National Junior College
JC 2 Term 2 Physics Topical Quiz 1
Nuclear Physics

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Total Marks: 11 / 18

Time: 20 mins

Useful Constants:

Unified atomic mass constant, u	1.66×10^{-27} kg
Speed of light in free space, c	3.00×10^{8} ms^{-1}

1a. Explain what is meant by

(i) the radioactive decay of a nucleus [1]

The ~~disintegr~~ spontaneous ~~dis~~ and random disintegration of a large unstable nucleus into smaller, more stable nuclei ~~with a release of energy~~ unstable parent nucleus undergoes spontaneous disintegration to form stable daughter nuclei.

(ii) nuclear fission. [1]

The ~~controlled~~ disintegration of a heavy ~~large~~ unstable ~~nuclei~~ nucleus into smaller, more stable lighter nuclei with higher binding energy, accompanied by a release of energy.

1b. The equation shows a typical fission reaction for uranium.

$$^{235}U+{}_0^1n\rightarrow{}_{55}^{141}Cs+{}_{37}^{93}Rb+2\left({}_0^1n\right)$$

Given:

Atomic mass of ^{141}Cs	=	140.91963 u
Atomic mass of ^{93}Rb	=	92.92157 u
Atomic mass of ^{235}U	=	235.04392 u
Mass of neutron, ${}_0^1n$	=	1.00866 u

Calculate the energy produced from the fission of 1.0 kg of ^{235}U. [4]

$235.04392uc^2 + 1.00866uc^2 = 140.91963uc^2 + 92.92157uc^2 + 2(1.00866u)c^2 + E$

Energy released ~~produced~~ $= 235.04392uc^2 + 1.00866uc^2 - 140.91963uc^2 - 92.92157uc^2 - 2(1.00866u)c^2$

$= 0.19406\,uc^2$

$= 0.19406(1.66\times10^{-27})(3.00\times10^{8})^2$

$= \cancel{2.8}\ 2.90\times10^{-11}$ J (3s.f)

Energy from 1.0 kg of $^{235}U = 2.899\times10^{-11} \times \cancel{235.04392}\ \frac{1000}{235.04392} \times 6.02\times10^{23}$

$= 7.43\times10^{13}$ J (3s.f)

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1c. When Uranium is mined, the ratio of fissionable ^{235}U to ^{238}U is 0.0072. Calculate how many years ago the ratio would have been 0.03. [4]

Half-life of ^{235}U = 7.0×10^8 years

Half-life of ^{238}U = 4.5×10^9 years

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

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

$\frac{0.0072}{0.03} = e^{-\lambda t}$

$\frac{0.0072}{0.03} = e^{-\frac{\ln 2}{4.5\times10^9} t}$

$\ln \frac{0.0072}{0.03} = -t \frac{\ln 2}{4.5\times10^9}$

$t = 9.27 \times 10^9$ years (3s-f)

For ^{235}U, $\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

$= 9.9 \times 10^{-10}\ y^{-1}$

$N_{235} = N_0 e^{-\lambda t}$ — (1)

For ^{238}U, $\lambda_{238} = \frac{\ln 2}{t_{\frac{1}{2}}}$

$= 1.5 \times 10^{-10}\ y^{-1}$

$N_{238} = N_0 e^{-\lambda t}$ — (2)

$\frac{N_{235}}{N_{238}} = \frac{(N_0)_{235}}{(N_0)_{238}} e^{-(\lambda_{235} - \lambda_{238})t}$

$0.0072 = 0.03 e^{-(9.9-1.5)\times10^{-10} t}$

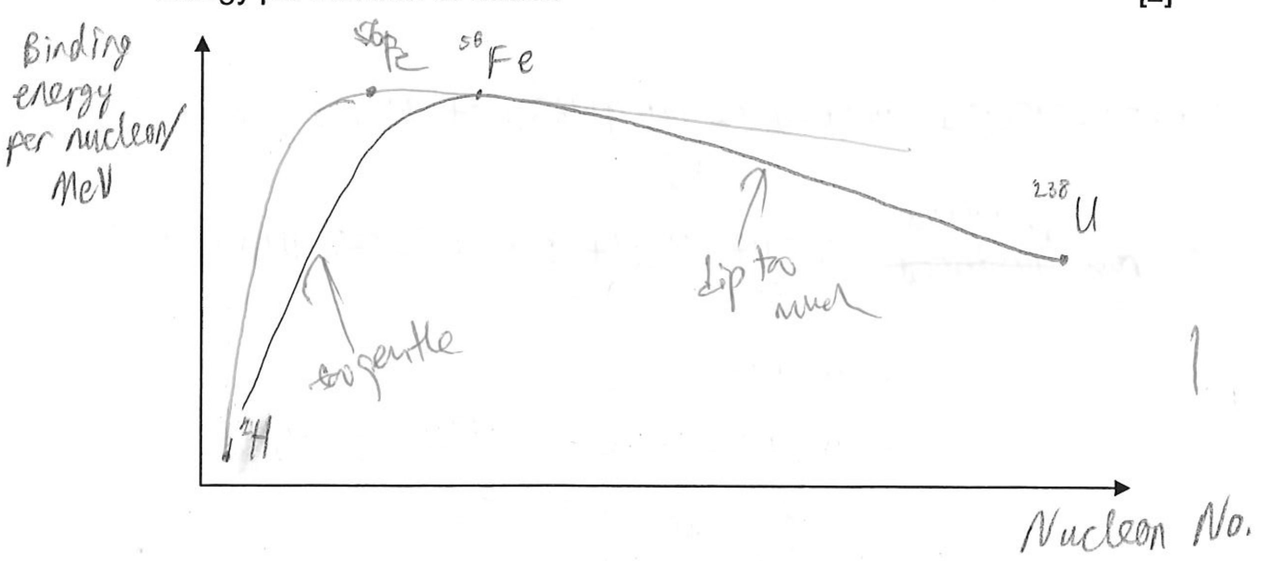
$t = 1.7 \times 10^9$ years

2a. State what is meant by the binding energy per nucleon of a nucleus. [1]

The amount of energy required to separate a nucleus into its constituent ~~nt~~ neutrons to infinite distance from each other divided by the total number of neutrons in the nucleus.

- ratio of binding energy of nucleus to no. of nucleons in that nucleus
- average energy needed to separate nucleus into individual nucleons

2b. Sketch a graph to show the variation with nucleon number of the binding energy per nucleon of nuclei. [2]



2c. By reference to your graph, explain how the process of nuclear fission may result in the release of energy. [2]

The binding energy per nucleon of heavier nuclides is less than the binding energy per nucleon of ~~56~~ 56 Fe. Nuclear fission may result in release of energy as the heavier nuclides disintegrate to form lighter nuclides with higher binding energy per nucleon, as the difference in energy is released. form nuclei of ↑ binding energy per nucleon as product nuclei have smaller nucleon no.

- energy required to break reactant nuclide < energy released in formation of product nuclides

2d. When Uranium-235 nuclei are fissioned by slow moving neutrons, the Uranium nucleus gives, among other fission products, a Strontium-90 nucleus and a Xenon-143 nucleus. The following information are also provided:

Type of nuclei	Binding energy per nucleon/ MeV
$^{235}_{92}U$	7.8
$^{90}_{38}Sr$	8.9
$^{143}_{54}Xe$	9.0

(i) Write down the nuclear equation for the above process. [1]

$$^{235}_{92}U + ^{1}_{0}n \longrightarrow ^{90}_{38}Sr + ^{143}_{54}Xe + 3(^{1}_{0}n)$$

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(ii) Use the values provided in the table to calculate the energy released during this fission process. [2]

$E + 235(7.8) = 90(8.9) + 143(9.0)$ ~~ΔE~~

Energy released $= 255$ MeV

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Energy released $= \Delta mc^2$

$= [\text{rest } m(\text{reactant}) - \text{rest } m(\text{pdt})]c^2$

OR $BE(\text{pdt}) - BE(\text{reactant})$

$A_{pdt}\left(\frac{BE}{N}\right) - A_{reactant}\left(\frac{BE}{N}\right)$