

VCE Physics: Unit 1 AOS 2 Cheat Sheet

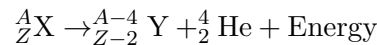
Nuclear Energy Utilisation — 2023–2027 Study Design — Heinemann 5th Ed.

1. Atomic Structure and Nuclear Forces

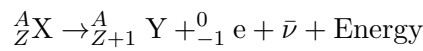
- **Isotope Notation:** A_ZX
 - A : Mass Number (Protons + Neutrons).
 - Z : Atomic Number (Protons).
 - $N = A - Z$: Neutron Number.
- **Strong Nuclear Force:** A short-range (1–3 fm), highly attractive force acting between all nucleons. It is essential for overcoming the electrostatic repulsion between protons.
- **Electrostatic (Coulomb) Force:** The repulsive force between positively charged protons. It acts over infinite range but is dominated by the strong force at very short distances.
- **Weak Nuclear Force:** Responsible for radioactive decay processes, specifically allowing for the conversion of flavors of quarks (e.g., in beta decay).
- **Mass Defect (Δm):** The difference between the sum of the masses of the individual nucleons and the actual mass of the intact nucleus. Because energy is released when a nucleus forms, the nucleus always has less mass than its constituent parts.

2. Radioactive Decay Equations

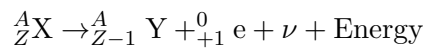
- **Alpha (α) Decay:** Emission of a helium nucleus (${}^4_2\text{He}$). Generally occurs in heavy nuclei.



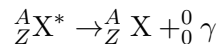
- **Beta-Minus (β^-) Decay:** A neutron decays into a proton, an electron (${}^0_{-1}e$), and an antineutrino ($\bar{\nu}$).



- **Beta-Plus (β^+) Decay:** A proton decays into a neutron, a positron (${}^0_{+1}e$), and a neutrino (ν).



- **Gamma (γ) Decay:** High-energy electromagnetic radiation emitted to shed excess energy from an excited nucleus (X^*).



3. Half-Life and Activity

- **Number of Half-Lives (n):** $n = \frac{t}{t_{1/2}}$
- **Activity (A):** The number of disintegrations per second, measured in Becquerels (Bq).

$$A = A_0 \left(\frac{1}{2}\right)^n$$

- **Remaining Nuclei (N):** The amount of undecayed material remaining after time t .

$$N = N_0 \left(\frac{1}{2}\right)^n$$

4. Energy and Stability

- **Mass-Energy Equivalence:** $E = \Delta mc^2$.
 - $c = 3.0 \times 10^8$ m/s.
 - E is in Joules (J) if Δm is in kg.
- **Energy Conversions:**
 - $1 \text{ eV} = 1.6 \times 10^{-19}$ J
 - $1 \text{ MeV} = 1.6 \times 10^{-13}$ J
- **Binding Energy per Nucleon:** Determined by dividing the total binding energy by the mass number A . Higher binding energy per nucleon indicates greater nuclear stability.
- **Stability Curve:**
 - **Fusion:** Light nuclei ($A < 56$) combine to increase binding energy per nucleon.
 - **Fission:** Heavy nuclei ($A > 56$) split to increase binding energy per nucleon.
 - **Iron-56:** The most stable nucleus (peak of the curve).

5. Nuclear Fission Reactors

- **Fission Chain Reaction:** A process where neutrons released by fission cause additional fission in surrounding nuclei.
- **Moderator:** Materials (e.g., water, heavy water, graphite) used to slow down fast neutrons. Slow (thermal) neutrons are more likely to be captured by ^{235}U nuclei.
- **Control Rods:** Rods made of neutron-absorbing materials (e.g., cadmium, boron) that are inserted or withdrawn from the reactor core to regulate the reaction rate.

6. Radiation Dosimetry and Biological Effects

- **Absorbed Dose (AD):** $AD = \frac{E}{m}$ (Units: Gray, Gy).
- **Equivalent Dose (ED):** $ED = AD \times QF$ (Units: Sievert, Sv).
- **Effective Dose (E_{eff}):** $E_{\text{eff}} = \sum(ED \times W_T)$ (Units: Sievert, Sv).

Radiation Type	QF	Tissue Type	W_T
Alpha (α)	20	Gonads	0.20
Neutrons (Fast)	10	Bone Marrow/Lung/Colon	0.12
Neutrons (Slow)	3	Bladder/Breast/Liver	0.05
Beta (β) / Gamma (γ)	1	Skin/Bone Surface	0.01

- **Somatic Effects:** Biological damage that affects the individual exposed to radiation (e.g., radiation burns, organ failure, or induced cancers).
- **Genetic Effects:** Damage to the DNA in reproductive cells (germ cells). These mutations do not affect the exposed individual but may be passed on to future offspring.