NUCLEAR PHYSICS : RADIOACTIVITY

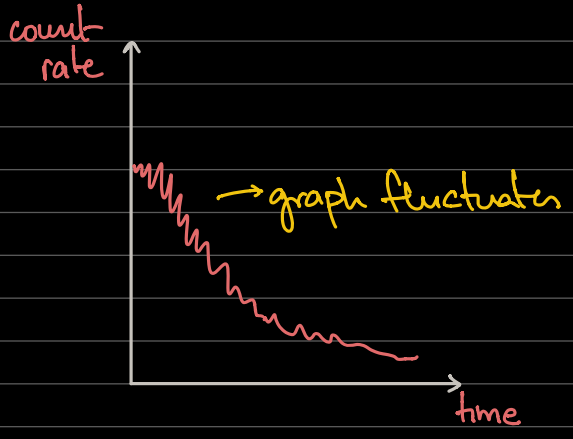
Subtopics of Radioactivity:
1. Nuclear Physics
2. Fundamental particles

- The process of radioactivity is a random and spontaneous process

Random:
The count rate emitted from any radioactive source fluctuates over time

Confirming the random nature of radioactivity:
- Plot a graph of count-rate on the y-axis against time on the x-axis.

↳ If the graph is not smooth, that confirms the random nature of radioactivity



Spontaneous:
- The term spontaneous nature means that the process of radioactivity does not depend on any changes taking place in the external environmental conditions (ie. temperature, pressure, presence or absence of electric/magnetic field, etc.)

How to check for the spontaneous nature:
- Take two identical radioactive sources and place them in different environments, ie. different temperature, pressure etc.

- Obtain the count rate at specific time intervals from both sources and plot a graph of count-rate vs. time.

- If the value of half-life obtained from both graphs is almost the same, then that confirms the spontaneous nature of the process

TYPES OF RADIATION & THEIR PROPERTIES

1. Alpha particles
   - Denoted by α or ${}^{4}_{2}\alpha$ or ${}^{4}_{2}He$
   - Resembles a helium nuclei

- Consists of 2 protons & 2 neutrons
- Carries a charge of $2e^-$ where $1e^- = 1.6 \times 10^{-19} C$, ie the charge of a proton
- α particles travel at a speed of 10% of the speed of light
- All α particles have the same kinetic energy, ∴, they travel roughly the same distance in air (ie. 4-5 cm)
- They have low penetration power and can be stopped by a piece of paper
- They have high ionizing effect in air
- During an α decay (ie. α emission), the mass number of the parent nucleus decreases by 4 and the proton number of the parent nucleus decreases by 2

Example: $^{220}_{82}X \longrightarrow {}^{4}_{2}\alpha + {}^{216}_{80}Y$

Parent Nucleus — Daughter Nucleus

General: $^{A}_{B}X \longrightarrow {}^{4}_{2}\alpha + {}^{A-4}_{B-2}Y$

2. Beta particles
- Resembles an electron; carries a charge of $-1e$ with a mass of 9.11×10^{-31} kg
- Denoted by $^{0}_{-1}e$ or $^{0}_{-1}\beta$
- Travel with speeds ranging from 90% to 99% of the speed of light
- They have a range of kinetic energies
- They have moderate penetration power: can pass through paper but can be stopped by Aluminium sheets that are a few mm thick.
- They offer a moderate ionization effect
- They deflect in electric and magnetic fields
- During β emission, the mass number of the parent nucleus remains unchanged whereas the proton number increases by 1.
- β particles have a range of a few metres in air
- Since β particles are lighter than α particles, they deflect more easily in electric and magnetic fields

Example: $^{40}_{20}X \longrightarrow {}^{0}_{-1}\beta + {}^{40}_{21}Y$

Parent Nucleus — Daughter Nucleus

General: $^{A}_{B}X \longrightarrow {}^{0}_{-1}\beta + {}^{A}_{B+1}Y$

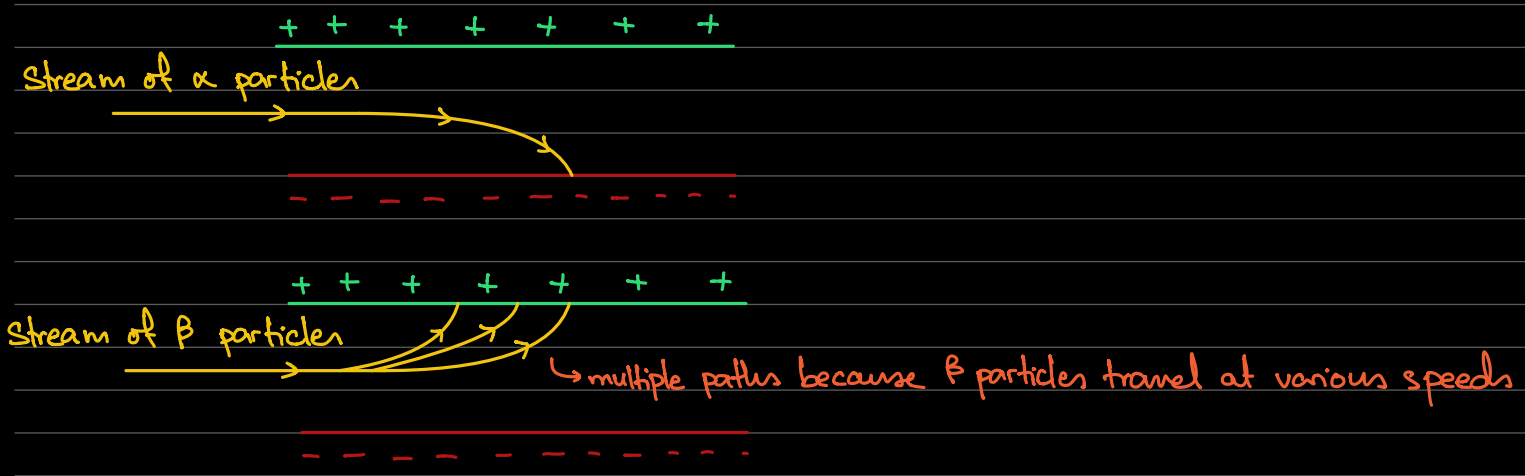
Why does proton number increase by 1 and mass number remain constant?

- It is believed that during a β emission, a neutron inside the nucleus splits to form a proton and an electron.

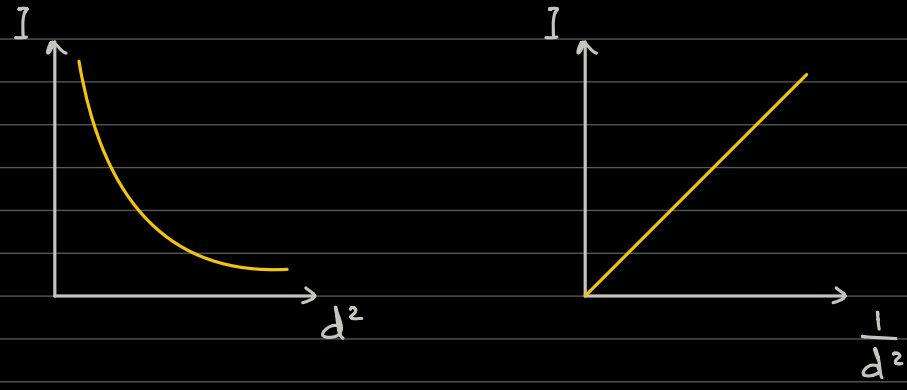
- The proton stays inside the nucleus and the electron is emitted from the nucleus in the form of a β particle

- The mass number remains unchanged because a neutron is lost but a proton is gained
- The proton number changes because a proton is gained.

Behaviour of α and β particles in electrical fields:



3. Gamma Radiation
- High frequency electromagnetic radiation
- Neither any mass nor any charge
- Denoted by γ
- Travels at the speed of light (since its part of the EM spectrum)
- Negligible / zero ionization effect
- Max / infinite range in air
- Passes through paper and aluminium, but can be stopped by a lead sheet that's a few cm thick
- No deflection in electric or magnetic fields
- Produced in almost all nuclear reactions.
- Being EM waves, they follow wave properties, ie. the intensity (I) of gamma rays is inversely proportional to the square of the distance (d)



Note: The above relationship means that if we double the distance from the source emitting γ-rays, the intensity reaching us will reduce to become $\frac{1}{4}$ of it's initial value.