Short Answer Questions – II (PYQ)

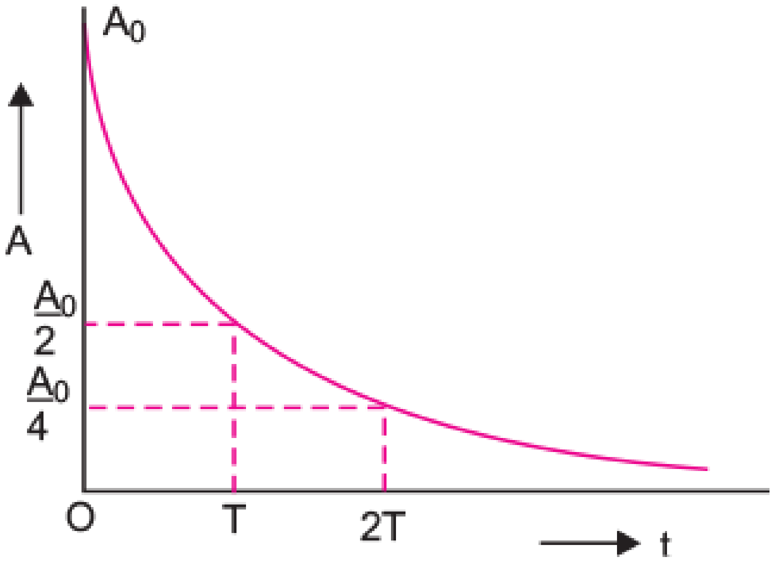
Q. 1. Define the term 'Activity' of a radioactive substance. State its SI unit. Give a plot of activity of a radioactive species versus time. [CBSE Delhi 2010, (AI) 2009]

Two different radioactive elements with half-lives T_1 and T_2 have N_1 and N_2 (undecayed) atoms respectively present at a given instant. Determine the ratio of their activities at this instant. [CBSE (F) 2016]

Ans. The activity of a radioactive element at any instant is equal to its rate of decay at that instant.

SI unit of activity is **Becquerel** (= 1 disintegration/second).

The plot is shown in fig.



Activity $\quad R\left(=\frac{\mathrm{dN}}{\mathrm{dt}}\right)=\lambda N$

Decay constant $\lambda=\frac{\log_e 2}{T}$

$\therefore$ Activity $\quad R=\frac{(\log_e 2)N}{T}$

$$\therefore \quad R_1=\frac{(\log_e 2)N_1}{T_1}, \quad R_2=\frac{(\log_e 2)N_2}{T_2}$$

For two elements $\frac{R_1}{R_2}=\frac{N_1}{T_1}\times\frac{T_2}{N_2}=\left(\frac{N_1}{N_2}\right)\left(\frac{T_2}{T_1}\right)$

Q. 2. Answer the following questions

A radioactive nucleus 'A' undergoes a series of decays as given below:

$$A \xrightarrow{\alpha} A_1 \xrightarrow{\beta} A_2 \xrightarrow{\alpha} A_3 \xrightarrow{\gamma} A_4$$

(i) The mass number and atomic number of A_2 are 176 and 71 respectively. Determine the mass and atomic numbers of A_4 and A.

(ii) Write the basic nuclear processes underlying β^+ and β^- decays.

Ans. (i) If we consider β– decay, the decay scheme may be represented as

$$^{180}_{72}A \xrightarrow{\alpha} {}^{176}_{70}A_1 \xrightarrow{\beta} {}^{176}_{71}A_2 \xrightarrow{\alpha} {}^{172}_{69}A_3 \xrightarrow{\gamma} {}^{172}_{69}A_4$$

A_4 : Mass Number = 172

Atomic Number = 69

A : Mass Number = 180

Atomic Number = 72

If we consider β+ decay, then

$$^{180}_{74}A \xrightarrow{\alpha} {}^{176}_{72}A_1 \xrightarrow{\beta^+} {}^{176}_{71}A_2 \xrightarrow{\alpha} {}^{172}_{69}A_3 \xrightarrow{\gamma} {}^{172}_{69}A_4$$

A_4 : Mass Number = 172

Atomic Number = 69

A : Mass Number = 180

Atomic Number = 74

(ii)

Basic nuclear process for β+ decay, $p \rightarrow n + {}_{1}^{0}e + \nu$

For β^{-} decay, $n \rightarrow p + {}_{-1}^{0}e + \bar{\nu}$

Q. 3. Answer the following questions

(i) Write the process of β⁻-decay. How can radioactive nuclei emit β-particles even though they do not contain them? Why do all electrons emitted during β-decay not have the same energy?

(ii) A heavy nucleus splits into two lighter nuclei. Which one of the two–parent nucleus or the daughter nuclei has more binding energy per nucleon? [CBSE (F) 2017]

Ans. (i) In β^- decay, the mass number *A* remains unchanged but the atomic number *Z* of the nucleus goes up by 1. A common example of β^- decay is

$$ {}_{15}^{32}P \rightarrow {}_{16}^{32}S + e^{-} + \bar{\nu} $$

A neutron of nucleus decays into a proton, an electron and an antineutrino. It is this electron which is emitted as β^- particle.

$$ {}_{0}^{1}n \rightarrow {}_{1}^{1}p + {}_{-1}^{0}e + \bar{\nu} $$

In β^-decay, particles like antineutrinos are also emitted along with electrons. The available energy is shared by electrons and antineutrinos in all proportions. That is why all electrons emitted during β^- decay not have the same energy.

(ii) Parent nucleus has lower binding energy per nucleon compared to that of the daughter nuclei. When a heavy nucleus splits into two lighter nuclei, nucleons get more tightly bound.

Q. 4. In a typical nuclear reaction, e.g.

$$_1^2H + _1^2H \rightarrow \; _2^3\text{He} + n + 3.27 \;\; \text{MeV} \, ,$$

Although number of nucleons is conserved, yet energy is released. How? Explain.
[CBSE Delhi 2013]

Ans. In nuclear reaction

Cause of the energy released:

(i) Binding energy per nucleon of becomes more than the (BE/A) of $_1^2$H.

(ii) Mass defect between the reactant and product nuclei

$\Delta E = \Delta m \; c^2$

$$= [2m(\,_1^2H) - \; m(_2^3\,\text{He}\,) + m(n)]c^2$$

Q. 5. Answer the following questions [CBSE (F) 2017]

(i) State the law of radioactive decay. Write the SI unit of 'activity'.

(ii) There are $4\sqrt{2} \times 10^6$ radioactive nuclei in a given radioactive sample. If the half-life of the sample is 20 s, how many nuclei will decay in 10 s?

Ans.

Given, $t_{1/2} = 20s$

Also, $t_{1/2} = \frac{\ln\ 2}{\lambda} = \frac{0.693}{\lambda} \quad \Rightarrow \quad \lambda = \frac{\ln\ 2}{t_{1/2}} \quad \Rightarrow \quad \lambda = \frac{\ln\ 2}{20}$

Also, according to equation of radioactivit

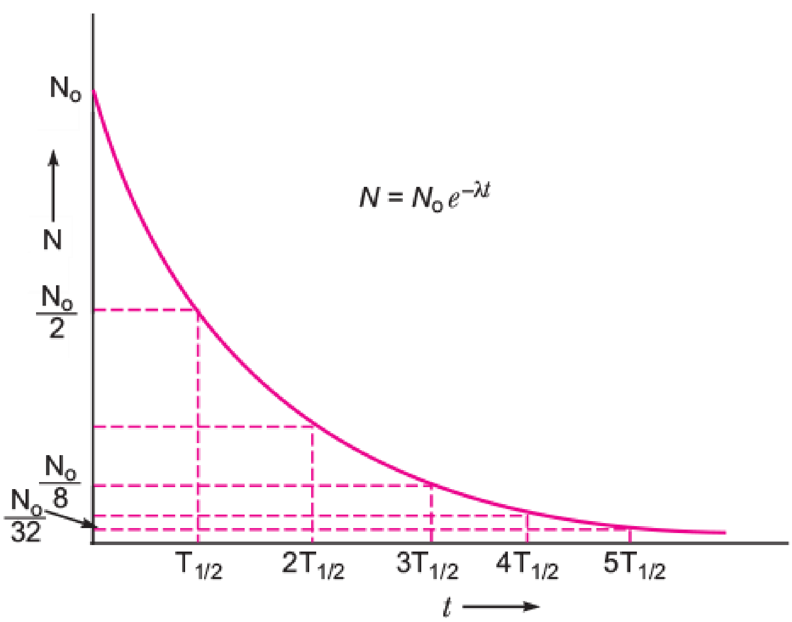
$$N = N_0 e^{-\lambda t}$$

$$N = 4\sqrt{2} \times 10^6 \times e^{-\frac{\ln 2}{20} \times 10}$$

$$= 4\sqrt{2} \times 10^6 \times \frac{1}{\sqrt{2}} = 4 \times 10^6 \text{ Nuclei}$$

Q. 6. State the law of radioactive decay. Plot a graph showing the number (N) of undebased nuclei as a function of time (t) for a given radioactive sample having half-life $T_{1/2}$. Depict in the plot the number of undecayed nuclei at [CBSE Delhi 2011]

(i) t = 3T1/2and
(ii) t = 5T1/2.



Ans. For the Law refer to above question.

Number of undecayed nuclei at

$t = 3T_{1/2}$ is $\frac{N_0}{8}$ and at $t = 5T_{1/2,}$ it is $\frac{N_0}{32}$.

Q. 7. Answer the following questions [CBSE Guwahati 2015]

In the following nuclear reaction

$$n + {}^{235}_{92}U \rightarrow {}^{144}_{Z}\text{Ba} + {}^{A}_{36}X + 3n,$$

(i) Assign the values of Z and A.

(ii) If both the number of protons and the number of neutrons are conserved in each nuclear reaction, in what way is the mass converted into energy? Explain.

Ans. (i)

$$n + {}^{235}_{92}U \rightarrow {}^{144}_{Z}\text{Ba} + {}^{A}_{36}X + 3n,$$

From law of conservation of atomic number

0 + 92 = Z + 36

⇒ Z = 92 – 36 = 56

From law of conservation of mass number,

1 + 235 = 144 + A + 3 × 1

A = 236 – 147 = 89

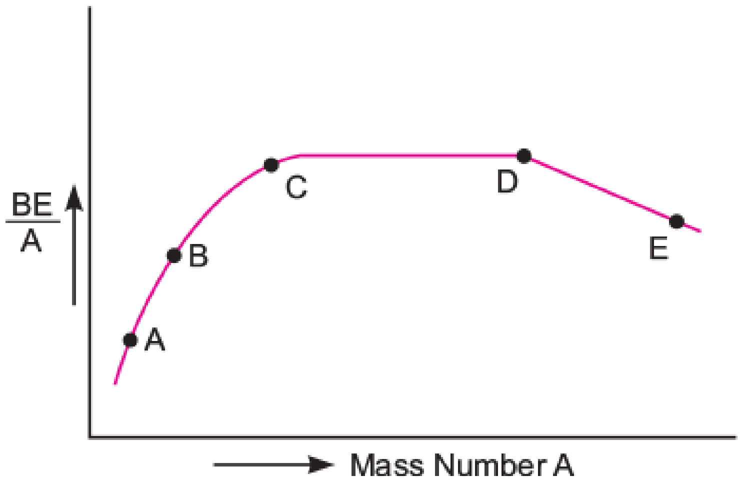
(ii)

i. BE of ${}_{92}{}^{235}U <$ BE of $({}_{56}{}^{144}\text{Ba} + {}^{89}_{36}X)$ and due to difference in BE of the nuclides. A large amount of the energy will released in the fission of ${}_{92}{}^{235}U$.

(ii) Mass number of the reactant and product nuclides are same but there is an actual mass defect. This difference in the total mass of the nuclei on both sides, gets converted into energy, i.e., $\Delta E = \Delta mc^2$.

Q. 8. Answer the following questions [CBSE Ajmer 2015]

(i) The figure shows the plot of binding energy (BE) per nucleon as a function of mass number A. The letters A, B, C, D and E represent the positions of typical nuclei on the curve. Point out, giving reasons, the two processes (in terms of A, B, C, D and E), one of which can occur due to nuclear fission and the other due to nuclear fusion.



(ii) Identify the nature of the radioactive radiations emitted in each step of the decay process given below:

$${}^{A}_{Z}X \rightarrow {}^{A-4}_{Z-2}Y \rightarrow {}^{A-4}_{Z-1}W$$

Ans. (i)

If a heavy nuclei of low $\frac{BE}{A}$ splits up into two fragments, then $\frac{BE}{A}$ of the product nuclei increases and becomes stable. So,

$$E \rightarrow C + D$$

If two nuclei of low $\frac{BE}{A}$ fuse together, the of the $\frac{BE}{A}$ product nuclei increases and becomes stable. So,

$$A + B \rightarrow C$$

(ii) If atomic number decreases by 2 and mass number decreases by 4 an alpha particle is emitted out. So,

$${}^{a}_{z}X \xrightarrow{\alpha} {}^{A-4}_{Z-2}Y$$

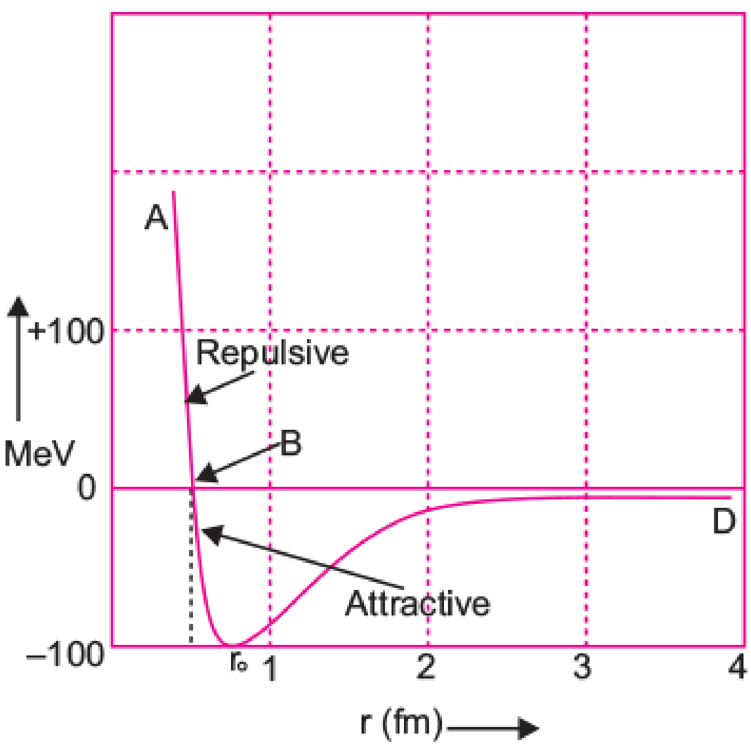
If a β– is emitted out, the atomic number increases by 1, while mass number remains unchanged. So,

$$ {}^{a-4}_{z-2}Y \xrightarrow{\beta} {}^{A-4}_{Z-1}W $$

Q. 9. Draw a graph showing the variation of potential energy between a pair of nucleons as a function of their separation. Indicate the regions in which the nuclear force is
(i) Attractive,
(ii) Repulsive.

Write two important conclusions which you can draw regarding the nature of the nuclear forces. [CBSE (AI) 2009, 2010, 2012, Allahabad 2015]

Ans.



Conclusions:

(i) The potential energy is minimum at a distance r0 of about 0.8 fm.

(ii) Nuclear force is attractive for distance larger than r0.

(iii) Nuclear force is repulsive if two are separated by distance less than r0.

(iv) Nuclear force decreases very rapidly at r0/equilibrium position.

Q. 10. Define the activity of a radioactive sample. Write its SI unit.

A radioactive sample has activity of 10,000 disintegrations per second (dps) after 20 hours. After next 10 hours its activity reduces to 5,000 dps. Find out its half-life and initial activity. [CBSE Bhubaneshwar 2015]

Ans. The activity of a radioactive element at any instant is equal to its rate of decay at that instant. SI unit of activity is Becquerel.

Let R_0 be initial activity of the sample, and its activity at any instant 't' is

$R = R_0 \, e^{-\lambda t}$

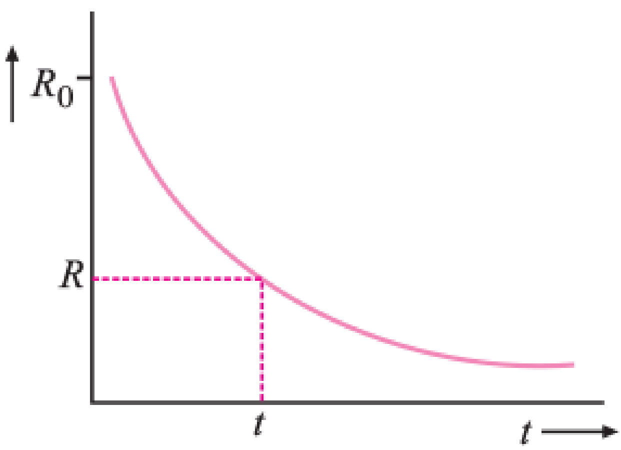
If t=20 h, then R=10000.

So, $10000 = R_0 \, e^{-\lambda \times 20}$ …(*i*)

After next 10 h, *i.e.*, at time t'=30 h R'=5000

∴ $5000 = R_0 \, e^{-\lambda \times 30}$ …(*ii*)

Dividing (i) by (ii), we get



$$\frac{10000}{5000} = \frac{e^{-20\lambda}}{e^{-30\lambda}} = e^{10\lambda}$$

On taking log on both side

$10\lambda = \lambda \log_e 2$

As we know that

$\lambda T_{1/2} = \log_e 2$

$\therefore \quad T_{1/2} =$ **10 h**

From initial time t=0 to t=20 h, there are two half-lives.

So, $\frac{R}{R_0} = \left(\frac{1}{2}\right)^2$ or $\frac{10,000}{R_0} = \frac{1}{4}$

Initial activity at t=0 is

$$R_0 = 4 \times 10000 = \mathbf{40000} \text{ dps}$$

Q. 11. In a given sample, two radioisotopes, A and B, are initially present in the ratio of 1:4. The half-lives of A and B are respectively 100 years and 50 years. Find the time after which the amounts of A and B become equal. [CBSE (F) 2012]

Ans. We have $N = N_0 e^{-\lambda t}$

For radio isotopes A and B, we can write

$$N_A = N_0 e^{-\lambda_A t_A} \qquad ...(i)$$

$$N_B = 4N_0 e^{-\lambda_B t_B} \qquad ...(ii)$$

Let t be the time after which $N_A = N_B$

$t_A = t_B = t$ (say)

$$\therefore \quad N_0 e^{-\lambda_A t} = 4N_0 e^{-\lambda_B t} \quad \Rightarrow \quad 4 = e^{\lambda_B t - \lambda_A t}$$

$$\Rightarrow \text{loge } 4 = (\lambda_B t - \lambda_A t) \log_e e$$

$$\Rightarrow 2\log_e 2 = \left[\frac{\log_e 2}{T_{B_{1/2}}} - \frac{\log_e 2}{T_{A_{1/2}}}\right]t \quad [\because \lambda = \frac{\log_e 2}{T}]$$

$$\Rightarrow 2 = \left(\frac{1}{50} - \frac{1}{100}\right)t \quad \Rightarrow \quad 2 = \left(\frac{2-1}{100}\right)t$$

$$\Rightarrow t = 200 \text{ years}$$

Short Answer Questions – II (OIQ)

Q. 1. Define half-life of a radioactive sample. Which of the following radiations: α-rays, β-rays and γ-rays

(i) are similar to X-rays
(ii) are easily absorbed by matter
(iii) travel with the greatest speed
(iv) are similar in nature to cathode rays?

Ans. Half-life: The half-life of a radioactive sample is defined as the time in which the mass of sample is left one half of the original mass.

(i) γ-rays are similar to X-rays

(ii) α-rays are easily absorbed by matter.

(iii) γ-rays travel with greatest speed

(iv) β-rays are similar to cathode rays.

Q. 2. The following table shows some measurements of the decay rate of a radionuclide sample. Find the disintegration constant.
[CBSE Sample Paper 2016]

Time (min)	lnR (Bq)
36	5.08
100	3.29
164	1.52
218	0

Ans.

$R = R_0 e^{-\lambda t}$

$\ln R = \ln R_0{}^{-\lambda t}$

$\ln R = -\lambda t + \ln R_0$

Slope of ln R v/s t is '$-\lambda$'

$-\lambda = \frac{0 - 1.52}{218 - 164} \quad \Rightarrow \quad \lambda = 0.028 \text{ minute}^{-1}$

Q. 3. A radioactive material is reduced to $\frac{1}{16}$ of its original amount in 4 days. How much material should one begin with so that 4×10^{-3} kg of the material is left after 6 days?

Ans.

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

where $n = \frac{t}{T}$is number of half lives.

Given $\frac{N}{N_0} = \frac{1}{16} = \left(\frac{1}{2}\right)^4$

∴ $\left(\frac{1}{2}\right)^4 = \left(\frac{1}{2}\right)^n$ or $n = 4$

∴ Given t=4 days ∴ $\frac{t}{T} = 4$ $\Rightarrow$ Half life, $T = \frac{t}{4} = \frac{4}{4} = 1\,\text{day}$

If m_0 is initial mass of radioactive material, then $\frac{m}{m_0} = \left(\frac{1}{2}\right)^n$.

Here $n = \frac{t}{T} = \frac{6}{1} = 6,\ m = 4\times10^{-3}$ kg

∴ $\frac{m}{m_0} = \left(\frac{1}{2}\right)^6 = \frac{1}{64}$

or m_0=64 m=64×4×10^{-3} kg=**0.256 kg**

Q. 4. Calculate the energy released if U^{238}–nucleus emits an α-particle.

OR

Calculate the energy released in MeV in the following nuclear reaction

$$^{238}_{92}U \to \,^{234}_{90}\text{Th} + \,^{4}_{2}\text{He} + Q$$

Given Atomic mass of ^{238}U =238.05079 u

Atomic mass of ^{234}Th =234.04363 u

Atomic mass of alpha particle =4.00260 u

1 u =931.5 MeV/c^2

Is the decay spontaneous? Give reason.

Ans.

The process is $^{238}_{92}U \rightarrow \ ^{234}_{90}\mathrm{Th} + ^{4}_{2}\mathrm{He} + Q$

The energy released (α – particle)

$Q = (M_U - M_{TH} - \mathrm{M_{He}})\, c^2$

$= (238.05079 - 234.04363 - 4.00260)\,\mathrm{u} \times c^2 = (0.00456\ \mathrm{u}) \times c^2$

$= 0.00456 \times \left(\frac{931.5\ \ \mathrm{MeV}}{c^2}\right).c^2 = \mathbf{4.25\ MeV}$

Yes, the decay is spontaneous (since Q is positive).