VCE Unit 1 Physics - Radiation & Nuclear Energy Cheat Sheet

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Fission/Fusion/Binding Summary

Process	What Happens?	Energy Source	Main Issues
Fission	Big nucleus splits into smaller ones	Mass defect	Radioactive waste, accidents
Fusion	Small nuclei combine into bigger one	Mass defect	Hard to achieve on Earth
Binding Energy	Energy holding nucleus together	Mass converted to energy	Indicates stability

Definitions in Nuclear Energy

Fission- When a nucleus splits into two or more pieces usually after bombardment by neutrons.
Fusion- A process taking place inside stars in which small nuclei are forced together to make larger nuclei. Energy is released in the process.
Chain reaction - A series of nuclear fissions that may or may not be controlled. The neutrons that are released cause the reaction.
Critical Mass: Minimum mass of fissile material for a self-sustaining chain reaction

Key Points in Nuclear Energy

Fission:
Used in nuclear reactors & bombs.
Releases 2-3 neutrons per event → can cause chain reaction.
Controlled with control rods (graphite/cadmium).
Fusion:
Powers the sun & stars.
More energy per nucleon than fission.
Hard to achieve on Earth due to electrostatic repulsion; needs high temp/pressure.
Binding Energy Graph:
Most stable nuclei: mass numbers 40–80 (e.g., iron-56).
Fusion: energy released for nuclei < iron.
Fission: energy released for nuclei > iron.
Australia:
1/3 of world's uranium, no nuclear power plants.
Relies on coal & gas.
Risks of Nuclear Power:
Radioactive waste—long half-lives.
Security of uranium (weapons risk).
Accidents (Chernobyl, Fukushima).
Fusion Power:
Not yet practical; research ongoing (e.g., ITER, JET).
Goal: produce more energy than consumed.

Half-life Formula

The number of nuclei remaining after a particular number of half-lives can be found mathematically using:

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

- Where N is the number of radioactive nuclei remaining
- N_0 is the initial number of radioactive nuclei
- n is the number o half-lives elapsed

The number of half-lives in a period of time can be found using

$n = \frac{T}{t_{1/2}}$

- Where T is the period of time that the radioactive nuclei has decayed
- $t_{\frac{1}{2}}$ is the half-life of the radioactive nuclei.

Activity Formula

The activity of the nuclei remaining after a number of half-lives can be found mathematically using:

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

where A is the activity of radioactive nuclei remaining
A_0 is the initial activity of radioactive nuclei
n is the number of half-lives elapsed.

Activity is measured in becquerel's (Bq)
1 Bq = 1 disintegration per second

Dose Formulas

$$\text{Absorbed dose} = \frac{\text{energy absorbed by tissue}}{\text{mass of tissue}}$$

Used to calculate radiation energy absorbed per kg of tissue.
Absorbed dose is measured in J/Kg or Greys (Gy).

Dose Formulas

$$\text{Equivalent dose} = \text{absorbed dose} \times \text{quality factor}$$
$$\text{ED} = \text{AD} \times \text{QF}$$

Takes into account Absorbed Dose so that must be calculated first
Equivalent dose is measured in Sieverts (Sv).

Dose Formulas

$$\text{Effective dose} = \Sigma(\text{equivalent dose} \times \text{W})$$

Effective dose (in Sieverts) is found by calculating the sum of equivalent doses multiplied by the weighting factor, W, for each organ affected
e.g: .. = (0.04 x 1) + (0.01 x 1) +.... -> Each multiplication is a separate organ

Mass Defect

The mass defect is calculated as:
Δm = total mass of individual protons and neutrons – actual mass of nucleus.

Used for E = mc^2
E = binding energy (J)
m = mass defect
c = 3.0 x 10^8 ms^{-1}

Electron Volt

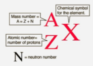
1 eV = 1.602 176 x 10^{-19} J	
KeV = 10^3, MeV =10^6, GeV = 10^9, TeV = 10^{12}	

Isotopes

Isotope: An atom with the same number of protons but different numbers of neutrons.

Radioisotope: A radioactive isotope that are sometimes unstable.

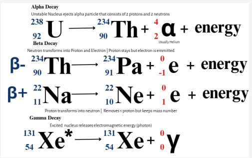
Atomic Notation



Mass Number (A) = Total number of protons & neutrons in the nucleus = Nucleons

Atomic Number (Z) = Number of protons in the nucleus

Radioactivity or Decay



Properties:

Alpha -> Heavy, slow-moving, double positive charge, low penetration, travels less than 10% of c

Beta -> Lighter than Alpha, fast-moving, travels up to 90% of c

Gamma -> High frequency, no charge, high penetration, travels 100% of c

Ionising Radiation

Alpha, beta, and gamma are all ionising radiation	Alpha has the greatest ionising power, followed by beta, then gamma

They are harmful to living things and have enough energy to remove outer-shell electrons to create ions

There are two types of effects of radiation on living organisms: Somatic and Genetic

Effects of Radiation

Somatic (physical) effects arise when ordinary body cells are damaged and depends on the size of the dose.

Genetic effects arise when the cells in the reproductive organs are damaged, genetic changes that happen in the developed ova or sperm could be passed on to a developing embryo.

Radiation in Therapy

Radioisotopes are used in the diagnosis and treatment of cancer.

Medical imaging is used in the diagnosis of different diseases.

X-rays, CT, Gamma radiation scans, MRI, PET scans, SPECT are all examples.

Cancer Treatment through Radiotherapy

Cobalt-60 external beam therapy: Gamma rays from C-60 source is directed through a patient into the tumour site.

Tomotherapy

The Gamma Knife: high dose of gamma radiation, treats brain tumours.

Chemotherapy: radioisotope must have a short half-life, emit alpha or beta, and not too much gamma

Brachytherapy: Kills abnormal cells using small wires/seeds