IMPORTANT QUESTIONS CLASS – 12 PHYSICS CHAPTER – 13 NUCLEI

Question 1.
Calculate the binding energy per nucleon of $Fe^{56}{}_{26}$ Given m_{Fe} = 55.934939 u, m_n = 1.008665 u and m_p = 1.007825 u
Answer:
Number of protons Z = 26
Number of neutrons (A – Z) = 30
Now mass defect is given by
$\Delta m = Z\, m_p + (A - Z)m_n - M$
$\Delta m = 26 \times 1.007825 + 30 \times 1.008665 - 55.934939$
= 0.528461 u

Therefore binding energy
BE = Δm × 931 MeV = 0.528461 × 931
= 491.99 MeV

BE/nucleon = 491.99/56 = 8.785 MeV

Question 2.
The activity of a radioactive element drops to one-sixteenth of its initial value in 32 years. Find the mean life of the sample.
Answer:

t = 32 years, $A = A_0 / 16$, using

$A = A_0\left(\frac{1}{2}\right)^n$ where $n = t / T$ we have

$$\frac{A_0}{16} = A_0\left(\frac{1}{2}\right)^{32/T}$$

$$\left(\frac{1}{2}\right)^4 = \left(\frac{1}{2}\right)^{32/T}$$

Or
32/T = 4 or 7 = 32 / 4 = 8 years.
Therefore mean life of the sample is τ = 1.44 7 = 1.44 × 8 = 11.52 years.

Question 3.
A radioactive sample contains 2.2 mg of pure 116C which has a half-life period of 1224 seconds. Calculate (i) the number of atoms present initially and (ii) the activity when 5 pg of the sample will be left.
Answer:
Mass of sample = 2.2 pg

Now 11 g of the sample contains 6.023×10^{23} nuclei, therefore the number of nuclei in 2.2 mg = 2.2×10^{-3} g are

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$$\frac{6.023 \times 10^{23}}{11} \times 2.2 \times 10^{-3} = 1.2 \times 10^{20}$$

Given $T = 1224$ s.

Number of nuclei in 5 µg

$$N = \frac{6.023 \times 10^{23}}{11} \times 5 \times 10^{-6} = 2.7 \times 10^{17}$$

$$A = -\lambda N = \frac{0.693}{T} \times N$$

$$= \frac{0.693}{1224} \times 2.7 \times 10^{17} = 1.53 \times 10^{14}\ s^{-1}$$

Question 4.
The half-life of 238 92U is 4.5×10^9 years. Calculate the activity of 1 g sample of $_{92}^{238}U$.

Answer:
Given T = 4.5×10^9 years.
Number of nuclei of U in 1 g
= N = 6.023×1023238 = 2.5×10^{21}

Therefore activity

$$A = \lambda N = \frac{0.693}{T} \times N = \frac{0.693}{4.5 \times 10^9} \times 2.5 \times 10^{21}$$
$$= 3.85 \times 10^{11}\ \text{dis}\ y^{-1}$$

Question 5.
The decay constant for a given radioactive sample is 0.3456 per day. What percentage of this sample will get decayed in a period of 4 days?

Answer:
Given $\lambda = 0.3456\ \text{day}^{-1}$
or
$T_{1/2} = 0.693/\lambda$ = 0. 693/ 0.3456 = 2.894 days, t = 4 days.

Let N be the mass left behind, then $N = N_0 e^{-\lambda t}$
or
$N = N_0\ e^{-0\ 3456 \times 4}$
or
$N = N_0\ e^{-1\ 3824} = N_0 \times 0.25$

Therefore the percentage of undecayed is

$$\frac{N_0 - N}{N_0} \times 100 = \frac{N_0 - 0.25N_0}{N_0} \times 100$$
$$= 75\ \%$$

Question 6.
It is observed that only 6.25 % of a given radioactive sample is left undecayed after a period of 16 days. What is the decay constant of this sample per day?

Answer:
Given N/N_0 = 6.25 %, t = 16 days, λ = ?

$$\frac{N}{N_0} = 6.25\ \% = \frac{1}{16}$$

Using the relation $N = N_0\left(\frac{1}{2}\right)^n$ we have

$$\frac{N}{N_0} = \left(\frac{1}{2}\right)^{16/T} \text{ or}$$

$$\left(\frac{1}{16}\right) = \left(\frac{1}{2}\right)^{16/T} \text{ or } \left(\frac{1}{2}\right)^4 = \left(\frac{1}{2}\right)^{16/T}$$

Or
16/ T = 4 or T = 4 days.

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Therefore $\lambda = 1/T = 1/4 = 0.25\ day^{-1}$

Question 7.
A radioactive substance decays to $1/32^{th}$ of its initial value in 25 days. Calculate its half-life.

Answer:
Given t = 25 days, $N = N_0 / 32$, using

$$N = N_0\left(\frac{1}{2}\right)^n \text{ where } n = t/T \text{ we have}$$

$$\frac{N_0}{32} = N_0\left(\frac{1}{2}\right)^{25/T} \text{ or } \left(\frac{1}{2}\right)^5 = \left(\frac{1}{2}\right)^{25/T}$$

Or
25/7= 5 or T= 25 / 5 = 5 days.

Question 8.
The half-life of a radioactive sample is 30 s. Calculate
(i) the decay constant, and

Answer:
Given $T_1/2 = 30$ s, $N = 3N_0 / 4$, λ = ?, t = ?
(i) Decay constant
λ = 0.693T1/2=0.69330 = 0.0231 s^{-1}

(ii) time taken for the sample to decay to 3/4 th of its initial value.

Answer:
Using $N = N_0e^{-\lambda t}$ we have

$$\frac{3N_0}{4} = N_0e^{-\lambda t} \text{ or } \ln\frac{4}{3} = \lambda t \text{ or}$$

$$t = \frac{2.303 \log 1.333}{\lambda}$$

$$= \frac{2.303 \log 1.333}{0.0231} = 12.49 \text{ s}$$

Question 9.
The half-life of 14 6C 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 2 hours.

Answer:
It means that in 5700 years the number of nuclei of carbon decay to half their original value.
Given $N_{ox} = N_{oY}$, $T_X = 1$ h, $T_Y = 2$ h, therefore
λXλY=21 = 2

Now after 2 hours X will reduce to one- fourth and Y will reduce to half their original value.
If activities at t = 2 h are R_x and R_y respectively, then

$$\frac{R_X}{R_Y} = \frac{\lambda_X}{\lambda_Y} \times \frac{N_X}{N_Y} = 2 \times \frac{(N_0)_X / 4}{(N_0)_Y / 2} = 1$$

Thus their rate of disintegration after 2 hours is the same.

Question 10.
A star converts all its hydrogen to helium achieving 100% helium composition. It then converts helium to carbon via the reaction.

$$^{4}_{2}He + ^{4}_{2}He + ^{4}_{2}He \rightarrow ^{12}_{6}C + 7.27 \text{ MeV}$$

The mass of the star is 5×10^{32} kg and it generates energy at the rate of 5×10^{30} watt.
How long will it take to convert all the helium to carbon at this rate?

Answer:

As 4×10^{-3} kg of He consists of 6.023×10^{23} He nuclei so 5×10^{32} kg He will contain
6.023×1023×5×10324×10−3 = 7.5×10^{58} nuclei

Now three nuclei of helium produce $7.27 \times 1.6 \times 10^{-13}$ J of energy
So all nuclei in the star will produce
E = 7.27×1.6×10−133 × 7.5×10^{58}
= 2.9×10^{46} J

As power generated is $P = 5 \times 10^{30}$ W, therefore time taken to convert all He nuclei into carbon is
t = EP=2.9×10465×1030 = 5.84×10^{15} s
or
1.85×10^{8} years

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