JEE Main Previous Year Solved Questions on Radioactivity

Q1: A sample of radioactive material A, that has an activity of 10 mCi (1 Ci = 3.7×10^{10} decays/s) has twice the number of nuclei as another sample of a different radioactive material B, which has an activity of 20 mCi. The correct choices for half-lives of A and B would then be respectively

(a) 20 days and 5 days

(b)10 days and 40 days

(c) 20 days and 10 days

(d) 5 days and 10 days

Solution

R_A = 10 mCi, R_B = 20 mCi, $N_A = 2N_B$

$R_A/R_B = \lambda_A N_A/\lambda_B N_B = [(T_{1/2})_B/ (T_{1/2})_A] \times [N_A/N_B]$

$(½) = [(T_{1/2})_B/ (T_{1/2})_A] \times 2 \Rightarrow (T_{1/2})_A= 4(T_{1/2})_B$

Answer: (a) 20 days and 5 days

Q2: Using a nuclear counter the count rate of emitted particles from a radioactive source is measured. At t = 0 it was 1600 counts per second and at t = 8 seconds it was 100 counts per second. The count rate observed, as counts per second, at t = 6 seconds is close to

(a) 200

(b) 360

(c) 150

(d) 400

Solution

According to the law of radioactivity, the count rate at t = 8 seconds is

$N_1 = N_0e^{-\lambda t}$

$dN/dt = \lambda N =\lambda N_0e^{-\lambda t}$

At t = 0, $1600 = \lambda N_0e^0 = \lambda N_0$ -------(1)

At t = 8s, $100 = \lambda N_0e^{-8\lambda}$ -------- (2)

$\Rightarrow 100 = 1600\ e^{-8\lambda}$

$e^{8\lambda} = 16$

Therefore half life is t1/2 = 2 sec

At t = 6 sec

$(dN/dt) = \lambda N_0 e^{-6\lambda} = 1600 \times (e^{-2\lambda})^3 = 1600 \times (1/8) = 200$

Answer: (a) 200

Q3: Radiation coming from transitions n = 2 to n = 1 of hydrogen atoms fall on He+ ions in n = 1 and n = 2 states. The possible transition of helium ions as they absorb energy from the radiation?

Solution

E = 13.6 (1/1 - ¼) = 13.6 x (¾) = 10.2 eV

Let us check the transitions possible on He

n = 1 or n = 2

E_1 = 4 x 13.6 (1 - ¼) = 40.8 eV [$E_1 > E$, hence not possible]

n = 1 or n = 3

E_2 = 4 x 13.6 (1 - (1/9)) = 48.3 eV [$E_2 > E$, hence not possible]

n = 2 or n = 3

E_3 = 4 x 13.6 ((¼) - (1/9)) = 7.56 eV [$E_3 < E$, hence it is possible]

n = 2 or n = 4

E_4 = 4 x 13.6 ((¼) - (1/6)) = 10.2 eV [$E_4 = E$, hence it is possible]

Hence E_3 and E_4 can be possible

Answer: E_3 and E_4 is possible

Q4: Two radioactive materials A and B have decay constants 10λ and λ, respectively. If initially, they have the same number of nuclei, then the ratio of the number of nuclei of A to that of B will be 1/e after a time

(a) 1/9λ

(b) 11/10λ

(c) 1/10λ

(d) 1/11λ

Solution

$N = N_0e^{-\lambda t}$

So, $N_1 = N_0e^{-10\lambda t}$ and $N_2 = N_0e^{-\lambda t}$

$\Rightarrow (1/e) = (N_1/N_2) = (N_0e^{-10\lambda t})/(N_0e^{-\lambda t})$

$\Rightarrow (1/e) = e^{-9\lambda t} = e^{-1} = e^{-9\lambda t}$

$\Rightarrow 1 = 9\lambda t \Rightarrow t = 1/9\lambda$

Answer: (a) 1/9λ

Q5: Half-lives of two radioactive nuclei A and B are 10 minutes and 20 minutes, respectively. If, initially a sample has an equal number of nuclei, then after 60 minutes, the ratio of decayed numbers of nuclei A and B will be

(a) 3: 8

(b) 1: 8

(c) 9: 8

(d) 8: 1

Solution

By the law of radioactivity $N = N_0\, e^{-\lambda t}$

For nuclei A,

$N_A = N_{0A}e^{-\lambda t}$

Or $(N_A/N_{0A}) = (½)^n = (½)^{t/10} = (½)^6$ -------(1)

$N_A = N_{0A}/\ 2^6$

For nuclei B,

$(N_B/N_{0B}) = (½)^n = (½)^{t/20} = (½)^3$-------(2)

$\Rightarrow N_B = (N_{0B})/2^3$

Ratio of nuclei decayed will be

$(N'_A/N'_B) = (N_{0A} - N_A)/(N_{0B} - N_B) = (N_{0A}/N_{0B})[1 - (½)^6/1 - (½)^3] = 9/8$

Answer: (c) 9: 8

Q6: Two radioactive substances A and B have decay constant 5λ and λ respectively. At t = 0, a sample has

the same number of the two nuclei. The time taken for the ratio of the number of nuclei to become $(1/e)^2$ will be

(a) 2/λ

(b) 1/λ

(c) 1/4λ

(d) 1/2λ

Solution

The number of undecayed nuclei at any time t,

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

As $N_{0A} = N_{0B}$ (given)

So, for nuclei A and B

$(N_A/N_B) = e^{(-\lambda_A + \lambda_B)t}$

$t = [1/(\lambda_B - \lambda_A)]In(N_A/N_B) = 1/(\lambda - 5\lambda)In(1/e^2) = 1/2\lambda$

Answer: (d) 1/2λ

Q7: The radiation corresponding to 3→2 transitions of hydrogen atom falls on a metal surface to produce photoelectrons. These electrons are made to enter a magnetic field of 3×10^{-4} T. If the radius of the largest circular path followed by these electrons is 10.0 mm, the work function of the metal is close to

(a) 1.6 eV

(b) 1.8 eV

(c) 1.1 eV

(d) 0.8 eV

Solution

Radius of a charged particle moving in a constant magnetic field is given by

$R = (mv/qB)$ or $R^2 = m^2v^2/q^2B^2$

$R^2 = [2m((½)mv^2)]/q^2B^2$

$R^2= 2m(K.E)/q^2B^2$

$\Rightarrow K.E = (q^2B^2R^2)/2m \Rightarrow K.E_{max} = (q^2B^2R^2_{max})/2m = 0.80$ eV

Energy of photon corresponding transition from orbit 3→ 2 in hydrogen atom.

$E = 13.6(1/2^2) - (1/3^2)) = 1.89$ eV

Using Einstein photoelectric equation.

$E = K.E_{max} + \Phi$

$\Rightarrow 1.89 = 0.8 + \Phi$

$\Rightarrow \Phi = 1.09 \approx 1.1$ eV

Answer (c) 1.1 eV

Q8: Assume that a neutron breaks into a proton and an electron. The energy released during this process is

(Mass of neutron = 1.6725×10^{-27} kg

Mass of proton = 1.6725×10^{-27} kg

Mass of electron = 9×10^{-31} kg)

(a) 7.10 MeV

(b) 6.30 MeV

(c) 5.4 MeV

(d) 0.73 MeV

Solution

Mass defect, $\Delta m = m_p + m_e - m_n$

$\Delta m = (1.6725 \text{ x } 10^{-27}) + (9 \text{ x } 10^{-31}) - (1.6725 \text{ x } 10^{-27})$ Kg

$\Delta m = 9 \text{ x } 10^{-31}$ kg

Energy released = Δmc^2

Energy released = $(9 \text{ x } 10^{-31}) \text{ x } (3 \text{ x } 10^8)^2$ J

Energy released = $[(9 \text{ x } 10^{-31}) \text{ x } (9 \text{ x } 10^{16})]/[1.6 \text{ x } 10^{-13}]$ Mev = 0.51 MeV

Answer: None of the given options are correct

Q9: The half-life period of a radioactive element X is the same as the mean lifetime of another radioactive element Y. Initially, they have the same number of atoms. Then

(a) X and Y decay at the same rate always

(b) X will decay faster than Y

(c) Y will decay faster than X

(d) X and Y have the same decay rate initially

Solution

$T_{1/2}$, half-life of X = T_{mean} , mean life of y

Or $0.693/\lambda_x = 1/\lambda_y$

$\lambda_x = 0.693\lambda_y$

$\lambda_x < \lambda_y$

Rate of decay = λN

Initially, number of atoms (N) of both are equal but since $\lambda_x < \lambda_y$, therefore y will decay at a faster rate than x

Answer: (c) Y will decay faster than X

Q10: If the binding energy of the electron in a hydrogen atom is 13.6 eV, the energy required to remove the electron from the first excited state of Li^{++} is

(a) 30.6 eV

(b) 13.6 eV

(c) 3.4 eV

(d) 122.4 eV

Solution

$E_2 = (-Z^2E_0)/n^2$

$E_2 = (-(3)^2 \times 13.6)/(2)^2$

= - 30.6 eV

Energy required = 30.6 eV

Answer: (a) 30.6 eV