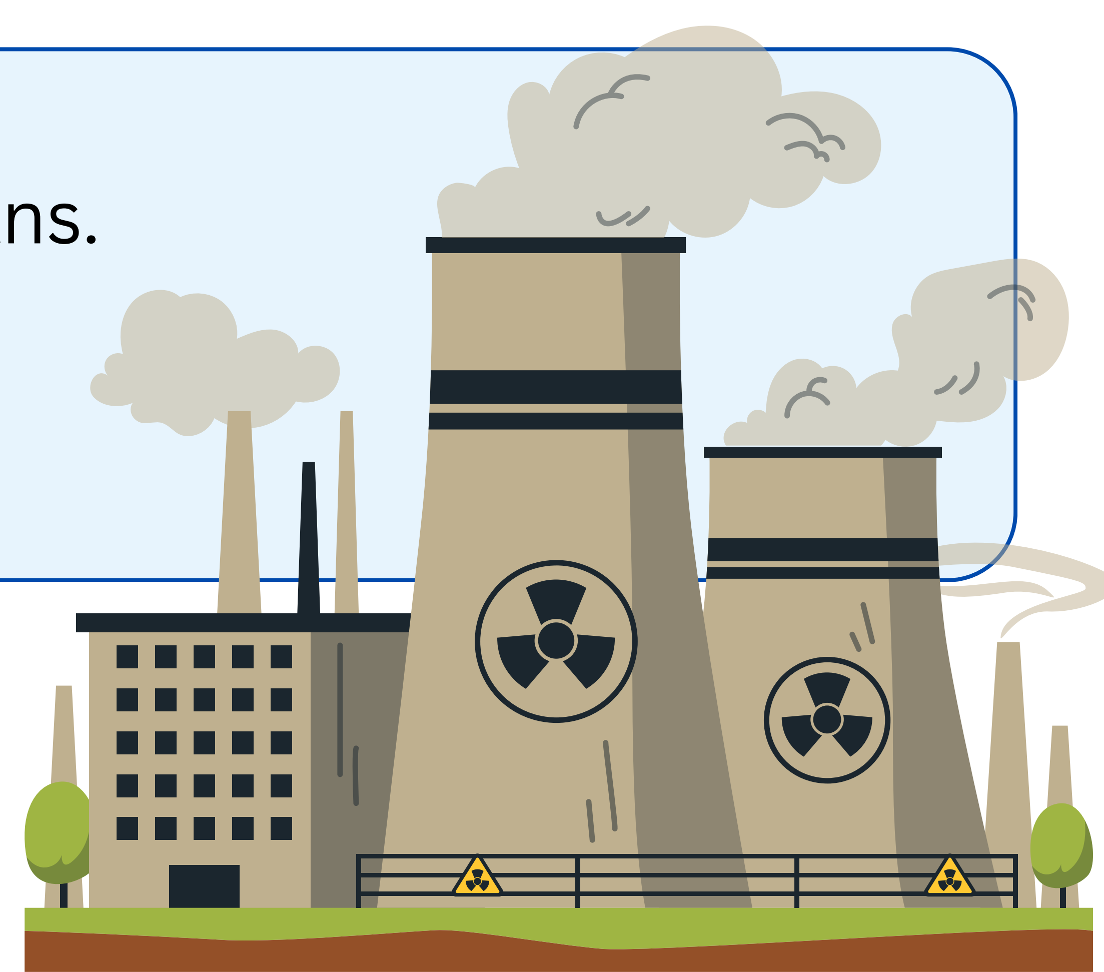
Radiation is used in medicine, industry, and science because of its penetrating power and ionising ability.

Formula(s):

- Activity measured in becquerels (Bq)
- Dose measured in sieverts (Sv)

Examples:

- Medical tracers (gamma) to image organs.
- Radiotherapy to kill cancer cells.
- Smoke detectors (alpha).
- Thickness control (beta).



ALPHA DECAY

Alpha decay is a type of radioactive decay in which an unstable nucleus emits an alpha particle. An alpha particle consists of 2 protons and 2 neutrons (the same as a helium nucleus). This process helps the atom become more stable by reducing its size and mass.

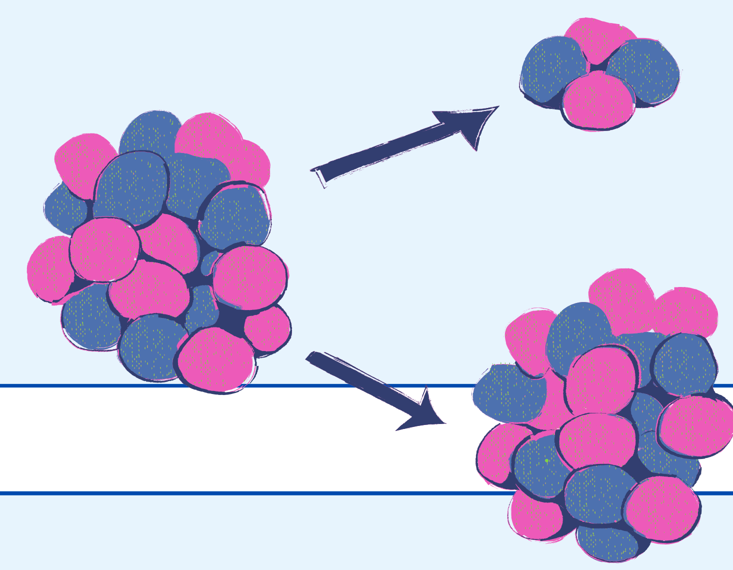
Formula:

- **Alpha decay**:

Parent nucleus→Daughter nucleus+α particle

- **Example**:

Radon-222→Polonium-218+α



Key Characteristics:

- Charge of alpha particle = +2 (positively charged)
- Mass of alpha particle ≈ 4 (relatively heavy)
- Penetrating power: Low (can be stopped by paper or skin).
- Ionising power: High (can cause significant damage to nearby molecules and cells).

Significance:

- Smoke detectors use alpha radiation.
    - A small amount of americium-241 (alpha emitter) is used in smoke detectors to ionise the air. When smoke disrupts the current, the alarm is triggered.
- Radiation therapy: Alpha particles are used to target cancer cells, as their high ionising power can cause severe damage to the DNA of cancerous cells.
- Dating materials: Alpha decay is used in the dating of rocks and minerals (e.g., uranium-lead dating).
- Shielding: Alpha particles are easily shielded, so they are usually not dangerous unless inhaled or ingested.

BETA DECAY

Beta decay occurs when a neutron in an unstable nucleus is converted into a proton, and an electron (beta particle) is emitted from the nucleus. This increases the atomic number by 1 but does not change the mass number.

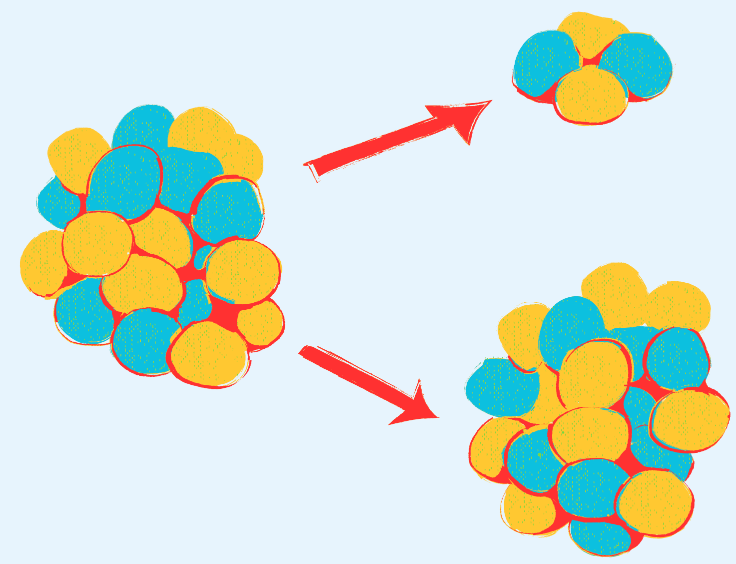
Formula:

- Beta decay:

Neutron→Proton+β− particle+antineutrino

- Example:

Carbon-14→Nitrogen-14+β−



Key Characteristics:

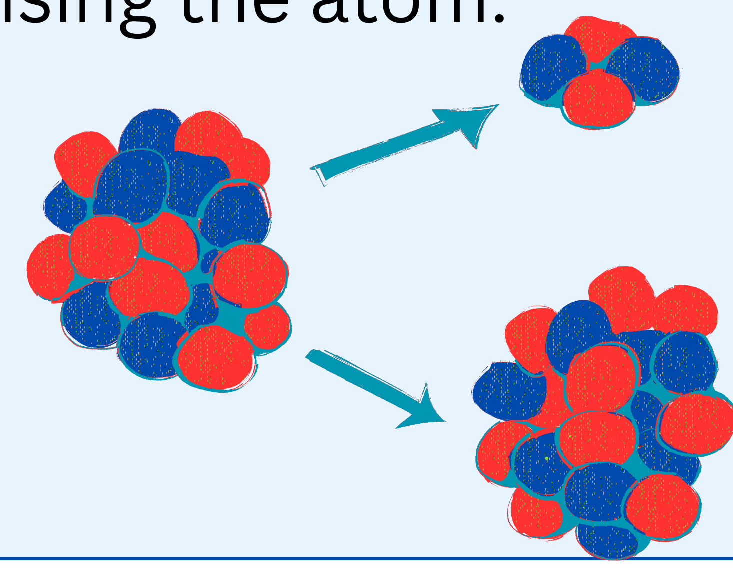
- **Charge of beta particle** = −1 (negatively charged electron)
- **Mass of beta particle** ≈ 1/2000 of a proton (very small)
- **Penetrating power:** Medium (stopped by a few millimetres of aluminium).

Significance:

- Medical applications: Beta particles are used in some forms of radiotherapy, especially to treat skin cancer and other shallow cancers.
- Industrial applications: Beta radiation is used for thickness gauging in manufacturing processes, such as paper or aluminium sheet production.
- Radioactive tracers: Beta-emitting isotopes can be used as tracers in medical diagnostics.
- Carbon dating: The decay of carbon-14 to nitrogen-14 is crucial in dating organic materials.

GAMMA DECAY

Gamma decay occurs when an unstable nucleus emits a gamma ray, a high-energy electromagnetic wave. This typically happens after alpha or beta decay, when the nucleus is left in an excited state and emits gamma radiation to release excess energy, stabilising the atom.



Formula:

- Gamma decay:

Excited nucleus→Stable nucleus+γ ray

- Example:

Cobalt-60→Cobalt-60 (excited)→Cobalt-60+γ

Key Characteristics:

- Charge of gamma ray = 0 (no charge)
- Mass of gamma ray = 0 (pure energy, no mass)
- Penetrating power: Very high (requires thick lead or several centimetres of concrete to shield).
- Ionising power: Low (ionises far less than alpha and beta radiation, but can penetrate deeper).

Significance:

- Cancer treatment: Gamma rays are widely used in radiotherapy to target and kill cancer cells.
- Medical imaging: Gamma radiation is used in positron emission tomography and other diagnostic imaging techniques.
- Sterilising medical equipment: Gamma radiation is used for sterilisation because of its ability to penetrate and kill microorganisms.
- Industrial applications: Gamma radiation is used in radiography (similar to X-rays) to inspect the internal structure of materials and machinery.
- Nuclear power: Gamma radiation is released during fission and fusion reactions in power plants.

RANDOM NATURE OF RADIOACTIVE DECAY

Radioactive decay is random. It is impossible to predict which nucleus will decay or exactly when a particular nucleus will decay.

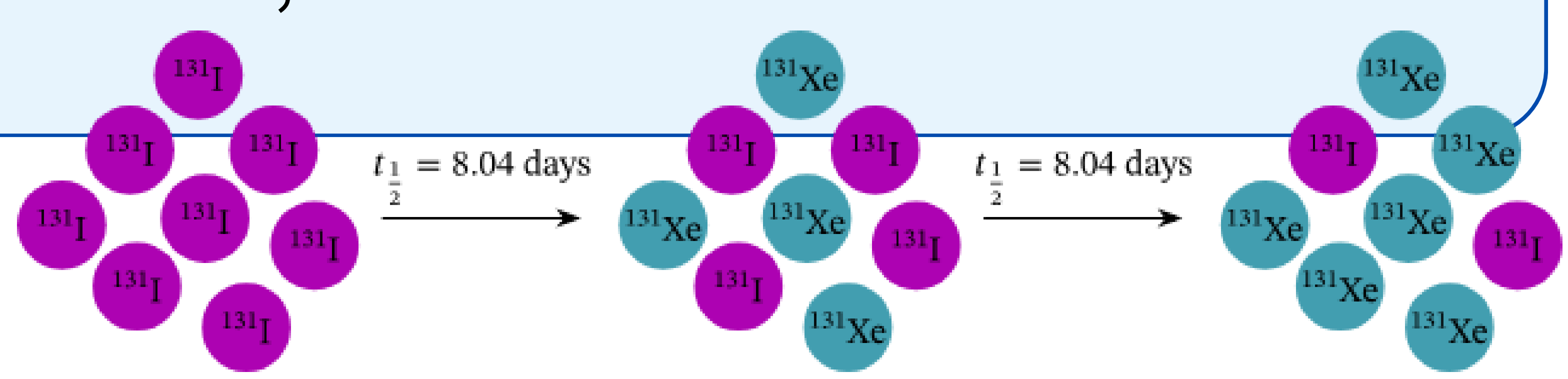
Examples:

- Two identical samples show different short-term decay patterns.

HALF-LIFE

Half-life is the time required for half of the atoms in a sample of a radioactive substance to decay. After each half-life, the activity of the substance (the number of decays per second) will be reduced to half of its previous value, and the number of undecayed nuclei will also decrease by half.

It's important to note that half-life is independent of the amount of material; it is a constant property of the substance. Whether you have a large or small amount of material, the time it takes for half of it to decay remains the same.



- Remaining fraction after n half-lives = (12)^n
- Where:
  - n = the number of half-lives passed.
  - **For example,** if 3 half-lives have passed, the remaining fraction of the original material would be (12)^3=1/8

- To find the remaining amount of substance (in terms of mass or activity), you can also use:
- Remaining amount = Initial amount × $(1/2)^n$
- Where:
- Initial amount = the starting amount of the radioactive substance.
- Remaining amount = the amount of substance that remains after n half-lives.
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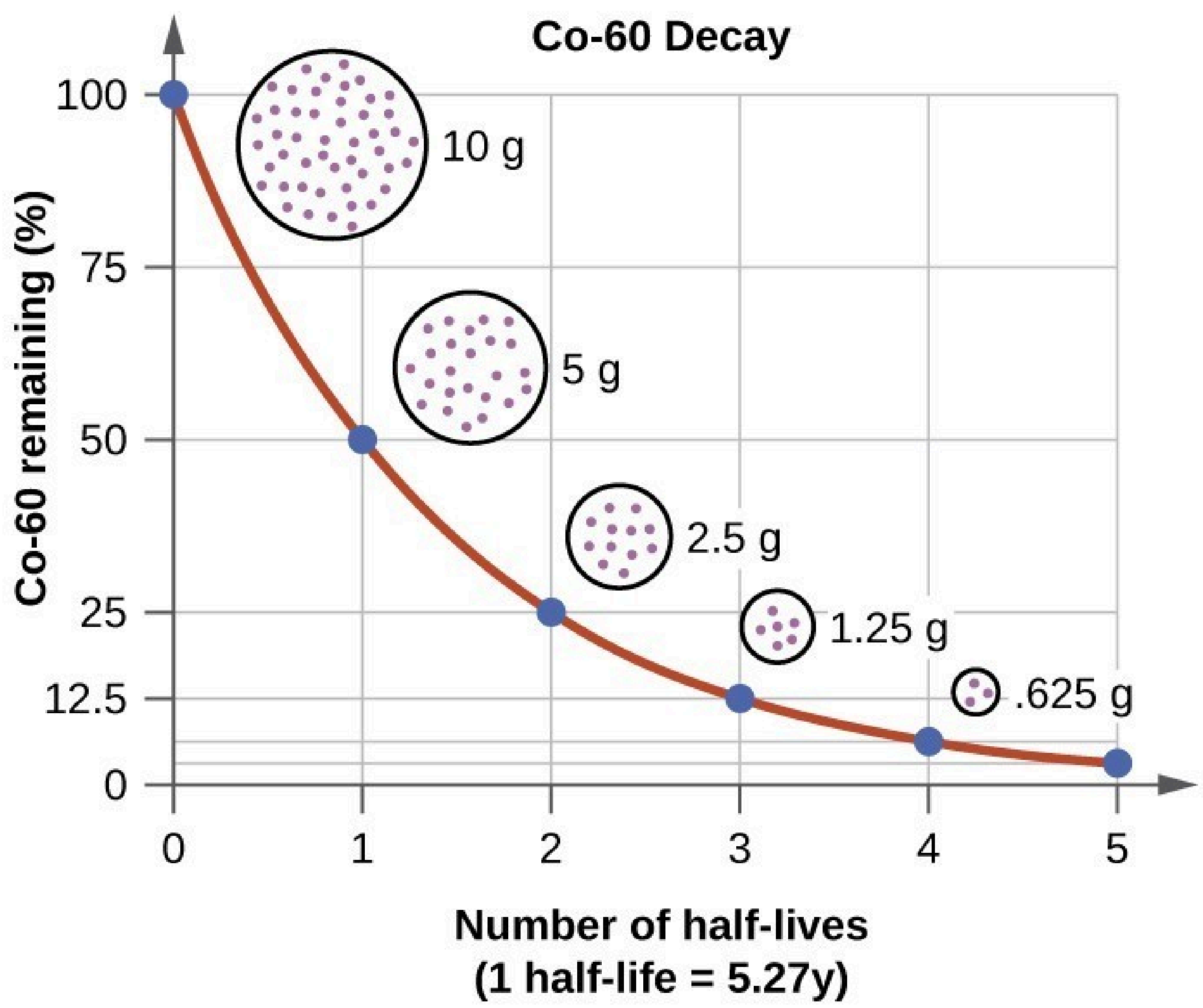


HALF-LIFE & RISK

Half-life refers to the time it takes for half of the atoms in a sample of a radioactive substance to decay. It's a measure of how fast a radioactive material loses its radioactivity. The risk associated with a radioactive material depends largely on its half-life, as longer half-lives mean the material remains dangerous for much longer. The decay process is random for individual atoms, but over a large sample, the half-life can be used to predict the decay rate.

Key points:

- The longer the half-life, the longer the material stays radioactive.
- Radioactive materials with short half-lives decay quickly, emitting high radiation in a short period.
- Materials with long half-lives release radiation slowly but remain dangerous for much longer periods.

Formula(s):

1. **Remaining fraction after n half-lives**: (1/2)^n

Where n is the number of half-lives passed.

2. **Remaining amount = Initial amount × (1/2)^n**
3. This formula helps calculate how much of a radioactive substance remains after a certain number of half-lives.

Example:

- If 1000 nuclei of a substance are present at the start, after 2 half-lives, the remaining number of nuclei would be:
- 1000×(12)2=1000×14=250

USES OF RADIATION IN MEDICINE

Medical Imaging (Diagnostic):

- Gamma radiation is used in medical imaging to view the internal structures of the body, particularly in the use of gamma cameras for scanning.
- Positron Emission Tomography (PET scans): Uses beta-plus radiation (positrons) to detect metabolic processes in tissues, such as identifying cancer cells.
- X-rays are a form of high-energy gamma radiation that passes through the body to produce detailed images of bones and organs.

Radiotherapy (Treatment of Cancer)

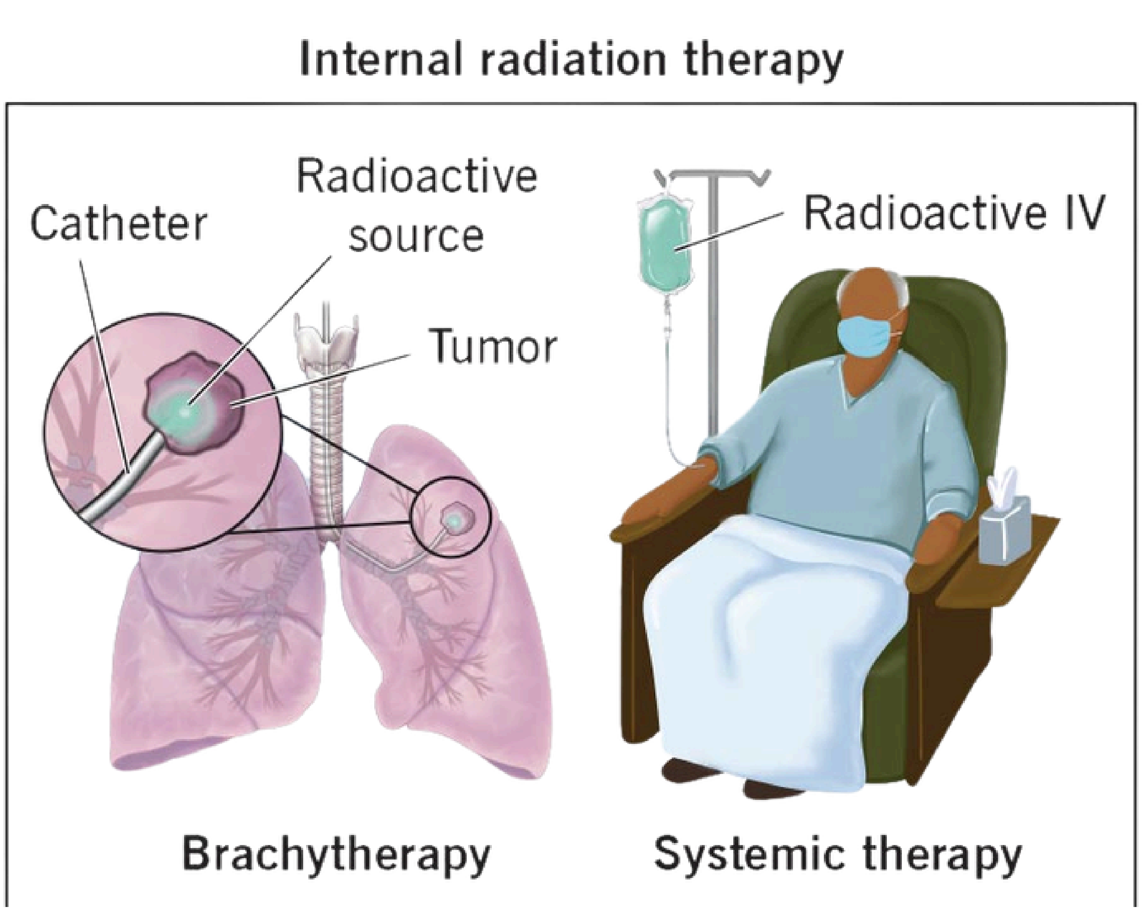
- Gamma radiation is used to treat cancer by killing cancerous cells or shrinking tumors. In external radiotherapy, gamma rays are targeted at the tumor from outside the body.
- Internal radiotherapy (Brachytherapy) involves placing a radioactive source inside the body near the tumor (for example, prostate cancer).

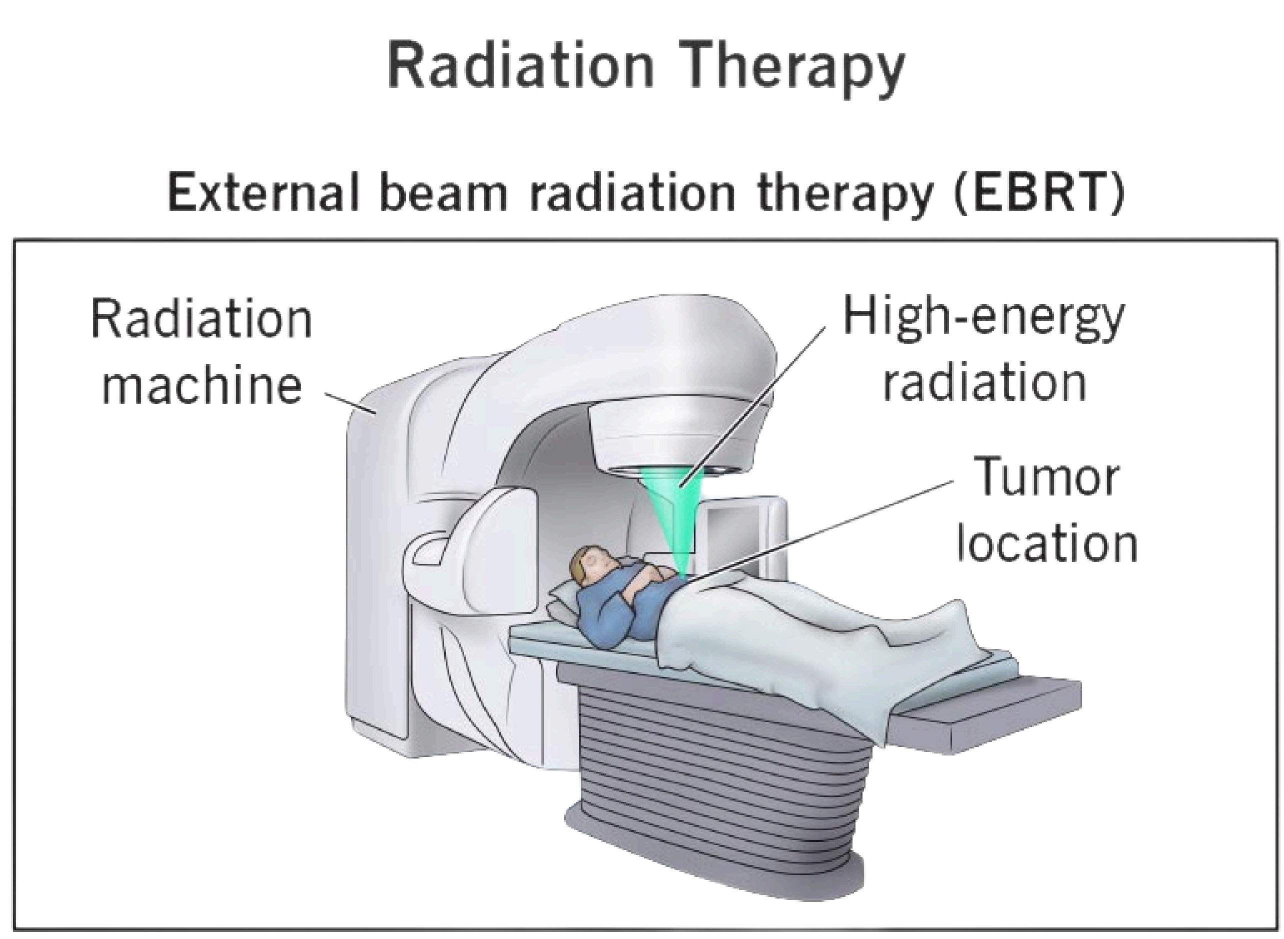
Sterilising Medical Equipment

- Gamma radiation is widely used to sterilise medical instruments, especially those that cannot be easily sterilised by heat or chemicals (such as surgical instruments, syringes, and sutures).
- Gamma radiation is highly penetrating and can kill microorganisms, viruses, and bacteria on the surfaces of instruments without damaging them.

Radioactive Tracers

- Radioactive isotopes are used as tracers to monitor the movement of substances within the body. These tracers emit radiation, which can be detected by imaging devices (like gamma cameras), allowing doctors to track the substance's journey and pinpoint blockages or diseased tissue.



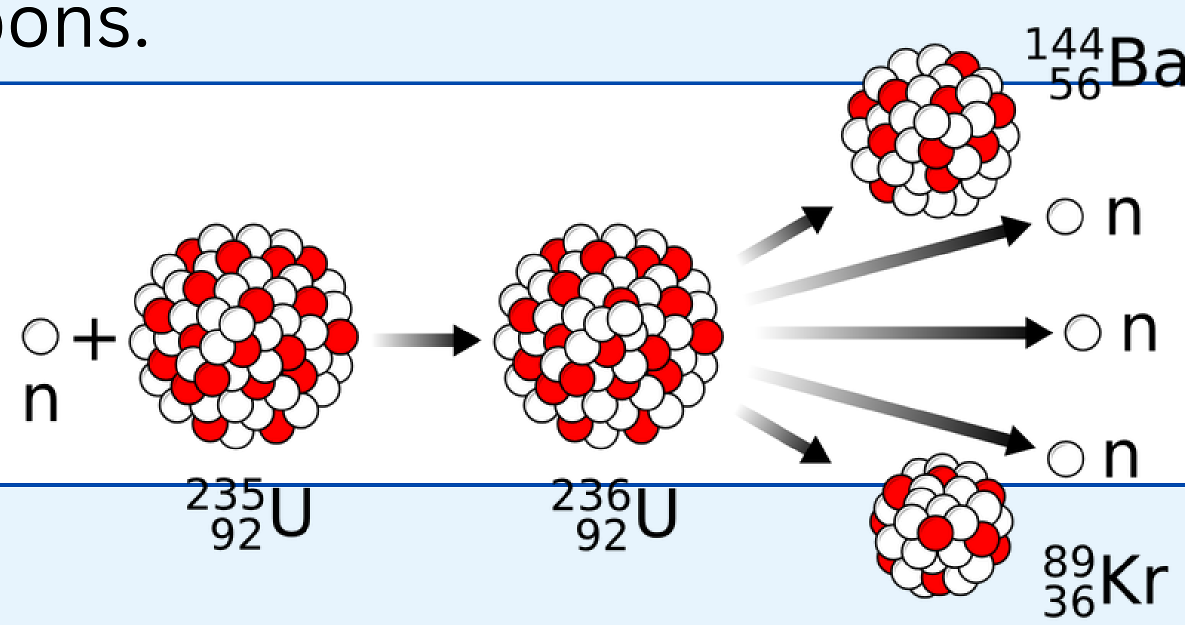


NUCLEAR FISSION

Nuclear fission is the process in which a large, unstable nucleus (usually of uranium-235 or plutonium-239) splits into two smaller nuclei, releasing a large amount of energy. This process also releases neutrons, which can cause further fission reactions, leading to a chain reaction. The energy released comes from the conversion of a tiny amount of mass into energy, according to Einstein's equation, E=mc^2

Key Points:

- Fission releases huge amounts of energy in the form of kinetic energy of the products and gamma radiation.
- The energy produced is used in nuclear reactors for electricity generation and in nuclear weapons.



Significance:

- Electricity Generation:
  - Nuclear reactors use controlled fission reactions to release energy in the form of heat. This heat is used to generate steam, which drives turbines connected to generators, producing electricity.
  - The control of the fission reaction is done by inserting control rods that absorb neutrons, slowing or stopping the chain reaction.
- Nuclear Weapons:
  - In nuclear bombs, a chain reaction of fission is allowed to occur rapidly, releasing immense amounts of energy in the form of an explosion.

NUCLEAR FUSION

Nuclear fusion is the process where two light atomic nuclei combine to form a heavier nucleus, releasing an enormous amount of energy. This is the process that powers stars, including our Sun. The energy produced in fusion comes from a small amount of mass being converted into energy, following Einstein's equation $E=mc^2$.

In stars, fusion occurs naturally, with hydrogen nuclei fusing to form helium, releasing vast amounts of energy. On Earth, nuclear fusion is a challenging process to replicate, as it requires extremely high temperatures (millions of degrees).

Significance:

- Energy Generation (Future Potential):
  - Nuclear fusion offers the potential for a clean and virtually limitless energy source. It does not produce long-lived radioactive waste like nuclear fission, and the fuel (isotopes of hydrogen like deuterium and tritium) is abundant in seawater.
  - Successful fusion could provide a massive solution to global energy needs in the future.
- Stars and Sun:
  - The Sun, and all stars, rely on fusion reactions to produce light and heat. This process has been ongoing for billions of years, and understanding it is key to understanding stellar life cycles.
- Nuclear Weapons:
  - Fusion bombs (also called hydrogen bombs) release significantly more energy than fission bombs. In these bombs, the fusion reaction is triggered by the initial fission explosion. The H-bomb releases energy from both fission and fusion reactions, causing much more devastation.

CHAIN REACTION

A chain reaction in nuclear fission refers to a series of nuclear fission reactions, where each fission event releases neutrons that can initiate further fission reactions in nearby nuclei. A sustained chain reaction occurs when the number of fissions remains constant over time. In a controlled chain reaction, the rate of reaction is regulated, such as in nuclear reactors. In an uncontrolled chain reaction, the process speeds up rapidly, as seen in nuclear explosions.

Formula (Conceptual):

- Chain reaction:
- Neutron+Uranium-235→Fission products+3Neutrons

These 3 neutrons can cause further fissions, leading to a rapid multiplication of fission events.

Significance:

- Nuclear Reactors:
  - Controlled chain reactions in reactors are used for peaceful purposes, such as generating electricity.
- Nuclear Weapons:
  - In nuclear bombs, a rapid, uncontrolled chain reaction releases huge amounts of energy, causing massive explosions. The first nuclear weapons tested used uranium-235 and plutonium-239 for the chain reaction.
- Medical Isotopes:
  - The chain reaction in nuclear reactors also produces radioactive isotopes that are used in medical applications, including radiotherapy for cancer treatment and as radioactive tracers.

NUCLEAR FUSION

Example:

1. **Fusion in the Sun:**
    - In the core of the Sun, hydrogen nuclei (protons) undergo fusion to form helium-4, releasing vast amounts of energy. The energy released by fusion produces light and heat, making the Sun shine.
    - Hydrogen-1 nuclei combine to form Helium-4, with a small mass difference converted into energy.
2. **Experimental Fusion on Earth (Tokamaks):**
    - On Earth, experimental fusion reactors like the Tokamak attempt to recreate these conditions by heating deuterium and tritium to millions of degrees Celsius. At these high temperatures, the nuclei have enough kinetic energy to overcome their repulsion and fuse together.