Very Short Answer Questions (PYQ)

Q. 1. Write the relationship between the size of a nucleus and its mass number (A).
[CBSE (F) 2012]

Ans. The relationship is $R = R_0 A^{1/3}$

Where R = Radius of nucleus and A = Mass number

Q. 2. How is the mean life of a radioactive sample related to its half-life?
[CBSE (F) 2011]

Ans.

Mean life (τ) and half life $(T_{1/2})$ are related as:

$$\tau = \frac{T_{1/2}}{0.6931}$$

Q. 3. Write two characteristic features of nuclear force which distinguish it from Coulomb's force. [CBSE (AI) 2011]

Ans. Characteristic Features of Nuclear Force

(i) Nuclear forces are short range attractive forces (range 2 to 3 fm) while Coulomb's forces have range upto infinity and may be attractive or repulsive.

(ii) Nuclear forces are charge independent forces; while Coulomb's force acts only between charged particles.

Q. 4. Why is it found experimentally difficult to detect neutrinos in nuclear β-decay?
[CBSE (AI) 2014]

Ans. Neutrinos are charge less (neutral) and almost massless particles that hardly interact with matter.

Q. 5. In both β^- decay processes, the mass number of a nucleus remains same whereas the atomic number Z increases by one in β^- decay and decreases by one in β^+ decay. Explain, giving reason. [CBSE (F) 2014]

Ans. In both processes, the conversion of neutron to proton or proton to neutron inside the nucleus.

$${}^{A}_{Z}X \rightarrow \beta^{-} + {}^{A}_{Z+1}Y + \bar{\nu}$$

$${}^{A}_{Z}X \rightarrow \beta^{+} + {}_{Z-1}{}^{A}Y + \bar{\nu}$$

Q. 6. The radioactive isotope D-decays according to the sequence.

$$\boldsymbol{D \overset{a}{\rightarrow} D^{1} \overset{B}{\rightarrow} D^{2}}$$

If the mass number and atomic number of D2 are 176 and 71 respectively, what is the (i) Mass number? (ii) Atomic number, of D? [CBSE Delhi 2010]

Ans.

The sequence is represented as ${}^{A}_{Z}D \overset{\alpha}{\rightarrow} {}^{A-4}_{Z-2}D_{1} \overset{\beta}{\rightarrow} {}^{A-4}_{Z-1}D_{2}$

(i) Given $A - 4 = 176 \Rightarrow$ Mass number of D, $A = 180$

(ii) $Z - 1 = 71 \quad \Rightarrow \quad$ Atomic number of D, $Z = 72$

Q. 7. Two nuclei have mass numbers in the ratio 1 : 2. What is the ratio of their nuclei densities? [CBSE Delhi 2009]

Ans. Nuclear density is independent of mass number, so ratio 1 : 1.

Q. 8. What is the nuclear radius of 125Fe, if that of 27Al is 3.6 fermi?
[CBSE (AI) 2008]

Ans.

Nuclear radius, $R = R_0 A^{1/3} \quad \Rightarrow \quad R \propto A^{1/3}$

For Al, $A = 27$, $R_{Al} = 3.6$ fermi, for Fe, $A = 125$

$$\therefore \quad \frac{R_{Fe}}{R_{Al}} = \left(\frac{A_{Fe}}{A_{Al}}\right)^{1/3} = \left(\frac{125}{27}\right)^{1/3}$$

$$\Rightarrow \quad R_{Fe} = \frac{5}{3} R_{Al} = \frac{5}{3} \times 3.6 \text{ fermi} = 6.0 \text{ fermi}$$

Q. 9. Two nuclei have mass numbers in the ratio 1 : 8. What is the ratio of their nuclear radii? [CBSE (AI) 2009]

Ans.

Nuclear radius, $R = R_0 A^{1/3}$

$$\therefore \qquad \frac{R_1}{R_2} = \left(\frac{A_1}{A_2}\right)^{1/3} = \left(\frac{1}{8}\right)^{1/3} = \frac{1}{2}$$

Q. 10. Which part of electromagnetic spectrum has largest penetrating power? [CBSE Delhi 2010]

Ans. γ-rays have largest penetrating power.

Very Short Answer Questions (OIQ)

Q. 1. Among alpha, beta and gamma radiations, which get affected by electric field?

Ans. Alpha and beta radiations are charged, so they are affected by electric field

Q. 2. What will be the ratio of radii of two nuclei of mass numbers A_1 and A_2?

Ans.

Radius of nucleus $R = R_0 A^{1/3}$

$$\Rightarrow \qquad \frac{R_1}{R_2} = \left(\frac{A_1}{A_2}\right)^{1/3}$$

Q. 3. A nucleus of mass number A, has a mass defect ∆m. Give the formula, for the binding energy per nucleon, of this nucleus.

Ans.

$$\text{BE per nucleon, } B_n = \frac{\text{Total binding energy}}{\text{Number of nucleons}} = \frac{\Delta\, mc^2}{A}$$

where c is the speed of light in vacuum.

Q. 4. The binding energy per nucleon of the two nuclei A and B are 4 MeV and 8.2 MeV. Which of the two nuclei is more stable?

Ans. The nucleus (B) having larger binding energy is more stable.

Q. 5. Write any one equation representing nuclear fusion reaction.

Ans. Equation of fusion reaction

$${}_1^2H \quad + \quad {}_1^2H \quad \rightarrow \quad {}_1^3H \quad + \quad {}_1^1H \quad + \quad 4.03\,\mathrm{MeV}$$

Q. 6. Give the mass number and atomic number of elements on the right hand side of the decay process.

$${}_{86}^{220}\mathrm{Ru} \quad \rightarrow \quad \mathrm{Po} \quad + \quad \mathrm{He}$$

Ans. The complete equation representing mass number and atomic number is given below

$${}_{86}^{220}\mathrm{Ru} \quad \rightarrow \quad {}_{84}^{216}\mathrm{Po} \quad + \quad {}_2^4\mathrm{He}$$

For Polonium $Z = 84, A = 216$

For Helium (α-particle) $Z = 2, A = 4$

Q. 7. What percentage of a given mass of a radioactive substance will be left undecayed after four half periods?

Ans. Percentage of mass of radioactive substance undecayed after n = 4 half-lives.

$$= \left(\tfrac{1}{2}\right)^4 \times 100\% = \tfrac{100}{16} = 6.25\%$$

Q. 8. If the nucleons of a nucleus are separated far apart from each other, the sum of masses of all these nucleons is larger than the mass of the nucleus. Where does this mass difference come from?

Ans. According to mass-energy equivalence relation $E = mc^2$ this mass difference in nucleus remains in the form of binding energy. When nucleons are separated this binding energy of nucleus is converted into mass.

Q. 9. Which one of the following cannot emit radiation and why? Excited nucleus, excited electron. [NCERT Exemplar]

Ans. Excited electron cannot emit radiation. This is because energy of electronic energy levels is in the range of eV only not in MeV. As γ–radiation has energy in MeV.

Q. 10. In pair annihilation, an electron and a positron destroy each other to produce gamma radiation. How is the momentum conserved? [NCERT Exemplar]

Ans. 2γ-photons are produced which move in opposite directions to conserve momentum.

Q. 11. Imagine removing one electron from He4 and He3. Their energy levels, as worked out on the basis of Bohr model will be very close. Explain why.
[NCERT Exemplar] [HOTS]

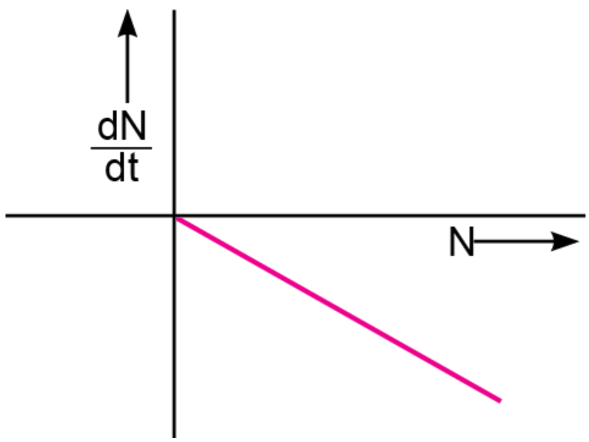
Ans. This is because both the nuclei are very heavy as compared to electron mass.

Q. 12. $^{3}_{2}\mathrm{He}$ **and** $^{3}_{1}H$ **nuclei have the same mass number. Do they have the same binding energy? [NCERT Exemplar] [HOTS]**

Ans.

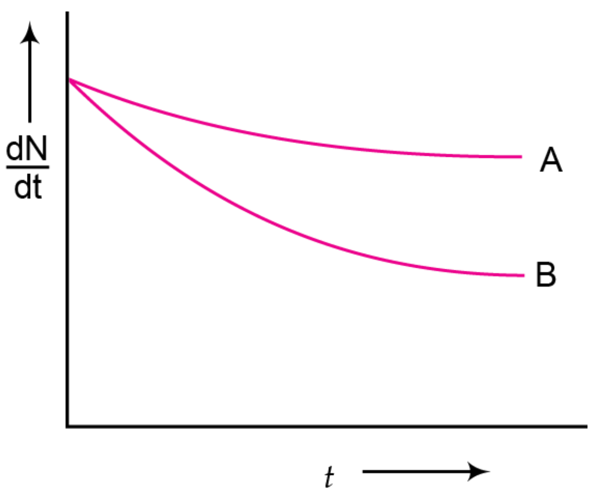
No, the binding energy of $^{3}_{1}H$ is greater. This is because $^{3}_{2}\mathrm{He}$ has 2 proton and 1 neutron, whereas $^{3}_{1}H$ has 1 proton and 2 neutron. Repulsive force between protons in $^{3}_{1}H$ is absent.

Q. 13. Draw a graph showing the variation of decay rate with number of active nuclei.
[NCERT Exemplar] [HOTS]



Ans. We know that $-\frac{dN}{dt} = \lambda N$ where λ is constant for a given radioactive material. So, the graph between $\frac{dN}{dt}$ and N is a straight line.

Q. 14. Which sample, A or B as shown in figure has shorter mean-life?
[NCERT Exemplar]



Ans. B has shorter mean life as λ is greater for B.

Short Answer Questions – I (PYQ)

Q. 1. (i) What characteristic property of nuclear force explains the constancy of binding energy per nucleon (BE/A) in the range of mass number 'A' lying 30 < A < 170?

(ii) Show that the density of nucleus over a wide range of nuclei is constant independent of mass number A. [CBSE Delhi 2012, 2015]

Ans. (i) Saturation or short range nature of nuclear forces.

(ii) The radius (size) R of nucleus is related to its mass number (A) as

$$R = R_0 A^{1/3} \qquad \text{where } R_0 = 1.1 \times 10^{-15}\ \text{m}$$

If m is the average mass of a nucleon, then mass of nucleus = mA, where A is mass number

$$\text{Volume of nucleus} = \frac{4}{3}\pi R^3 = \frac{4}{3}\pi (R_0 A^{1/3})^3 = \frac{4}{3}\pi R_0^3 A$$

$$\therefore \text{Density of nucleus, } \rho_N = \frac{\text{mass}}{\text{volume}} = \frac{\text{mA}}{\frac{4}{3}\pi R_0^3 A} = \frac{m}{\frac{4}{3}\pi R_0^3} = \frac{3m}{4\pi R_0^3}$$

Clearly nuclear density ρ_N is independent of mass number A.

Q. 2. (i) Write the basic nuclear process involved in the emission of β+ in a symbolic form, by a radioactive nucleus. [CBSE Central 2016]

(ii) In the reactions given below:

(a) ${}_{6}^{11}C \rightarrow {}_{y}^{z}B + x + \nu$

(b) ${}_{6}^{12}C + {}_{6}^{12}C \rightarrow {}_{a}^{20}\text{Ne} + {}_{b}^{c}\text{He}$

Find the values of x, y, z and a, b, c.

Ans. (i) Basic nuclear reaction for β^+ decay is the conversion of proton to neutron.

$p \rightarrow n + e^+ + \nu$

(ii)

a. $x = \beta^{+} / {}^{0}_{1}e,\ y = 5,\ z = 11$ (b) $a = 10,\ b = 2,\ c=4$

b. $a = 10,\ b = 2,\ c=4$

Q. 3. Calculate the energy in fusion reaction: [CBSE Delhi 2016]

$${}^{2}_{1}H + {}^{2}_{1}H \rightarrow {}^{3}_{2}\text{He} + n, \text{ where BE of } {}^{2}_{1}H = 2.23 \text{ MeV and of } {}^{3}_{2}\text{He} = 7.73 \text{ MeV}$$

Ans. Initial binding energy

BE_1= (2.23 + 2.23) = 4.46 MeV

Final binding energy

BE_2 = 7.73 MeV

∴ Energy released = (7.73 – 4.46) MeV = 3.27 MeV

Q. 4. Why is it found experimentally difficult to detect neutrinos in nuclear β-decay?
[CBSE (AI) 2014]

Ans. Neutrinos are charge less (neutral) and almost massless particles that hardly interact with matter.

Q. 5. State three properties of nuclear forces. [CBSE Allahabad 2015]

Ans. Properties of nuclear forces

(i) Nuclear forces are the strongest attractive forces.

(ii) Nuclear forces are short ranged upto 10^{-15} m.

(iii) Nuclear forces are charge independent.

Q. 6. Answer the following questions [CBSE (F) 2015]

(i) Write the β-decay of tritium in symbolic form.

(ii) Why is it experimentally found difficult to detect neutrinos in this process?

Ans. (i)

$$ {}_{1}^{3}H \xrightarrow{\beta} {}_{2}^{3}\mathrm{He} + {}_{1}^{0}e + \bar{\nu} + Q $$

(ii) It is due to very weak interaction with matter.

Q. 7. The half-life of ${}_{92}^{238}U$ against α-decay is 4.5×10^{9} years. Calculate the activity of 1g sample of ${}_{92}^{238}U$. [Given Avogadro's number 6×10^{26} atoms/K mol] [CBSE East 2016]

Ans.

$$ T_{1/2} = 4.5\times10^{9} \text{ years} = 4.5\times10^{9} \times 3.15\times10^{7}\text{seconds} $$

$$ \text{Number of atoms in 1 } g \text{ sample of } {}_{92}^{238}U \text{ is } N = 6.023 \times 10^{23} \times \frac{1}{238} $$

$$ \text{Activity of sample } A = \lambda N = \frac{\log_e 2}{T_{1/2}} \times N $$

$$ = \left(\frac{0.6931}{4.5\times10^{9}\times3.15\times10^{7}}\right) \times 6.023 \times 10^{23} \times \frac{1}{238} $$

$$ = 1.237\times10^{4} \text{ becquerel} $$

Q. 8. A heavy nucleus X of mass number 240 and binding energy per nucleon 7.6 MeV is split into two fragments Y and Z of mass numbers 110 and 130. The binding energy per nucleon in Y and Z is 8.5 MeV per nucleon. Calculate the energy Q released per fission in MeV. [CBSE Delhi 2010]

Ans. Energy released $Q = (M_Y + M_Z)\,c^2 - M_X\,c^2$

= 8.5 (110 + 130) MeV – 7.6 × 240 MeV

= (8.5 – 7.6) × 240 MeV

= 0.9 × 240 MeV **= 216 MeV**

Q. 9. When four hydrogen nuclei combine to form a helium nucleus, estimate the amount of energy in MeV released in this process of fusion. (Neglect the masses of electrons and neutrinos) Given:

(i) Mass of $_1^1 H$ = 1.007825 u

(ii) Mass of helium nucleus = 4.002603 u, 1 u = 931 MeV/c^2 [CBSE (F) 2011]

Ans.

Energy released $= \Delta m \times 931$ MeV

$$\Delta m = 4m = (_1^1 H) - m(_2^4 \text{He})$$

Energy released (Q) $[4.m(_1^1 H) - m(_2^4 \text{He})] \times 931 \text{ MeV}$

$$= [4 \times 1.007825 - 4.002603] \times 931 \text{ MeV}$$

= 26.72 MeV

Short Answer Questions – I (OIQ)

Q. 1. Prove that the instantaneous rate of change of the activity of a radioactive substance is inversely proportional to the square of its half-life. [HOTS]

Ans. Activity of a radioactive substance

$$R\left(=-\frac{\text{dN}}{\text{dt}}\right) = \lambda N \quad \ldots(i)$$

Rate of change of activity

$$\frac{\text{dR}}{\text{dt}} = \lambda\left(\frac{\text{dN}}{\text{dt}}\right) = \lambda.(-\lambda N) = -\lambda^2 N$$

As $\lambda = \frac{\log_e 2}{T_{1/2}}$ $\quad\therefore\quad$ $\frac{\text{dR}}{\text{dt}} = -\left(\frac{\log_e 2}{T_{1/2}}\right)^2 N$

$\therefore$ Instantaneous activity, $\frac{\text{dR}}{\text{dt}} \propto \frac{1}{T_{1/2}^2}$

Q. 2. Explain how radioactive nuclei can emit β-particles even though atomic nuclei do not contain these particles? Hence explain why the mass number of radioactive nuclide does not change during β-decay? [HOTS]

Ans. Radioactive nuclei do not contain electrons (β-particles), but β-particles are formed due to conversion of a neutron into a proton according to equation

$$^{1}_{0}n \rightarrow ^{1}_{1}p + \underset{\beta\text{-particle}}{^{0}_{-1}\beta} + \underset{\text{antineutrino}}{\bar{v}}$$

The β-particle so formed is emitted at once. In this process one neutron is converted into one proton; so that the number of nucleons in the nucleus remains unchanged; hence mass number of the nucleus does not change during a β-decay.

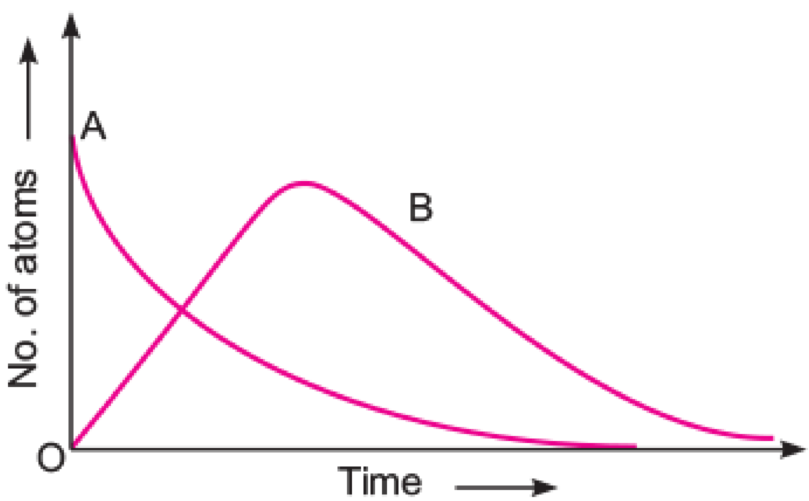
Q. 3. Why do stable nuclei never have more protons than neutrons? [NCERT Exemplar] [HOTS]

Ans. Protons are positively charged and repel one another electrically. This repulsion becomes so great in nuclei with more than 10 protons or so, that an excess of neutrons which produce only attractive forces, is required for stability.

Q. 4. Consider a radioactive nucleus A which decays to a stable nucleus C through the following sequence:

A → B → C

Here B is an intermediate nuclei which is also radioactive. Considering that there are N_0 atoms of A initially, plot the graph showing the variation of number of atoms of A and B versus time. [NCERT Exemplar] [HOTS]



Ans. At $t = 0$, $N_A = N_0$ while $N_B = 0$. As time increases, N_A falls off exponentially, the number of atoms of B increases, becomes maximum and finally decays to zero at ∞ (following exponential decay law).

Q. 5. A nuclide 1 is said to be the mirror isobar of nuclide 2 if $Z_1 = N_2$ and $Z_2 = N_1$. [NCERT Exemplar] [HOTS]

(i) What nuclide is a mirror isobar $^{23}_{11}$Na of?

(ii) Which nuclide out of the two mirror isobars has greater binding energy and why?

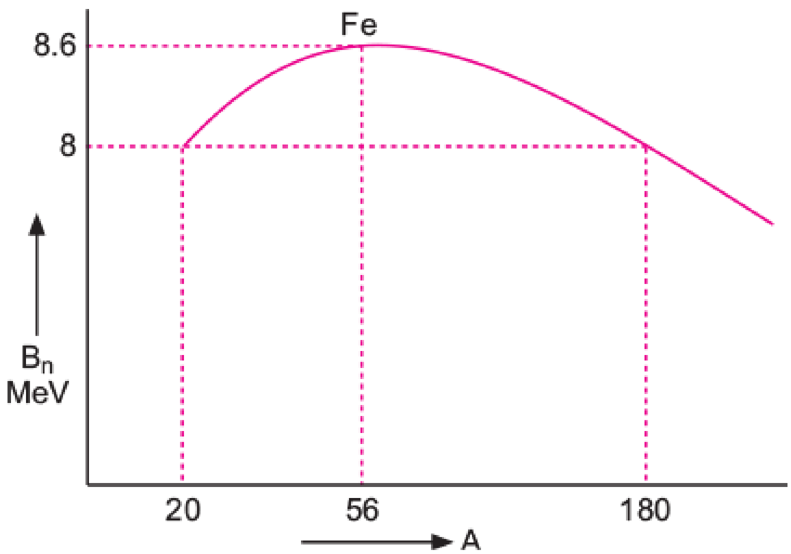
Ans. (i)

$$^{23}_{11}\text{Na} \ : Z_1 = 11, \ N_1 = 12$$

$$\therefore \ \text{Mirror isobar of } ^{23}_{11}\text{Na} = ^{23}_{11}\text{Mg}.$$

(ii) Since $Z_2 > Z_1$, Mg has greater binding energy than Na.

Q. 6. Draw the graph showing the variation of binding energy per nucleon with mass numbers. Give the reason for the decrease of binding energy per nucleon for nuclei with higher mass number.



Ans. The graph of the binding energy per nucleon versus mass number A is shown in figure. The decrease of the binding energy per nucleon for nuclei with high mass number is due to increased coulomb repulsion between protons inside the nucleus.

Q. 7. If both the number of protons and number of neutrons are conserved in each nuclear reaction, in what way is mass converted into energy (or vice-versa) in a nuclear reaction?

Ans. In fact the number of protons and number of neutrons are same before and after a nuclear reaction, but the binding energies of nuclei present before and after a nuclear reaction are different. This difference is called the mass defect. This mass defect appears as energy of reaction. In this sense a nuclear reaction is an example of mass-energy interconversion.

Q. 8. What is obtained by fusion of two deuterons?

Ans. By fusion of two deuterons, either tritium $\left({}_{1}^{3}H\right)$ or an isotope of helium $\left({}_{2}^{3}He\right)$ is obtained with release of energy. The reactions are

$$ {}_{1}^{2}H + {}_{1}^{2}H \rightarrow \underset{(\text{ tritium })}{{}_{1}^{3}H + {}_{1}^{1}H + 4.03 \text{ MeV}} $$

$$ {}_{1}^{2}H + {}_{1}^{2}H \rightarrow {}_{2}^{3}\text{He} + {}_{0}^{1}n \quad + \underset{(\text{ isotope of helium })}{3.27 \text{ MeV}} $$

Q. 9. Distinguish between isotopes and isobars. Give one example for each of the species.

Ans.

Isotopes	Isobars
The nuclides having the same atomic number (Z) But different atomic masses (A) are called isotopes. Examples : ${}_{1}^{1}H, {}_{1}^{2}H, {}_{1}^{3}H$	The nuclides having the same atomic mass (A) but Different atomic numbers (Z) are called isobars. Examples : ${}_{1}^{3}H, {}_{2}^{3}He$

Q. 10. A radioactive nucleus A undergoes a series of decay according to following scheme:

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

The mass number and atomic number of A are 180 and 72 respectively. What are these numbers for A_4?

Ans. The decay scheme may completely be represented as

${}_{72}^{180}A \xrightarrow{\alpha} {}_{70}^{176}A_1 \xrightarrow{\beta} {}_{71}^{176}A_2 \xrightarrow{\alpha} {}_{69}^{172}A_3 \xrightarrow{\gamma} {}_{69}^{172}A_4$ Clearly, mass number of A_4 is 172 and atomic number is 69.

Q. 11. Assuming the nuclei to be spherical in shape, how does the surface area of a nucleus of mass number A_1 compare with that of a nucleus of mass number A_2?

Ans. Radius of nucleus of mass number *A* is

$R = R_0 A^{1/3}$ where $R_0 = 1.2 \times 10^{-15}$ m = constant

Surface area of nucleus, $S = 4\pi R^2 \propto R^2$

$$\therefore \qquad \frac{S_1}{S_2} = \left(\frac{R_1}{R_2}\right)^2 = \left(\frac{A_1}{A_2}\right)^{2/3}$$

Q. 12. The half-life of $^{14}_{6}C$ is 5700 years. What does it mean? Two radioactive nuclei X and Y initially contain an equal number of atoms. Their half-lives are 1 hour and 2 hours respectively. Calculate the ratio of their rates of disintegration after two hours.

Ans. The half-life of $^{14}_{6}C$ is 5700 years. It means that one half of the present number of radioactive nuclei of $^{14}_{6}C$ will remain undecayed after 5700 years.

$$\text{Number of nuclei } X \text{ after 2 hours, } N_X = N_0\left(\tfrac{1}{2}\right)^{\frac{t}{T/2}} = \frac{N_0}{4}$$

$$\text{Number of nuclei } Y \text{ after 2 hours, } N_Y = N_0\left(\tfrac{1}{2}\right)^{\frac{2}{2}} = \frac{N_0}{2}$$

$$\therefore \text{ Ratio of rates of disintegration } \frac{R_X}{R_Y} = \frac{N_0/4}{N_0/2} = \frac{1}{2}$$

Q. 13. Explain with example, whether the neutron-proton ratio in a nucleus increases or decreases due to β-decay.

Ans. In β-decay a neutron is converted into a proton, so the neutron-proton ratio decreases. Equation of β-decay is

$$_{Z}X^{A} \rightarrow Z +_{1} Y^{A} +_{-1} \beta^{0} + \bar{\nu}$$

$$_{90}\mathrm{Th}^{234} \rightarrow {}_{91}\mathrm{Pa}^{234} + {}_{-1}\beta^{0} + \bar{\nu}$$

Neutron to proton ratio before β-decay $= \frac{234-91}{90} = \frac{144}{90} = 1.60$

Neutron to proton ratio after β-decay $= \frac{234-91}{91} = \frac{143}{91} = 1.57$

$\frac{143}{91} < \frac{144}{90}$, so neutron to proton ratio in β-decay decreases.

Q. 14. With the help of an example, explain how the neutron to proton ratio changes during α-decay of a nucleus.

Ans.

Let us take the example of α-decay of $^{238}_{92}U$. The decay scheme is

$$^{238}_{92}U \rightarrow {}^{234}_{90}\mathrm{Th} + {}^{4}_{2}\alpha \ (\text{or } {}^{4}_{2}\mathrm{He})$$

Neutron to proton ratio before α-decay $= \frac{238-92}{92} = \frac{146}{92} = 1.59$

Neutron to proton ratio after α-decay $= \frac{238-90}{90} = \frac{144}{90} = 1.60$

$$\frac{146}{92} < \frac{144}{90}$$

This shows that the neutron to proton ratio increases during α-decay of a nucleus.

Q. 15. A radioactive isotope has a half-life of 5 years. After how much time is its activity reduced to 3.125%of its original activity?

Ans.

We know $\frac{R}{R_0} = \left(\frac{1}{2}\right)^n$

Given $\frac{R}{R_0} = 3.125\% = \frac{3.125}{100}$

$\therefore$ $\frac{3.125}{100} = \left(\frac{1}{2}\right)^n$ or $\frac{1}{32} = \left(\frac{1}{2}\right)^n$

or $\left(\frac{1}{2}\right)^5 = \left(\frac{1}{2}\right)^n \Rightarrow n = 5$

Given T=5 years

As $n = \frac{t}{T}$

$\therefore$ $\frac{t}{T} = 5$

or $t = 5 \times 5 = \mathbf{25\ years}$

Q. 16. Calculate the binding energy per $^{40}_{20}$ CA nucleon nucleus.

[Given: m $\left(^{40}_{20}Ca\right)$ =39.962589 u

m_n(mass of a neutron) =1.008665 u

m_p(mass of a proton) =1.007825 u

1 u = 931 MeV/c^2]

Ans.

Total Binding energy of $^{40}_{20}$Ca nucleus $=20m_p+20m_n - M(^{40}_{20}\text{Ca})$

= 20×1.007825 + 20 × 1.008665 – 39.962589

= 0.367211 u = 0.367211 × 931 MeV = 341.87 MeV

$\therefore$ Binding energy per nucleus = $\frac{341.87}{40}$ MeV/nucleon

= 8.55 MeV/nucleon

Short Answer Questions – II (PYQ)

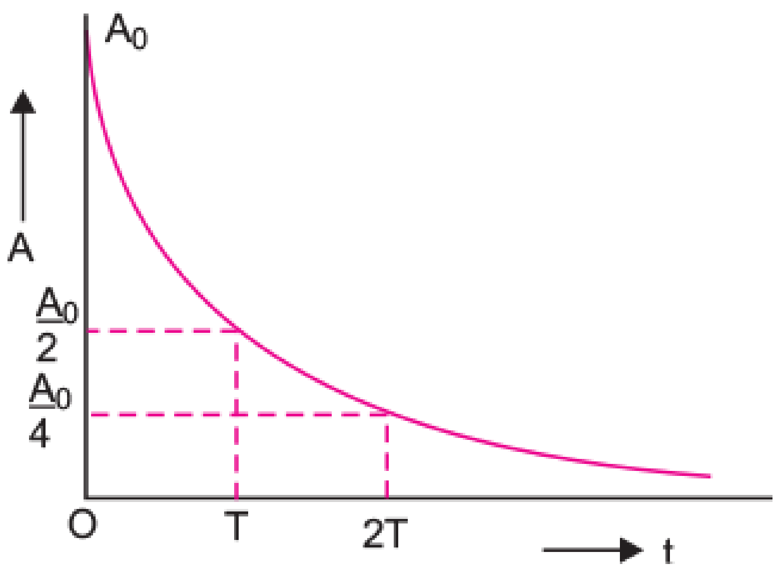
Q. 1. Define the term 'Activity' of a radioactive substance. State its SI unit. Give a plot of activity of a radioactive species versus time. [CBSE Delhi 2010, (AI) 2009]

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.

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

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 ${}_1^2H$.

(ii) Mass defect between the reactant and product nuclei

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

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

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

Also, according to equation of radioactivit

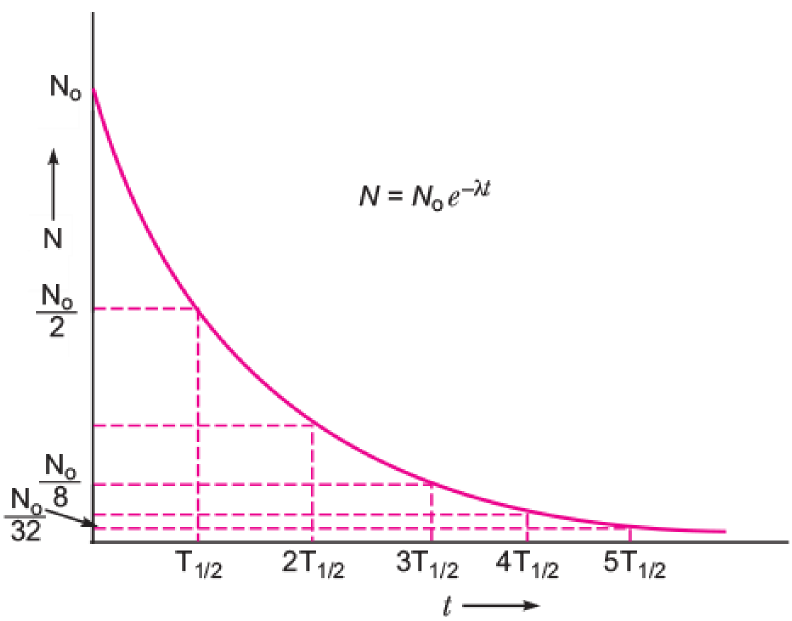
$$N = N_0 e^{-\lambda t}$$

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

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

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

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

(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)

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

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

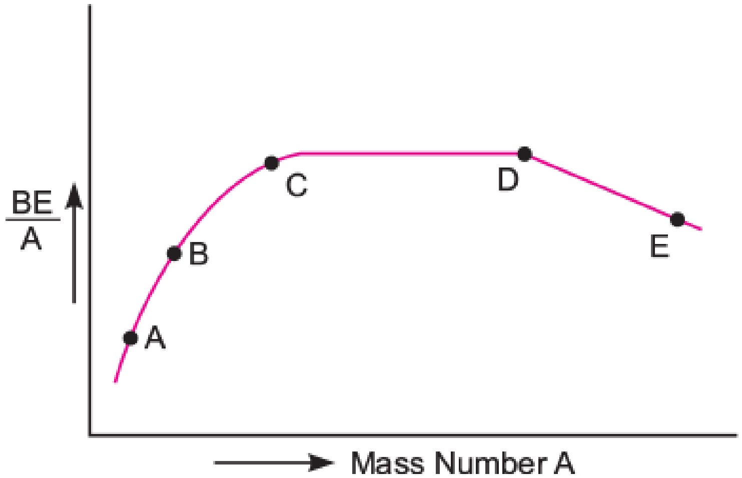
(ii)

i. BE of ${}_{92}^{235}U <$ BE of $\left({}_{56}^{144}\mathrm{Ba} + {}_{36}^{89}X\right)$ 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:

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

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,

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

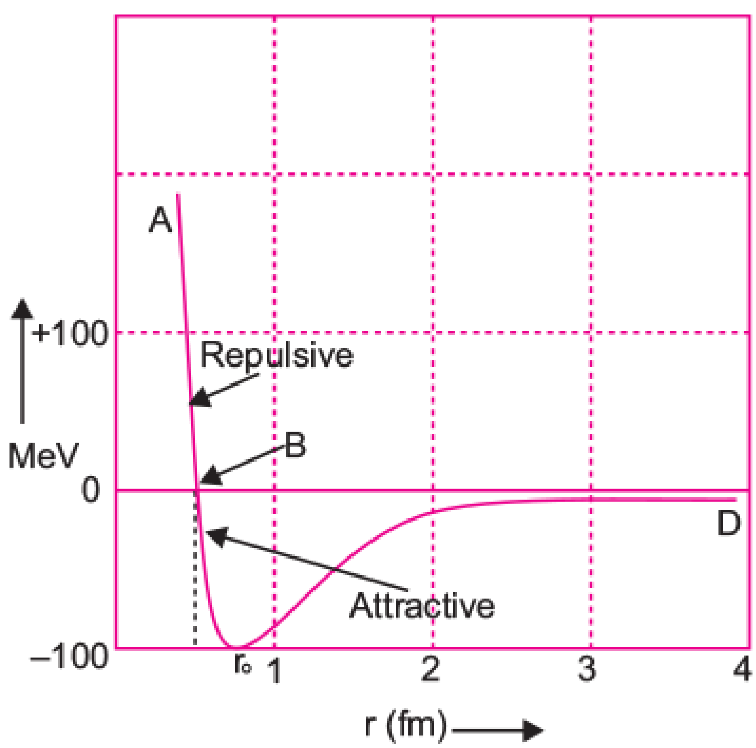
If a β– is emitted out, the atomic number increases by 1, while mass number remains unchanged. So,

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

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

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

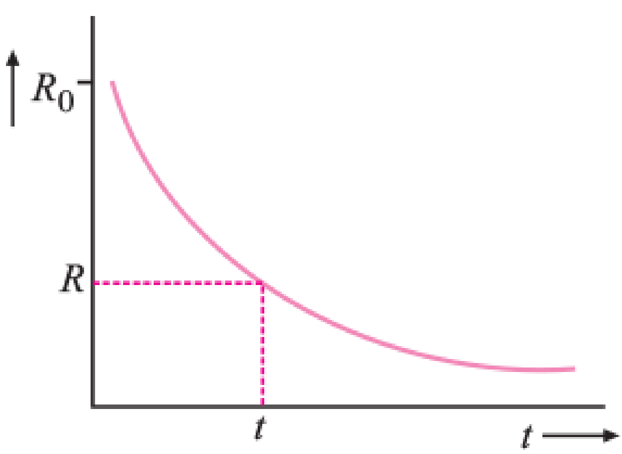
If t=20 h, then R=10000.

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

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

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

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

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

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)

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

$$\Rightarrow \log e\ 4 = (\lambda_B t - \lambda_A t) \log_e e$$

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

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

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

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.

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

$$\text{In } R = 1\text{n } R_0{}^{-\lambda t}$$

$$\text{In } R = -\lambda t + 1\text{n } R_0$$

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

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

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

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

$\therefore$ Given t=4 days $\therefore$ $\frac{t}{T} = 4$ $\Rightarrow$ 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

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

or m_0=64 m=$64\times4\times10^{-3}$ 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

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

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)

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

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

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

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

Long Answer Questions

Q. 1. Draw the graph showing the variation of binding energy per nucleon with the mass number for a large number of nuclei 2< A < 240. What are the main inferences from the graph? How do you explain the constancy of binding energy in the range 30 < A < 170 using the property that the nuclear force is short-ranged? Explain with the help of this plot the release of energy in the processes of nuclear fission and fusion.
[CBSE (AI) 2010, 2011, Chennai 2015, South 2016]

Ans. The variation of binding energy per nucleon versus mass number is shown in figure. Inferences from graph

(1) The nuclei having mass number below 20 and above 180 have relatively small binding energy and hence they are unstable.

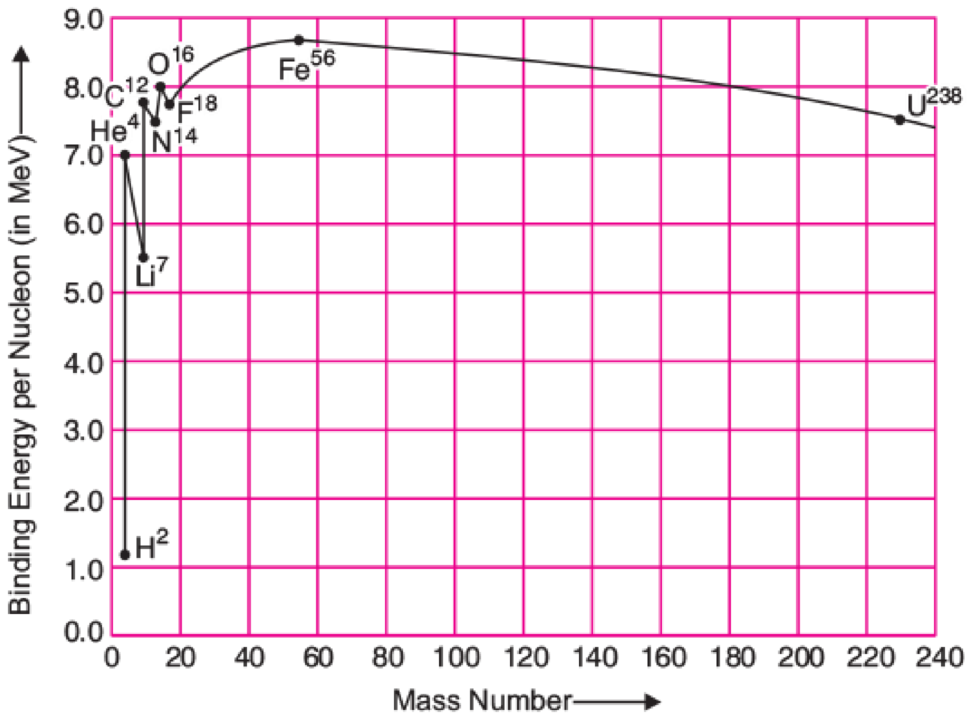
(2) The nuclei having mass number 56 and about 56 have maximum binding energy – 5·8 MeV and so they are most stable.

(3) Some nuclei have peaks, e.g., ${}_{2}^{4}\mathrm{He},\ {}_{6}^{12}C,\ {}_{6}^{12}O;$ this indicates that these nuclei are relatively more stable than their neighbours.

(i) Explanation of constancy of binding energy: Nuclear force is short ranged, so every nucleon interacts with its neighbours only, therefore binding energy per nucleon remains constant.

(ii) Explanation of nuclear fission: When a heavy nucleus (A ≥ 235 say) breaks into two lighter nuclei (nuclear fission), the binding energy per nucleon increases i.e, nucleons get more tightly bound. This implies that energy would be released in nuclear fission.

(iii) Explanation of nuclear fusion: When two very light nuclei (A ≤ 10) join to form a heavy nucleus, the binding is energy per nucleon of fused heavier nucleus more than the binding energy per nucleon of lighter nuclei, so again energy would be released in nuclear fusion.



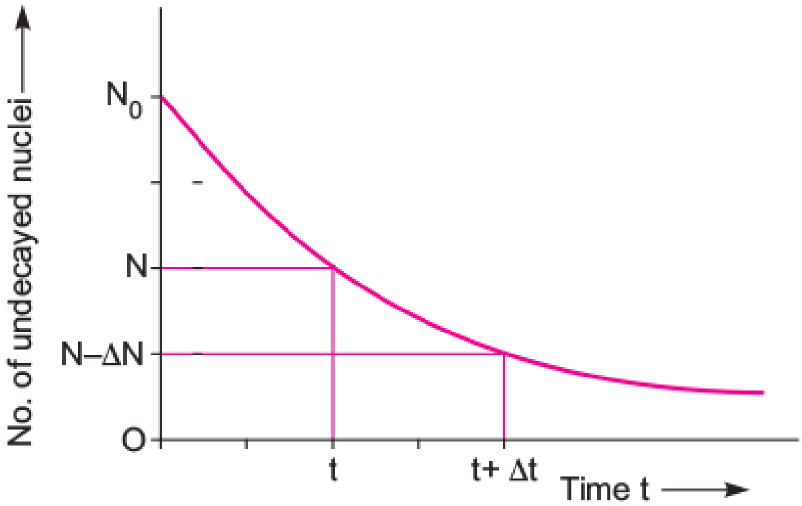
Q. 2. Derive the expression for the law of radiactive decay of a given sample having initially N_0 nuclei decaying to the number *N* present at any subsequent time *t*.

Plot a graph showing the variation of the number of nuclei versus the time *t* lapsed.

Mark a point on the plot in terms of $T_{1/2}$ value when the number present $N = N_0 /16$. [*CBSE Delhi 2014, (F) 2013*]

Ans. Radioactive decay Law: The rate of decay of radioactive nuclei is directly proportional to the number of undecayed nuclei at that time.

Derivation of formula



Suppose initially the number of atoms in radioactive element is N_0 and N the number of atoms after time t.

After time t, dN let be the number of atoms which disintegrate in a short interval dt then rate of disintegration will be $\frac{dN}{dt}$ this is also called the activity of the substance/element.

According to Rutherford-Soddy law

$$\frac{dN}{dt} \propto N \qquad \text{or} \qquad \frac{dN}{dt} = -\lambda N \qquad ...(i)$$

Where λ is a constant, called decay constant or disintegration constant of the element. Its unit is S^{-1}. Negative sign shows that the rate of disintegration decreases with increase of time. For a given element/substance λ is a constant and is different for different elements. Equation (*i*) may be rewritten as

Integrating $\log_e N = -\lambda t + C$ ...(*ii*)

Where C is a constant of integration.

At $t = 0, N = N_0$

∴ $\log_e N_0 = 0 + C$ ⇒ $C = \log_e N_0$

∴ Equation (*ii*) gives $\log_e N = -\lambda t + \log_e N_0$

Or $\log_e N - \log_e N_0 = -\lambda t$

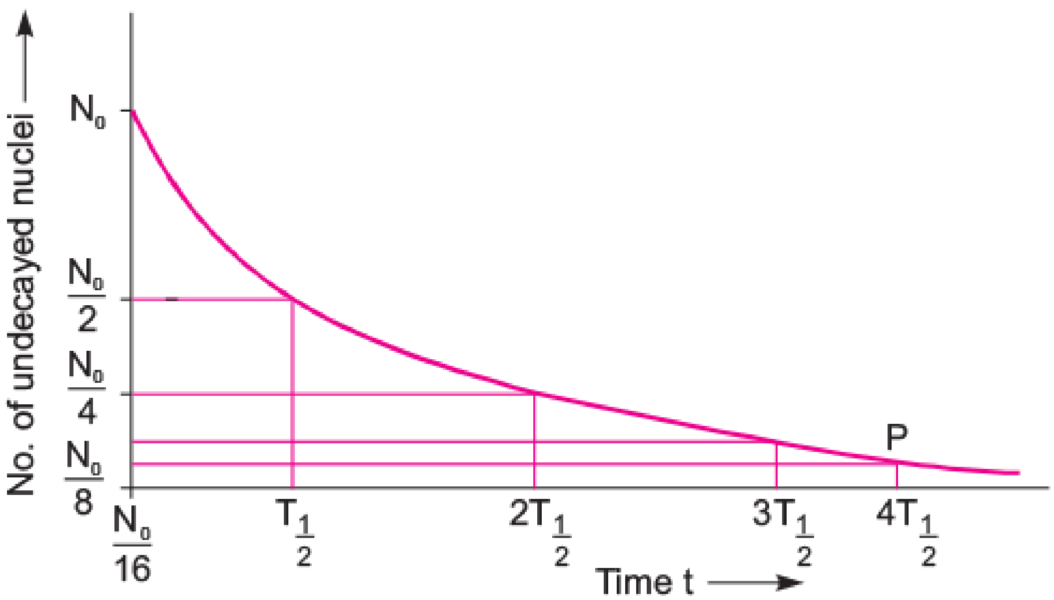
or $\log_e \frac{N}{N_0} = -\lambda t$

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

$\therefore$ $N = N_0\, e^{-\lambda t}$ ...(iii)

According to this equation, the number of undecayed atoms/nuclei of a given radioactive element decreases exponentially with time (i.e., more rapidly at first and slowly afterwards).

Mark of $N = \frac{N_0}{16}$ in terms of $T_{1/2}$ is shown in fig.



Q. 3. Define the term: Half-life period and decay constant of a radioactive sample. Derive the relation between these terms. [CBSE Patna 2015]

Ans. Half-life period: The half-life period of an element is defined as the time in which the number of radiactive nuclei decay to half of its initial value.

Decay constant: The decay constant of a radioactive element is defined as the reciprocal of time in which the number of undecayed nuclei of that radioactive element falls to $\frac{1}{e}$ times of its initial value.

Relation between Half-life and Decay constant: The radioactive decay equation is

$$N = N_0 e^{-\lambda t} \qquad \ldots(i)$$

when $\quad t = T,\ N = \frac{N_0}{2}$

$\therefore \qquad \frac{N_0}{2} = N_0 e^{-\lambda T}$

or $\qquad e^{-\lambda T} = \frac{1}{2} \qquad \ldots(ii)$

Taking log of both sides

$$-\lambda T \log_e e = \log_e 1 - \log_e 2$$

or $\qquad \lambda T = \log_e 2$

$\therefore \quad T = \frac{\log_e 2}{\lambda} = \frac{2.3026 \log_{10} 2}{\lambda} = \frac{2.3026 \times 0.3010}{\lambda} \qquad \ldots(iii)$

or $\quad T = \frac{0.6931}{\lambda}$

Q. 4. Derive expression for average life of a radio nuclei. Give its relationship with half-life. [CBSE (AI) 2010]

Ans. All the nuclei of a radioactive element do not decay simultaneously; but nature of decay process is statistical, *i.e.*, it cannot be stated with certainty which nucleus will decay when. *The time of decay of a nucleus may be between 0 and infinity. The mean of lifetimes of all nuclei of a radioactive element is called its mean life. It is denoted by* τ.

Expression for mean life

According to Rutherford - Soddy law, rate of decay of a radioactive element

$$R(t) = \left|\frac{dN}{dt}\right| = \lambda N$$

Therefore, the number of nuclei decaying in-between time t and $t + dt$ is

$dN = \lambda N dt$

If N_0 is the total number of nuclei at $t = 0$, then mean lifetime

$$\tau = \frac{\text{Total lifetime of all the nuclei}}{\text{Total number of nuclei}} = \frac{\sum t \,.\, dN}{N_0} = \frac{\sum t\ \lambda N dt}{N_0}$$

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

$$\therefore \qquad \tau = \frac{\sum t\lambda (N_0 e^{-\lambda t})\, dt}{N_0} = \lambda \sum t\ e^{-\lambda t}\, dt$$

As nuclei decay indefinitely, we may replace the summation into integration with limits from t = 0 to t = ∞ i.e.,

$$\tau = \lambda \int_0^\infty t\ e^{-\lambda t}\, dt.$$

Integrating by parts, we get

$$\tau = \lambda \left[\left\{ \frac{te^{-\lambda t}}{-\lambda} \right\}_0^\infty - \int_0^\infty 1 \left(\frac{e^{-\lambda t}}{-\lambda} \right) dt \right] = \lambda \left[0 + \frac{1}{\lambda} \left\{ \frac{e^{-\lambda t}}{-\lambda} \right\}_0^\infty \right]$$

$$= -\frac{1}{\lambda} [e^{-\lambda t}]_0^\infty = -\frac{1}{\lambda} [0 - 1] = \frac{1}{\lambda}$$

Thus, $\quad \tau = \frac{1}{\lambda}$

i.e., the **mean lifetime of a radioactive element is reciprocal of its decay constant.**

Relation between mean life and half life

Half life $\qquad T = \frac{0.6931}{\lambda} \qquad \ldots(i)$

Mean life $\qquad \tau = \frac{1}{\lambda} \qquad \ldots(ii)$

Substituting value of λ from (ii) in (i), we get

$T = 0.6931\ \tau \qquad \ldots(iii)$

Q. 5. Answer the following questions [CBSE (F) 2014]

(1) Define the terms (i) half-life ($T_{1/2}$) and (ii) average life (τ). Find out their relationships with the decay constant (λ).

(2) A radioactive nucleus has a decay constant λ = 0.3465 (day)$^{-1}$. How long would it take the nucleus to decay to 75% of its initial amount?

Ans. (1) (i) Half-life ($T_{1/2}$) of a radioactive element is defined as the time taken by a radioactive nuclei to reduce to half of the initial number of radio nuclei.

(ii) Average life of a radioactive element is defined as the ratio of total life time of all radioactive nuclei, to the total number of nuclei in the sample.

Relation between half-life and decay constant is given by $T_{1/2} = \frac{0.693}{\lambda}$

Relation between average life and decay constant $\tau = \frac{1}{\gamma}$.

(2) Let N_0 = the number of radioactive nuclei present initially at time t= 0 in a sample of radioactive substance.

N = the number of radioactive nuclei present in the sample at any instant t.

$$\text{Here, } N = \frac{3}{4}N_0$$

$$\text{From the equation, } N = N_0 e^{-\lambda t}$$

$$\frac{3}{4}N_0 = N_0 e^{-0.3465t} \quad \Rightarrow \quad e^{0.3465t} = \frac{4}{3}$$

$$= 2.303\ (0.6020 - 0.4771) = 2.303 \times 0.1249$$

$$\therefore \quad t = \frac{2.303 \times 0.1249}{0.3465} = 0.83 \text{ day.}$$

Q. 6. Compare and contrast the nature of α-, β- and γ-radiations.

Ans. Comparison of Properties of α-, β- and γ-rays.

	Property	α-particle	β-particle	γ-rays
1.	Nature	Nucleus of Helium	Very fast-moving electron (e^-)	electromagnetic wave of wavelength $\approx 10^{-2}$ Å
2.	Charge	$+2e$	$-e$	No charge
3.	Rest mass	6.6×10^{-27} kg	9.1×10^{-31} kg	zero
4.	Velocity	1.4×10^7 m/s to 2.2×10^7 m/s	0.3 c to 0.98 c	$c = 3 \times 10^8$ m/s
5.	Ionising Power	high, 100 times that of β-particle	100 times more than γ-rays	very small
6.	Penetrating Power	very small	high, 100 times more than α-particles	very high, 100 times more than β-particles

Q. 7. State Soddy-Fajan's displacement laws for radioactive transformations.

Ans. The atoms of radioactive element are unstable. When an atom of a radioactive element disintegrates, an entirely new element is formed. This new element possesses entirely new chemical and radioactive properties. The disintegrating element is called the parent element and the resulting product after disintegration is called the daughter element. Soddy and Fajan studied the successive product elements of disintegration of radioactive elements and gave the following conclusions:

(i) Alpha-Emission: a-particle is nucleus of a helium atom having atomic number 2 and atomic weight 4. It is denoted by $^2He_4$. Therefore when an α-particle is emitted from a radioactive parent atom (*X*), its atomic number is reduced by 2 and atomic weight is reduced by 4. Thus the daughter element has its place two groups lower in the periodic table. Thus the process of a-emission may be expressed as

$$_ZX^A \rightarrow {}_{Z-2}Y^{A-4} + \underset{(\alpha\text{–particle})}{{}_2\mathrm{He}^4}$$

Examples:

(i) 92U238 90Th234 + 2He4

(ii) 80Ra226 86Rn222 + 2He4

2. **Beta-Emission:** β-particle is an electron (e) and is denoted by $_{-1}\beta^0$. When a β-particle is emitted from a parent atom (X), it s atomic number increases by 1, while atomic weight remains unchanged. As a result the daughter element (Y) has a place one group higher in the periodic table. Thus the process of β-emission may be expressed as

   $_ZX^A \rightarrow {}_{Z+1}Y^A + {}_{-1}\beta^0 + \bar{\nu}$

   where $\bar{\nu}$ is a fundamental particle called antineutrino which is massless and chargeless.

   Example: $_{90}Th^{228} \rightarrow {}_{89}Ac^{228} + {}_{-1}b^0 + \bar{\nu}$

3. **Gamma-Emission:** The emission of λ-ray from a radioactive atom neither changes its atomic number nor its atomic weight. Therefore its place in periodic table remains undisplaced. In natural radioactivity λ-radiation is accompanied with either α or β-emission.