NUCLEAR PHYSICS

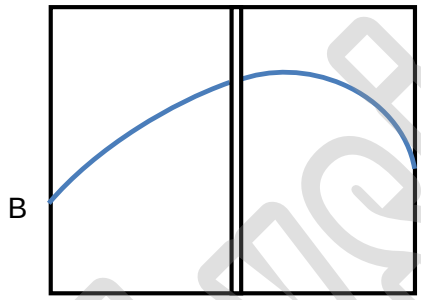
Challenging **MCQ** questions by The Physics Cafe

Compiled and selected by The Physics Cafe

1 The activity of a radioactive sample decreases to one third of its original activity A_o in a period of 3 years. After 3 more years, its activity would be

A $\frac{1}{9}A_0$ **B** $\frac{1}{6}A_0$ **C** $\frac{1}{3}A_0$ **D** $\frac{2}{3}A_0$

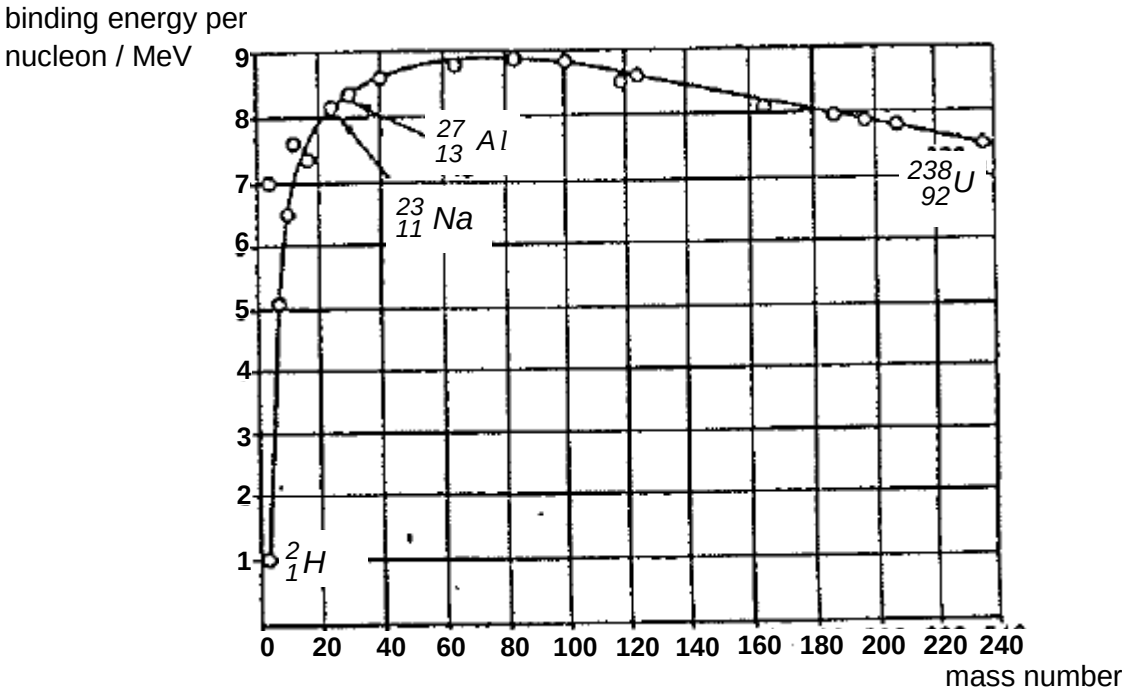
2 Radiation from a radioactive source enters an evacuated region in which there is a uniform magnetic field perpendicular to the plane of the diagram. This region is divided into two by a sheet of aluminum about 1 mm thick. The curved, horizontal path followed by the radiation is shown in the diagram below.



Which of the following correctly describes the type of radiation and its point of entry?

	type of radiation	point of entry
A	alpha	A
B	alpha	B
C	beta	A
D	beta	B

3 The diagram shows a graph of the binding energy per nucleon for a number of naturally occurring nuclides plotted against their mass number.



Which of the following statements is a correct deduction from the graph?

A Energy will be released if a nucleus with a mass number less than about 80 undergoes fission as a result of particle bombardment.

B Energy must be supplied for a nucleus with a mass number greater than about 80 to undergo fusion with any other nucleus.

C $^{238}_{92}U$ is the stable end-point of a number of radioactive series.

D $^{27}_{13}Al$ will spontaneously emit an alpha particle to become $^{23}_{11}Na$.

4 The probability of decay in one second of a radioactive nucleus is λ. During a particular one second interval, a nucleus does not decay.

What is the probability of decay of this nucleus during the next one second interval?

A $\frac{1}{\lambda}$ **B** λ **C** 2λ **D** λ^2

5 At time *t,* a sample of a radioactive substance contains *N* atoms of a particular nuclide.

At time $(t + \Delta t)$, where Δt is a short period of time, the number of atoms of the nuclide is $(N - \Delta N)$.

Which expression is equal to the decay constant of the nuclide?

A $\frac{\Delta N}{N}$ **B** $\frac{N - \Delta N}{t + \Delta t}$ **C** $\frac{\Delta N}{N \Delta t}$ **D** $\frac{N \Delta N}{\Delta t}$

6 Hydrogen and oxygen nuclei may result from the bombardment of nitrogen nuclei with helium nuclei. The reaction can be represented by the following nuclear equation:

$$^{14}_{7}\mathrm{N} + ^{4}_{2}\mathrm{He} \rightarrow ^{17}_{8}\mathrm{O} + ^{1}_{1}\mathrm{H}$$

The speed of light is *c*, and the masses of the particles are:

Nitrogen : m_N

Helium : m_{He}

Hydrogen : m_H

Oxygen : m_O

What is the net energy released during such a reaction?

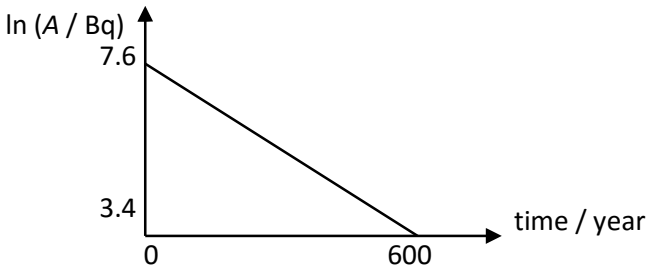
A $[m_H + m_O - (m_N + m_{He})]c^2$

B $[(m_N + m_{He}) - (m_H + m_O)]c^2$

C $(m_H + m_O + m_N + m_{He})c^2$

D $\frac{[m_N + m_{He} - (m_H + m_O)]}{c^2}$

7 A graph of the natural logarithm of the activity *A* of a radioactive source plotted against time is given.



What is the half-life of the source in years?

A 99 **B** 186 **C** 300 **D** 517

8 A sample of a radioactive nuclide X has the same initial activity as a sample of a radioactive nuclide Y. The sample of X contains twice the number of atoms as the sample of Y. If the half-life of X is *T* then the half-life of Y is

A 2*T* **B** 1.5 *T* **C** *T* **D** 0.5 *T*

9 A radioactive isotope can be used as a trace element in the fields of medicine, agriculture and industries. Radioactive isotope when used within a plant or animal allows an observer to follow the movement of certain chemicals. In the selection of such a radioactive isotope, which of the following is given the least consideration?

A Daughter nuclide of nucleus.

B Half-life of radioisotope.

C Intensity of radiation emitted.

D Mass of the radioactive isotope.

10 What is not conserved in nuclear processes?

A charge

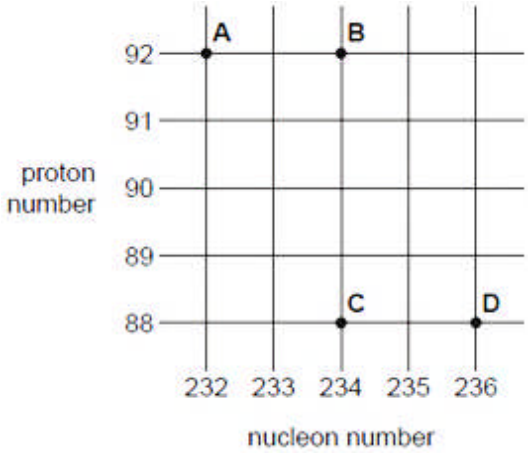
B energy and mass together

C neutron number

D nucleon number

11 Thorium-234 ($^{234}_{90}Th$) decays by β-emission into a daughter product which in turn decays by further β-emission into a granddaughter product.

Which letter in the diagram represents the granddaughter product?



12 In the alpha-particle scattering experiment, it was observed that most of the alpha particles pass through the thin gold foil with small deflections.

Which of the following is not a correct conclusion inferred from the experiment?

A The overall charge of an atom is neutral.

B The diameter of the gold nucleus is much smaller than the diameter of the gold atom.

C Almost all the mass of the gold atom is concentrated in its nucleus.

D The gold nucleus has a positive charge.

13 X, Y and Z are typical nuclear particles or radiations emitted during nuclear processes. The table below lists their properties.

	X	Y	Z
Affected by electric and magnetic fields	No	No	Yes
Mass	u	zero	$0.0005u$
Speed	$0.1c$	c	$0.7c$

Which of the following correctly identifies the particles or radiations labelled X, Y and Z?

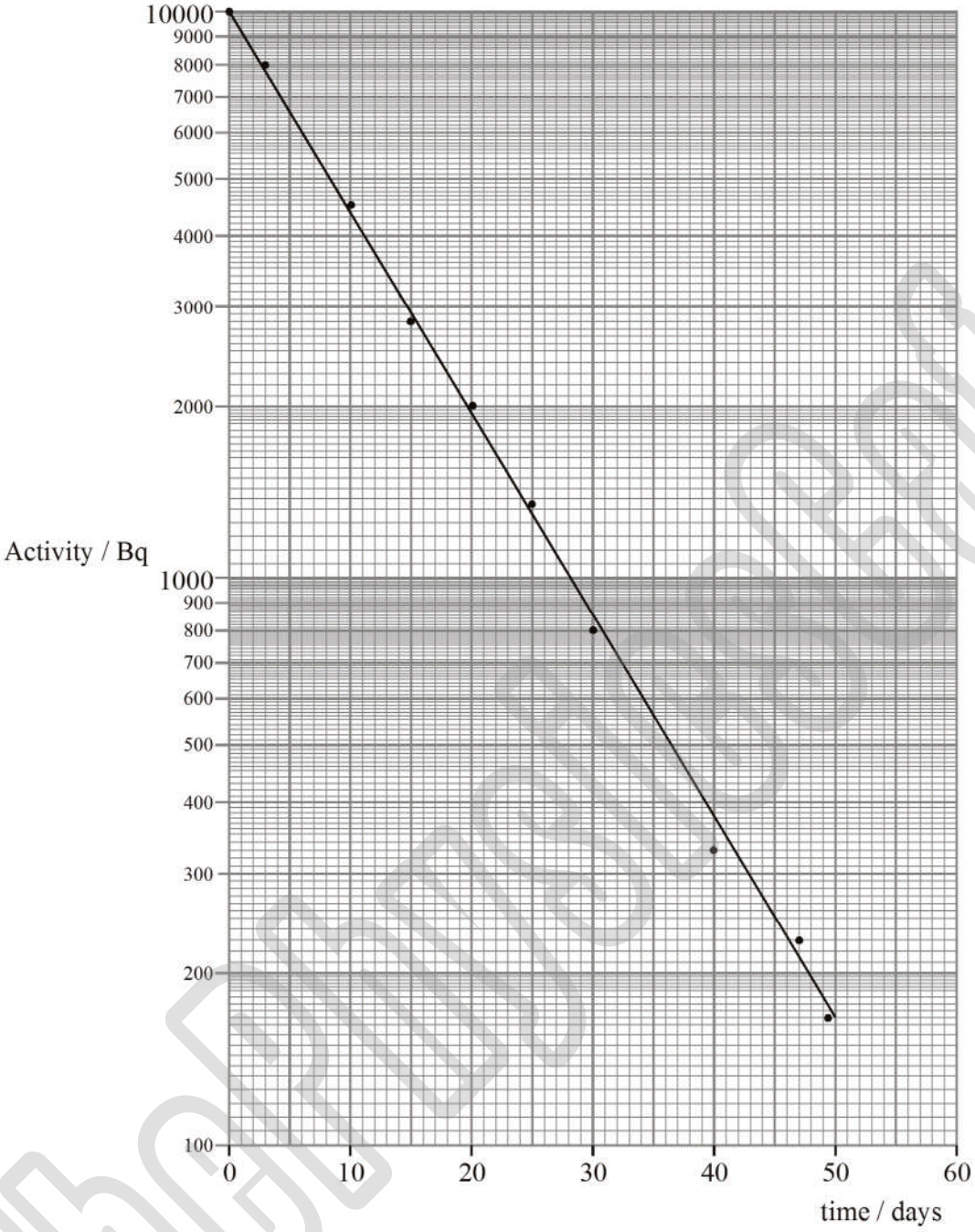
	X	**Y**	**Z**
A	neutron	γ-photon	electron
B	γ-photon	electron	neutron
C	α-particle	neutron	γ-photon
D	electron	α-particle	α-particle

14 Radon $^{222}_{86}Rn$ decays by $\alpha-$ and $\beta-$emission to bismuth $^{214}_{83}Bi$.

For the decay of each nucleus of radon, how many $\alpha-$ and $\beta-$particles are emitted

	$\alpha-$ particles	$\beta-$particles
A	1	1
B	2	1
C	1	2
D	2	2

15 The activity of a sample of Iodine-131 varies with time as shown. The activity scale is logarithmic.



What is the approximate half-life of Iodine-131?

A 8 days **B** 28 days **C** 55 days **D** 180 days

NUCLEAR PHYSICS WORKED SOLUTIONS

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1 Ans: **A**

Apply $I = I_o e^{-\lambda t}$ when $t = 3$ and $t = 6$

2 Ans: **D**

It is beta as the particles are able to penetrate through the thin film of aluminum where alpha particles will be stopped by the aluminum film.

Entry is at B because the beta particles lose energy after passing through the aluminum. Hence, they have a lower speed and hence, a smaller radius, greater curvature of path under the influence of magnetic field. ($Bqv = \frac{mv^2}{r} \Rightarrow r = mv / Bq$)

3 Ans: **B**

A Incorrect. When a nucleus with a mass number less than about 80 splits into smaller nuclei, there is a decrease in the binding energy per nucleon, hence, energy is required to trigger the fission process i.e. energy is absorbed..

B Correct. When a nucleus with a mass number greater than 80 fuses with another nucleus, there is a decrease in the binding energy per nucleon, hence, energy is required to trigger this fusion process.

C Incorrect. For $^{238}_{92}U$ to be the daughter nucleus of a radioactive decay, the parent nucleus has to have a greater mass number than 238. However, from the graph, $^{238}_{92}U$ is the nucleus with greatest mass number. Hence, it is not the stable end-point of a number of radioactive series.

D Incorrect. $^{27}_{13}Al$ is more stable than $^{23}_{11}Na$. Hence, the former will not spontaneously emit an alpha particle to become the latter.

4 Ans: **B**

Radioactive decay is a random process where the probability of decay per unit time is constant.

5 Ans: **C**

Definition of decay constant: It is the fraction of the total number of undecayed nuclei present which decays per unit time. Suppose N is the size of a population of radioactive atoms at a given time t, and dN is the amount by which the population decreases in time dt; then the rate of change is given by the equation $\frac{dN}{dt} = -\lambda N$, where λ is the decay constant.

$$\frac{dN}{dt} = -\lambda N$$

$$\lambda = -\frac{\frac{dN}{dt}}{N} = \frac{\frac{\Delta N}{\Delta t}}{N}$$

$$= \frac{\Delta N}{N \Delta t}$$

6 Ans: **B**

The net energy released

$= \Delta mc^2$

$= [(m_N + m_{He}) - (m_{H+} m_O)]c^2$

7 Ans: **A**

8 Ans: **D**

9 Ans: **D**

10 Ans: **C**

Except for the neutron number, the energy and mass together, nucleon number and charge are conserved.

11 Ans: **B**

$^{234}_{90}\text{Th} \rightarrow {}^{234}_{91}\text{X} + {}^{0}_{-1}\text{e}$

$^{234}_{91}\text{X} \rightarrow {}^{234}_{92}\text{Y} + {}^{0}_{-1}\text{e}$

12 Ans: **A**

A is not proven using this experiment. **C** and **D** are proven by the other result from this experiment, that is, a very small fraction of the alpha particles undergo large deflections.

13 Ans: **A**

Recall properties of neutron (X), γ-photon (Y) and electron (Z).

14 Ans: **B**

$^{222}_{86}\text{Rn} \rightarrow {}^{214}_{83}\text{Bi} + 2\,{}^{4}_{2}\text{He} + {}^{0}_{-1}\text{e}$

15 Ans: **A**

8 DAYS