31 - Nuclear Physics

Q-1) Nuclear reactions.

> α decay

$${}^{A}_{Z}X \longrightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}He$$

> β^- decay (emission of electron)

$${}^{A}_{Z}X \longrightarrow {}^{A}_{Z+1}Y + {}^{0}_{-1}e$$

> β^+ decay (emission of positron)

$${}^{A}_{Z}X \longrightarrow {}^{A}_{Z-1}Y + {}^{0}_{+1}e$$

> γ decay (emission of energy; gamma rays).

$${}^{A}_{Z}X \longrightarrow {}^{A}_{Z}X + \gamma$$

What is conserved?

> proton number
> nucleon number
> mass-energy.

eg: ${}^{14}_{7}N + {}^{4}_{2}He \longrightarrow {}^{17}_{8}O + {}^{1}_{1}H$

Radioactive decay is when a nucleus spontaneously / randomly emits α, β or γ radiation photons.

Q-2) What is the mass defect?
> The mass of a nucleus is slightly less than the mass of the seperate protons and neutrons.
This is because when the nucleons are seperated, energy is added to overcome the strong nuclear force.
This energy is added as mass.

$$E = mc^2 \quad \rightarrow c = 3.00 \times 10^8 \ ms^{-1}$$

The mass defect of a nucleus is equal to the difference between the total mass of the individual seperate nucleons, and the mass of the nucleus.
* use rest mass.

$$1eV = 1e \times 1V$$
$$= 1.60 \times 10^{-19} \times 1$$
$$= \underline{\underline{1.60 \times 10^{-19}}} \ J$$

Q-3) What is mass excess?
> The mass of an atom in atomic mass unit (u) is ~~di~~ slightly different than its nucleon number. The difference in these values is known as mass excess.

mass excess = mass (in u) − nucleon no.

Q-4) What is atomic mass unit?
> 1u is 1/12 of the mass of a neutral atom of carbon-12

$1u = 1.49 \times 10^{-10}$ J $\rightarrow$ By using $E = mc^2$

$1u = 931$ MeV $\qquad = 1u \times c^2$

Q-5) What is binding energy?

> Its the minimum energy required to split up a nucleus into its seperate nucleons (protons & neutrons) to infinity

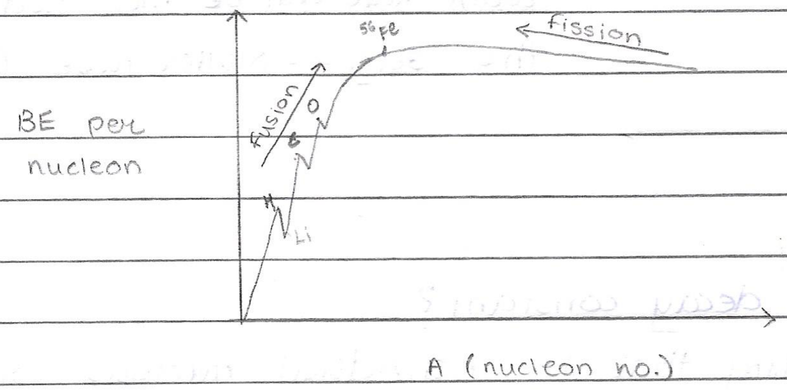
OR

its the energy released when the seperate nucleons combine together to form the nucleus.

$$BE = \Delta m c^2$$

If BE is greater, the nucleus is more stable as more energy is required to break the BE.

$$\text{BE per nucleon} = \frac{\Delta m c^2}{\text{no. of nucleons}}$$



Q-6) What is nuclear fission and fusion?

> Nuclear fission : a large nucleus splits into two smaller fragments. (it's hit by a neutron releasing 3 more neutrons)

> Nuclear Fusion : two light nuclei join / fuse to form a heavier nucleus.

Both process' increas BE per nucleon.

Q-7) Radioactive decay. properties

> Radioactive decay is spontaneous because:

→ the decay of a particular nucleus is not affected by the presense of other nuclei.

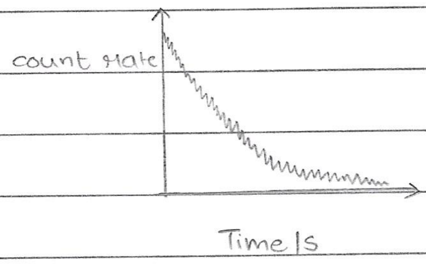
→ the decay is not affected by chemical reactions or external factors such as temperature and pressure.

It's random because:

→ It's impossible to predict when a particular nucleus in the sample is going to decay.

→ each nucleus in the sample has the same chance of decaying per unit time.

→ there are fluctuations in the count rate.



count rate can be measured using the Geiger-Müller tube (GM-tube).

Q-8) What is the decay constant?

> The probability that an individual nucleus will decay per unit time interval is called the decay constant

(λ) unit = s^{-1} or h^{-1}...

eg: after one hour, 2 nuclei out of the 10 observed decayed.

$\lambda = \frac{2}{10 \times 1} = 0.20\,h^{-1}$ $\lambda = \frac{\Delta N}{N \Delta t}$

Q-9) What is the activity?

> The activity of a radioactive sample is the rate at which the nuclei decay.

(A) unit = 1 Bq (becquerel) = $1s^{-1}$

$$A = -\lambda N$$

OR

$$A = -\frac{\Delta N}{\Delta t}$$

- λ = decay constant
- N = no. of undecayed nuclei present
- ΔN = no. of emissions / decays

Q-10) What is the half-life?

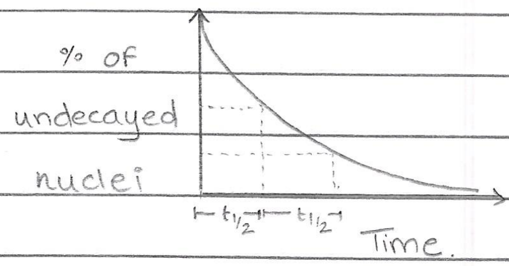
> Half life is the mean time taken for half of the active nuclei in a sample to decay.

($t_{1/2}$)

$$t_{1/2} = \frac{\ln 2}{\lambda} = \frac{0.693}{\lambda}$$

Q-11) Exponential decay.

$$X = X_0 e^{-\lambda t} \quad \text{ie} \quad \frac{X_0}{e^{\lambda t}}.$$



- X_0 = original
- x = new (undecayed nuclei)

This formula can be applied for:

$$N = N_0 e^{-\lambda t}$$

$$A = A_0 e^{-\lambda t}$$ — because $A \propto N$

$$R = R_0 e^{-\lambda t}$$ — R = count rate.

Using $N = N_0 e^{-\lambda t}$

> $\frac{N}{N_0} = e^{-\lambda t_{1/2}}$ —o in one half life, ratio $\frac{N}{N_0} = 1/2$

> $\therefore e^{-\lambda t_{1/2}} = 1/2$

$\therefore e^{\lambda t_{1/2}} = 2$ —o taking logs on both sides.

$\lambda t_{1/2} = \ln 2$

$\lambda t_{1/2} = 0.693$

$\therefore \lambda = \frac{0.693}{t_{1/2}}$ OR $t_{1/2} = \frac{0.693}{\lambda}$