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Mass Defect and Binding Energy

Mass Defect :
- The difference between the sum of the masses of the individual nucleons and the actual mass.

Binding Energy :
- The energy difference between the separated nucleons and the assembled nucleus.
- represents the energy required to hold protons and neutrons together in a nucleus.
- If the binding energy is zero, it indicates that there is no net attractive force acting to keep the nucleons (protons and neutrons) together.

Extra Points :
- a nucleon has a proton and neutron.
- Strong nuclear force holds proton in the nucleus.
- Relationship between mass and energy : $E = mc^2$

Formula :

Total mass = $Z \times m_H + N \times m_n$
- **Z** : atomic no. (number of protons)
- **m_H** : mass of hydrogen
- **N** : number of neutrons (A - Z)
- **m_n** : mass of neutron

$\Delta m = T.m - M_{atom}$(actual measured mass in *Given*)

B.E.(in MeV) = Δm(in u) × 931.494 MeV/u

Binding Energy per Nucleon (B.E./A)
- B.E. / A = Total Binding Energy/ Mass Number

- mhydrogen atom 1.007825 u
- mneutron 1.008665 u
- mdeuterium atom 2.014102 u
- mhelium atom 4.002603 u

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Nuclear Decay and Reactions

Radioactive decay :
- is the emission of energy in the form of ionizing radiation.

Radiation :
- is the energy that comes from a source and travels through space at the speed of light.

3 modes of nuclear decay : *you go in-terms of the **Atomic No.**

1. **Alpha decay** : Helium nuclei; alpha particles($^{4}_{2}$**He**) being emitted.

- ***Mass no.*** : Decreases by 4; and ***Atomic no.*** : decreases by 2

Example :

Emitted	Bombarded
$^{238}_{92}U \Rightarrow {}_{90}^{234}Th + {}_{2}^{4}He$	${}_{86}^{222}Rn + {}_{2}^{4}He \Rightarrow {}_{88}^{226}Ra$

2. **Beta decay** : Antineutrino and β-particles($_{-1}^{0}$**e**) are being emitted.

- ***Mass no.*** : does not change; and ***Atomic no.*** : increases by 1(Bc changing of 1 neutron to portion)

Example :

Emitted	Bombarded
${}_{7}^{14}N + \beta^{-} + \bar{v}_{e} \Rightarrow {}_{6}^{14}C$	${}_{6}^{14}C \Rightarrow {}_{7}^{14}N + \beta^{-} + \bar{v}_{e}$

3. **Gamma Decay** : Redistribution of energy with nucleus. $\Rightarrow \gamma$ | Results in no isotope change
- ***Mass no.*** and ***Atomic no.*** : do not change.

Example :

Emitted	Bombarded
${}^{99m}_{43}Tc \Rightarrow {}_{43}^{99}Tc + \gamma$	${}_{43}^{99}Tc + \gamma \Rightarrow {}^{99m}_{43}Tc$

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Nuclear Decay Series

- This is an application/solving Lesson

- '↙' ⇒ Alpha Decay; '→' ⇒ βeta Decay
- The previous product becomes the next reactant.

- The are 8 alpha decays, and 6 beta decays.

———

Half Life

Half life : *denoted by t

- The time required for half of the atoms in any given quantity of a radioactive isotope for decay.

Practical Applications of Half life : *momerize 4

- Radioactive Dating
- Nuclear Medicine
- Pharmacology
- Environmental Science
- Nuclear Power
- Food Preservation

Formulas :

$$t = \text{No. of days passed} / \text{Half life}$$

$$\text{Remaining} = \text{original } (1/2)^t$$

Units of Radioactivity :

- **Curie** : corresponds to activity of 1 gram of Radium 226

• Original unit

- 1 Curie = 3.7 x 1010 radioactive decay per second

• SI unit is Becquerel

- 1 Bq = 1 radioactive decay per second = 2.703 x 10-11 Ci

- Also as a measure of quantity of radioactive material
  - i.e. the no. of atoms that will produce 1 Ci of radiation is

$$N = 3.7 \times 10^{10} / \lambda$$

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Nuclear Fission and Fusion

Nuclear Fission : *decomposition of nucleus
- the division nucleus into 2 or more fragments.

- **How it happens** :
    - Large nucleus is bombarded with a small particle.
    - The nucleus splits into smaller nuclei and several neutrons.
    - Large amounts of energy are released

- The released energy is around 173 MeV

- **Central rods** absolve fast neutrons to make them slower and reduce their speed to initiate nuclear fission.
    - Because fast neutrons don't cause **nuclear fission**.
- A **moderator** slows down fast neutrons.

Nuclear Fission Equation :
- $n + {}_{92}^{235}U \rightarrow {}_{92}^{236}U \rightarrow {}_{56}^{142}Ba + {}_{36}^{91}Kr + 3n + Energy$

Chain Reaction :
- occurs when a critical mass of uranium undergoes fission.

*speed of neutrons; $c = 3x10^8$

Fast Neutrons	Slow Neutrons
c/7	c/8

Nuclear Power Plants :
- Fission is used to produce energy
- control rods in the reactor absorb neutrons to slow and control the chain reactions of fission.

Nuclear Fusion : *occurs at extremely high temps (10M C°)
- Light-mass nuclei combine to form a beavier, more

- Fusion releases more energy than Fission.

Nuclear Fusion Equation :
- Proton proton cycle

${}_{1}^{2}H + {}_{1}^{3}H \rightarrow {}_{2}^{4}He + n + energy$