FORM 5 SPM PHYSICS **SHORTHAND NOTES**
Chapter 6 Radioactivity
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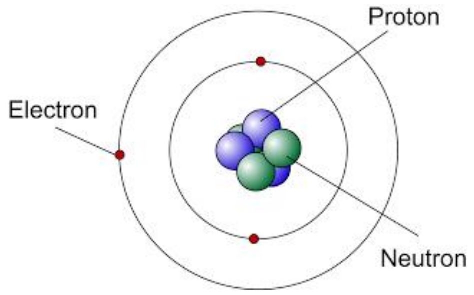
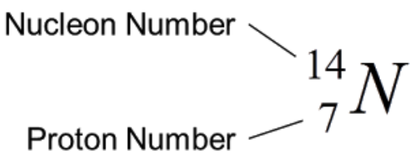
Chemistry Revision

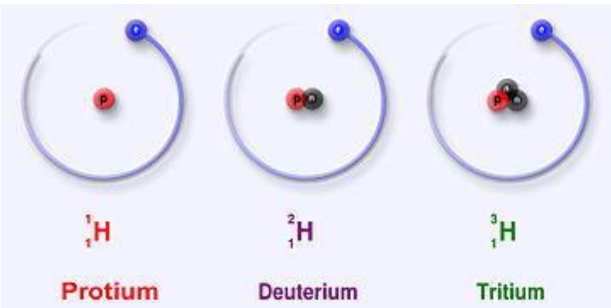




Almost all the mass of an atom is concentrated in the nucleus. The nucleus consists of protons and neutrons. Their total number is called the nucleon number. Isotopes are atoms of certain elements which have the same proton numbers but different nucleon numbers obviously because the number of neutrons is different. Isotopes have the same chemical properties but different physical quantities (eg. molecular mass, density, etc.). So think of protons as a type of atomic DNA.

e.g. of isotopes

Protium, Deuterium, Tritium are isotopes of the hydrogen element.



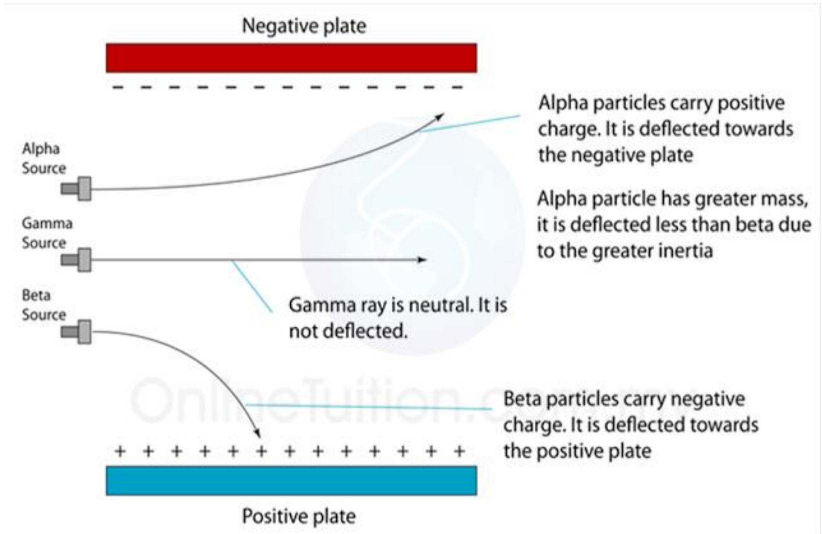
Uranium-232, Uranium-233, Uranium-234, Uranium-235, Uranium-236, Uranium-237, Uranium-238 and Uranium-239 are isotopes of the uranium element.

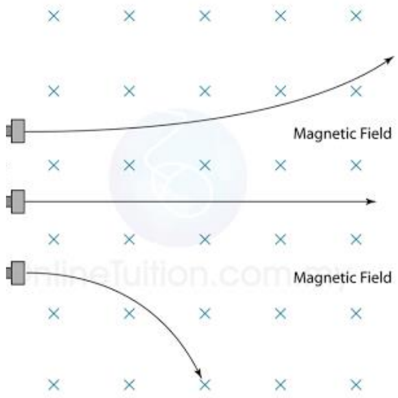
1.0 Radioactive Decay

This is the spontaneous process of an *unstable nucleus* emitting radioactive emission in order to become more stable.

3 types of Radioactive Emission

	α	β	γ
Charge	Positive	Negative	No charge
Ionization	Strongest ionization	Less than α	Less than β
Penetration	Least	More than α	Most penetrating
Protection	A thick sheet of paper	A few millimetres of Perspex or aluminium	Several centimetres of lead
Deflection in electric field	Can be deflected	Can be deflected	Not deflected
Deflection in magnetic field	Can be deflected	Can be deflected	Not deflected





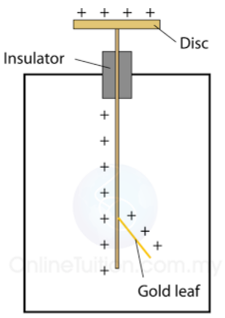
Determine which emission is alpha, beta and gamma.

Hint: Use Flemming LHR

Detecting nuclear radiation:

Detectors	Alpha	Beta	Gamma
Gold Leaf Electroscope	✓	✗	✗
Geiger-Muller Tube	✓	✓	✓
Cloud Chamber	✓	✓	✓
Spark-Chamber Detector	✓	✗	✗
Film Badge (Dosimeter)	✓	✓	✓

Gold Leaf Electroscope



When the charged plate of the electroscope is exposed to the source of radioactive the gold leaf will collapse slowly. This is due to the ions produced by the radioactive source neutralize the charge in the electroscope. This method is suitable for detecting alpha particles only because these particles have a sufficiently high ionizing power.

Radioactive decay

The nucleus of an unstable isotope emits nuclear radiation such as α, β and γ rays until it becomes stable. The process where a nucleus of an unstable isotope emits nuclear radiation is called **radioactive decay**. Radioactive decay occurs *spontaneously* and *randomly*. The unstable nucleus before the decay is called the parent nuclide while the stable nucleus produced after the decay is called the daughter nuclide.

Alpha decay

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

1) During an alpha decay, a radioactive atom X decay and emits an alpha particle ($24He$).
2) Atom X losses 2 neutron and 2 proton and become atom Y.

e.g., $^{238}_{92}U \rightarrow ^{234}_{90}Th + ^{4}_{2}He$

Beta decay

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

1) A beta particle is an electron emitted from a nucleus.
2) The beta particles are very small and move with very high speed.
3) During a beta decay, a radioactive atom X decay and emits a beta particle $(-10e)$.
4) One of the neutron is disintegrated to become proton and electron. The electron is emitted out from the nucleus whereas the proton stay in the nucleus
5) Hence, the proton number goes up by 1 while the nucleon number remains unchanged.

$$\text{e.g., } ^{234}_{90}Th \rightarrow {}^{234}_{91}Pa + {}^{0}_{-1}e$$

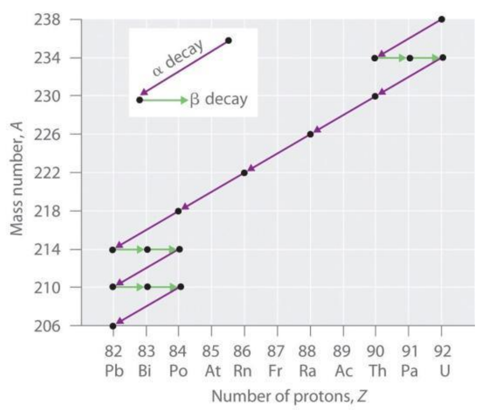
Gamma Emission

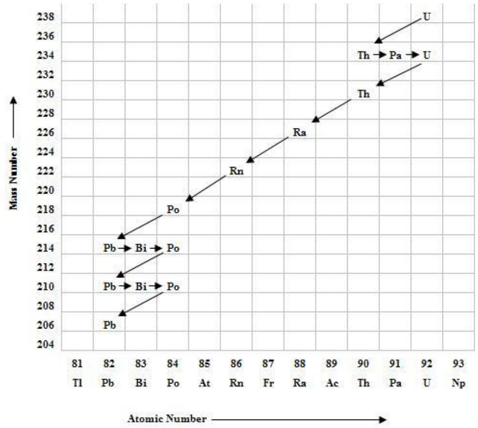
Gamma emission causes no change in nucleon or proton number. This is because gamma ray is an electromagnetic radiation and not a particle.

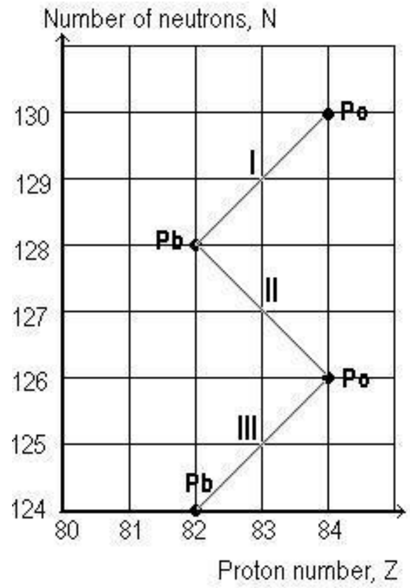
$$^{A}_{Z}X \rightarrow {}^{A}_{Z}Y + \gamma$$

Series Decay

When an unstable nucleus undergoes radioactive decay, the daughter nucleus may still be unstable. The daughter nuclide will then undergo another radioactive. This process continues until a stable nuclide is reached. This is called series decay.





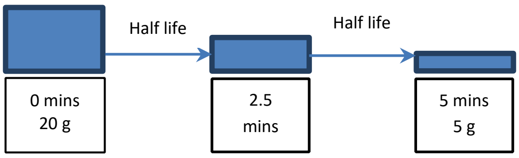


State the radioactive decays that the element has gone through.

Half-life

As mentioned previously, during a radioactive decay, an unstable nucleus becomes a more stable nucleus in a process that occurs randomly and spontaneously. As a result, the number of unstable nucleus in a sample of radioactive substance decreases with time. The half-life of a radioactive sample is defined as *the time taken for the number of unstable nucleus in the sample to reduce to half of its original number*.

e.g., Antimony-133 has a half-life of 2.5 minutes



Applications of radioisotopes

1) In archaeology
   Carbon-14 is used for carbon dating
2) In industry
   Monitoring content of food
3) In medicine
   Radiotherapy
4) In agriculture
5) Pest control

2.0 Nuclear energy

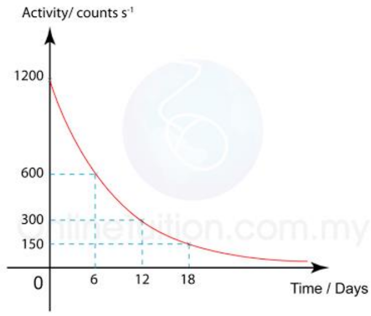
Atomic mass unit (u) is a special unit used to measure the mass of an atom. 1 u defined as 1/12 of the mass of a C-12 atom. Hence, 1 u is equivalent to 1.66×10^{-27} kg given that the mass of a C-12 atom is 1.993×10^{-26} kg.

Nuclear fission is a process involving the splitting of a heavy nucleus into two nuclei. Both smaller nuclei have almost equal mass. Nuclear fission starts when a heavy nucleus is bombarded by a neutron. When the nucleus of U-235 is bombarded by a neutron, the nucleus of U-236 is produced. The nucleus of U-236 is unstable and disintegrates quickly. When the unstable U-236 nucleus disintegrates, it fragments into two smaller nuclei such as barium-141 and krypton-92. During the process new neutrons are also produced thus continuing the process.

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{144}_{56}Ba + ^{89}_{36}Kr + 3^{1}_{0}n + Energy$$

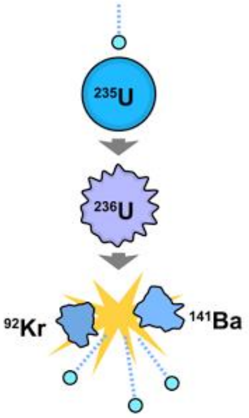
$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{140}_{54}Xe + ^{94}_{38}Sr + 2^{1}_{0}n + Energy$$

A radioisotope has half-life of 8 hours. Initially, there were 3.6×10^{18} radioisotope atoms in a sample. How much time is taken for the number of atoms of the radioisotope to fall to 4.5×10^{17}?



The diagram shows the graph of the activity of a radioisotope, X, against time. What is the half-life of the radioisotope substance?

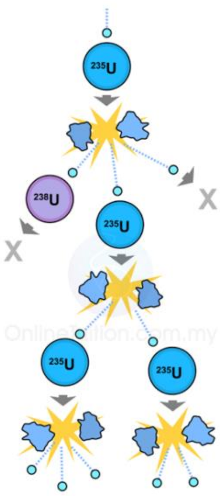
A piece of wood found in a cave of an archaeology site has a C-14 activity of 25% of the activity from a live plant. Estimate the age of the wood. Half-life of C-14 = 5730 years.



Hint: This part is a potential essay question in exam

Chain reaction

- When a neutron is bombarded into a nucleus of U-235, the nucleus becomes unstable and undergoes fission.
- Two smaller nuclei of almost equal mass along with neutrons are produced.
- The new neutrons produced then bombard other U-235 nucleus which continues the process/
- This self-sustaining reaction is called chain reaction.
- A chain reaction is a reaction in which the products of the reaction can initiate another similar reaction to occur.



Nuclear fusion is a reaction where two or more small and light nuclei combine to form a heavier nucleus. Nuclear fusion also releases a huge amount of energy. One example of fusion is the reaction between hydrogen-1 and hydrogen-2 that produces helium-3 nucleus. Note that the downside of fusion is that it can only occur at a very high temperature. For example the fusion of H-2 nuclei requires a temperature higher than 50 million degree Celsius.

$$ {}^{1}_{1}H + {}^{2}_{1}H \rightarrow {}^{3}_{2}He + \gamma $$

The mass of a U-235 atom is 235.043925 u. Calculate the mass of a U-235 atom in kg.

How to calculate nuclear energy produce

Simple use

$$e = mc^2$$

Here e is the energy produced, c is the speed of light and m is the mass defect.

Mass defect is the *mass before and after the nuclear reaction.* A mass difference is present due to a slight decrease in total mass of the system as the mass has been converted into nuclear energy.

Note: Please do not confuse mass defect with the total mass of uranium…….

e.g., you are given a nuclear fusion reaction

$$^2_1H + ^3_1H \rightarrow ^4_2He + ^1_0n$$

Determine the mass defect in amu

Mass of ^2_1H = 2.014101u

Mass of ^3_1H = 3.016049u

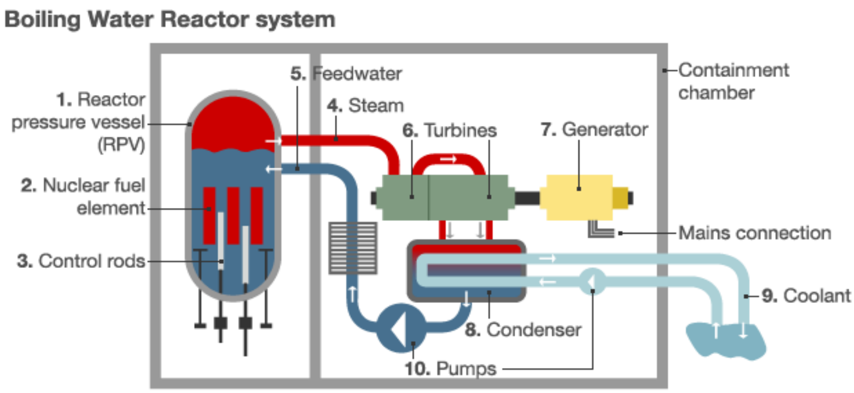
Mass of ^4_2He = 4.002602u

Mass of ^1_0n = 1.008664u

Mass defect is therefore *mass before – mass after nuclear reaction*

2.014101 amu + 3.016049 amu – 4.002602 amu - 1.008664 amu = 0.018884 amu

Generation of electricity from nuclear fission



In a nuclear reaction, the mass difference in the reaction is 1.5×10^{-8} kg. Find the heat released in this reaction

A nuclear explosion released 8.2×10^{13} J of energy. What is the mass defect of U-235 in this reaction?