DPP – 3 (Nuclear Physics)

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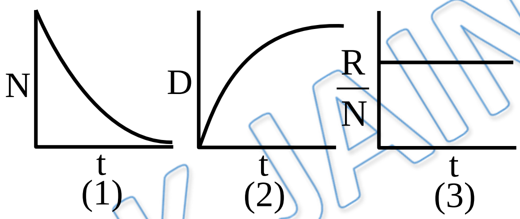
Q 1. In a radioactive decay, let N represent the number of residual active nuclei, D the number of daughter nuclei, and R the rate of decay at any time t. Three curves are shown in Fig. The correct ones are –



(a) 1 and 3 (b) 2 and 3 (c) 1 and 2 (d) all three

Q 2. A freshly prepared radioactive source of half-life 2 hr emits radiation of intensity which is 64 times the permissible safe level. The minimum time after which it would be possible to work safely with this source is -
(a) 6 h (b) 12 h (c) 24 h (d) 128 h

Q 3. The count rate of activity of a radioactive sample of a very large population decreased from 1024 to 128 in 3 minutes. Then the rate of disintegration at the end of 5 minutes is -
(a) 96 (b) 64 (c) 48 (d) 32

Q 4. If 10% of a radioactive substance decays in every 5 years, then the percentage of the substance that will have decayed in 20 years will be -
(a) 40% (b) 50% (c) 65.6 % (d) 34.4 %

Q 5. A radioactive material of half-life T was produced in a nuclear reactor at different instants, the quantity produced second time was twice of that produced first time. If now their present activities are A_1 and A_2 respectively then their age difference equals -

(a) $\frac{T}{\ln 2}\left|\ln\frac{2A_1}{A_2}\right|$ (b) $T\left|\ln\frac{A_1}{A_2}\right|$

(c) $\frac{T}{\ln 2}\left|\ln\frac{A_2}{2A_1}\right|$ (d) $T\left|\ln\frac{A_2}{2A_1}\right|$

Q 6. The half life period of a radioactive element X is same as the mean life time of another radioactive element Y. Initially both of them have the same number of atoms. Then -
(a) X & Y have the same decay rate initially

(b) X & Y decay at the same rate always
(c) Y will decay at a faster rate than X
(d) X will decay at a faster rate than Y

Q 7. A radioactive substance is being produced at a constant rate of 200 nuclei/s. The decay constant of the substance is 1 s^{-1}. After what time the number of radioactive nuclei will become 100. Initially there are no nuclei present?

(a) 1 s (b) 1/(ln(2))s (c) In (2) s (d) 2 s

Q 8. There are two radioactive substances A and B. Decay constant of B is two times that of A. Initially both have equal number of nuclei. After n half lives of A rate of disintegration of both are equal. The value of n is:

(a) 1 (b) 2 (c) 4 (d) all of these

Q 9. A radioactive isotope A decays into another isotope B which has a half-life equal to 1/2 of that of A. Both isotopes emit α-particles during their decay, and B decays into a stable nucleus. If a sample consists initially of atoms of A only, then the net activity of the sample initially:

(a) increases with time
(b) decreases with time
(c) remains constant
(d) any of the above may be true

Q 10. There are two radio nuclei A and B. A is an alpha emitter and B a beta emitter. Their disintegration constants are in the ratio of 1: 2. What should be the ratio of number of atoms of A and B at any time t so that probabilities of getting alpha and beta particles are same at that instant ?

(a) 2 : 1 (b) 1 : 2 (c) e (d) e^{-1}

Q 11. After 280 days, the activity of a radioactive sample is 6000 dps. The activity reduces to 3000 dps after another 140 days. The initial activity of the sample in dps is:

(a) 6000 (b) 9000 (c) 3000 (d) 24000

Q 12. In radioactivity number of nuclei of two radioactive substances 1 and 2 are shown in figure. Match the following

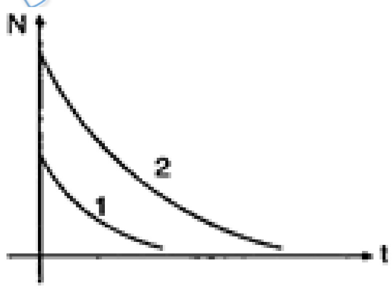


Table-1		Table-2	
(A)	Initial activity of	(P)	1 is more

(B)	Half-life of	(Q)	2 is more
(C)	Decay constant of	(R)	nothing can be said

COMPREHENSION (Q13 to Q15)

We have two radioactive nuclei A and B. Both convert into a stable nucleus C. Nucleus A converts into C after emitting two α-particles and three β-particles. Nucleus B converts into C after emitting one α -particle and five β particles. At time t = 0, nuclei of A are 4 N_0 and that of B are N_0. Half-life of A (into the conversion of C) is 1min and that of B is 2 min. Initially number of nuclei of C are zero. :

Q 13. If atomic numbers and mass numbers of A and B are Z_1, Z_2, A_1 and A_2 respectively. Then:

(a) $Z_1 - Z_2 = 6$ (b) $A_1 - A_2 = 4$
(c) both (a) and (b) are correct (d) both (a) and (b) are wrong

Q 14. What are number of nuclei of C, when number of nuclei of A and B are equal?

(a) $2N_0$ (b) 3 N_0 (c) $\frac{9N_0}{2}$ (d) $\frac{5N_0}{2}$

Q 15. At what time rate of disintegrations of A and B are equal.

(a) 4 min (b) 6 min (c) 8 min (d) 2 min

Q 16. A radioactive material decays by simultaneous emission of two particles with respective half-lives 1620 and 810 years. The time, in years, after which one-fourth of the material remains is

(a) 1080 (b) 2430 (c) 3240 (d) 4860

Q 17. Equal masses of two samples A and B of charcoal are burnt and the activity of resulting carbon-di-oxide from two samples is measured. The gas from sample A gives 10^4 counts per month and that from sample B gives 2.5×10^3 counts per month. The age difference of two samples is - (Half life of C^{14} is 5730 years) –

(a) 5730 Y (b) 11460 Y
(c) 17190 Y (d) 22920 Y

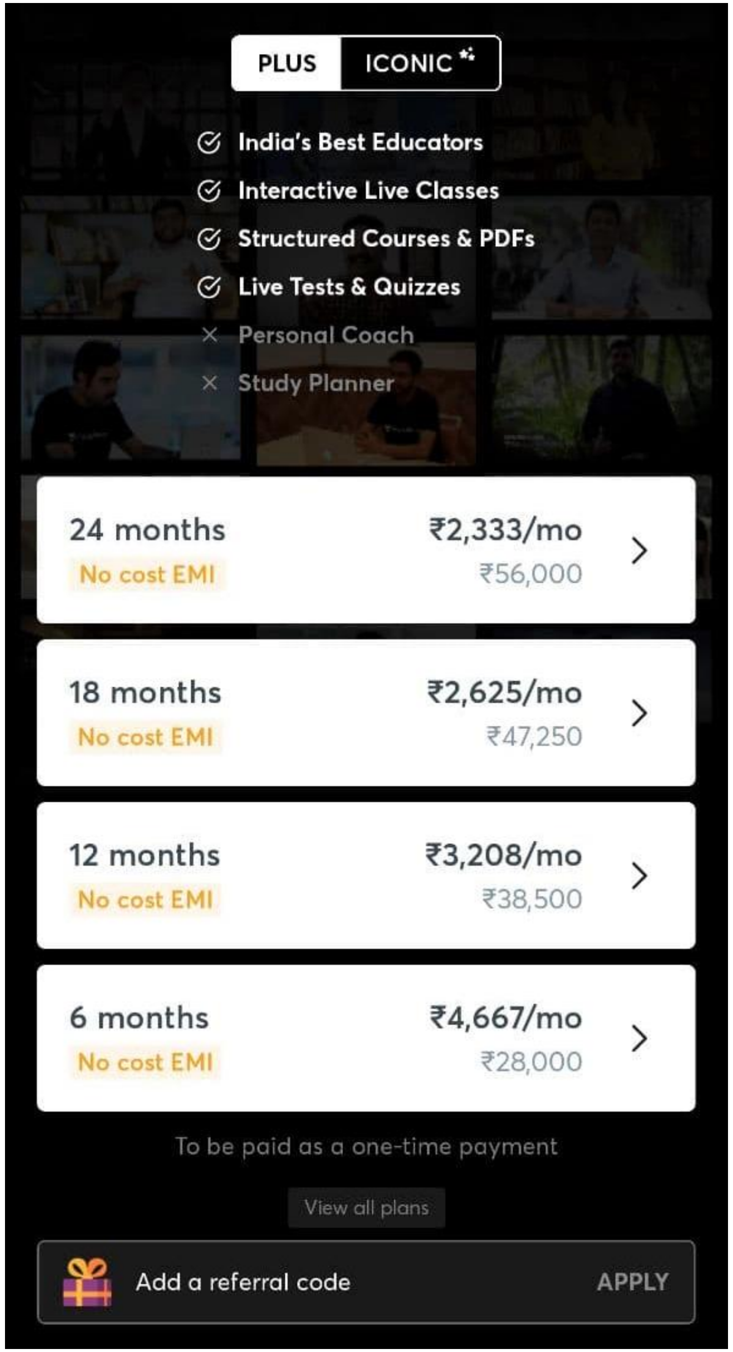
Q 18. The radioactive carbon gets produced by the process of –

(a) reaction of radium rays on simple carbon
(b) reaction of cosmic rays on simple carbon
(c) reaction of high energy neutrons on nitrogen
(d) reaction of cosmic rays on oxygen.

Answer Key

Q.1 d	**Q.2 b**	**Q.3 d**	**Q.4 d**	**Q.5 c**
Q.6 c	**Q.7 c**	**Q.8 a**	**Q.9 a**	**Q.10 a**
Q.11 d	**Q.13 b**	**Q.14 c**	**Q.15 b**	**Q.16 a**
Q.17 b	**Q.18 c**			

Ans 12. (A) R, (B) Q, (C) P



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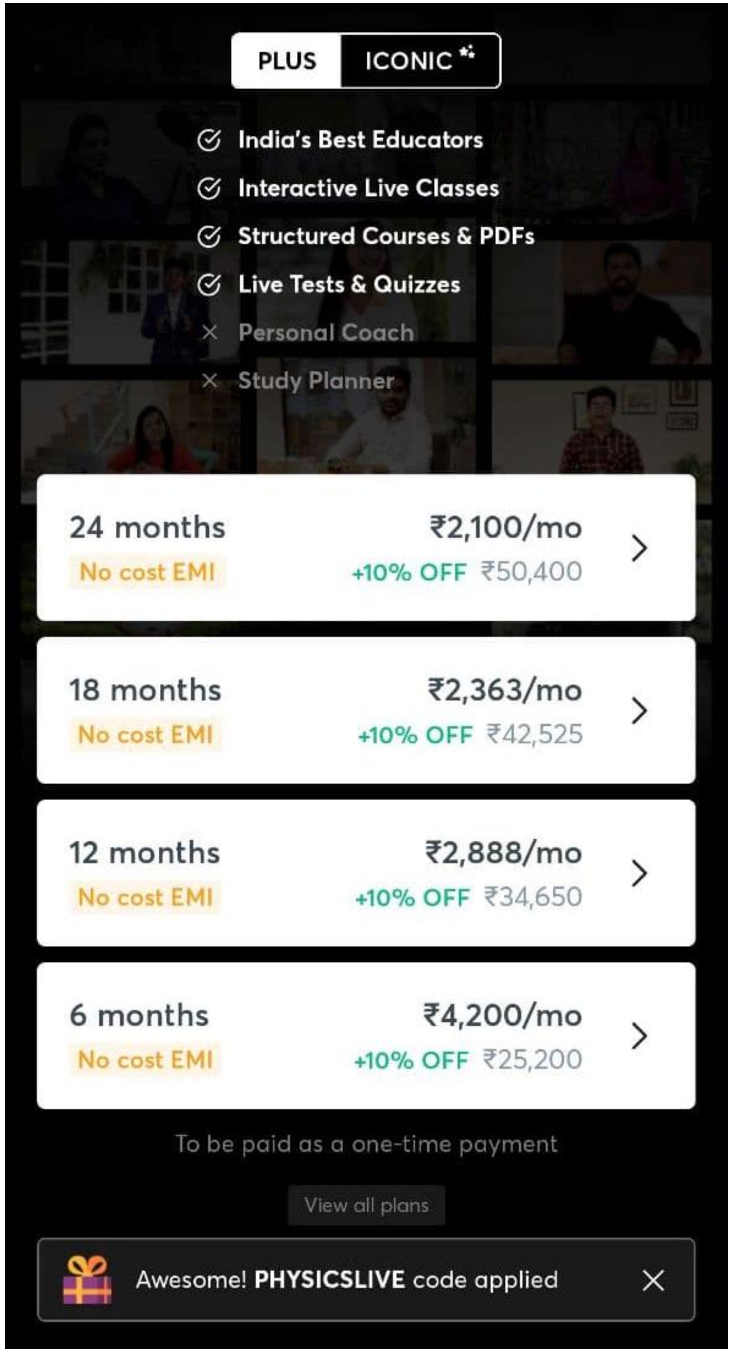

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Physics DPP - Solution

DPP – 3 Nuclear Physics : Radioactivity

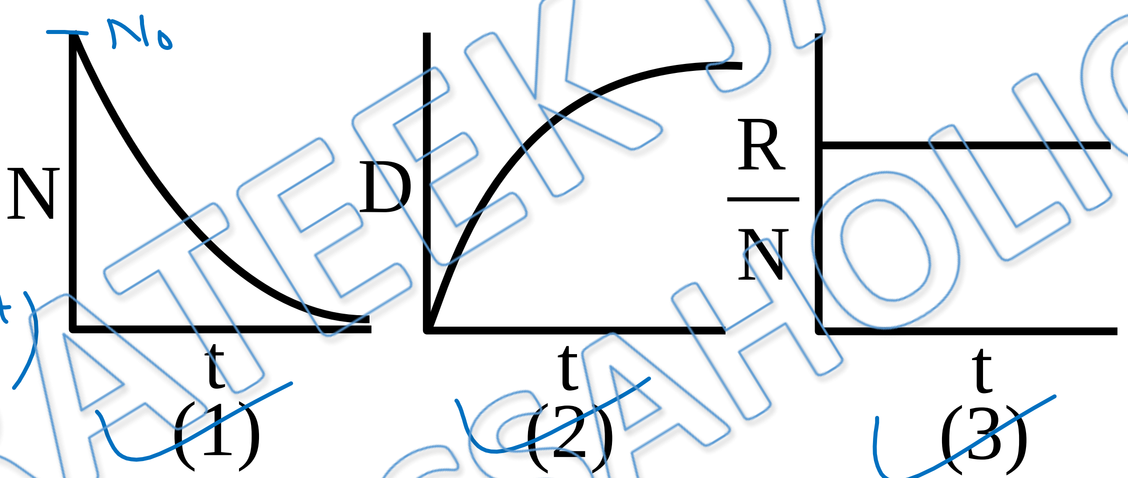
By Physicsaholics Team

Q1) In a radioactive decay, let N represent the number of residual active nuclei, D the number of daughter nuclei, and R the rate of decay at any time t. Three curves are shown in Fig. The correct ones are –

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

$D = N_0 - N$

$= N_0(1 - e^{-\lambda t})$



$R = \lambda N$

$\frac{R}{N} = \lambda = \text{Constant}$

(a) 1 and 3 (b) 2 and 3 (c) 1 and 2 (d) all three

Q2) A freshly prepared radioactive source of half-life 2 hr emits radiation of intensity which is 64 times the permissible safe level. The minimum time after which it would be possible to work safely with this source is -

$t_{1/2} = 2\,hr$

$A = A_0 \left(\frac{1}{2}\right)^{t/t_{1/2}}$

$\Rightarrow \frac{A_0}{64} = A_0 \left(\frac{1}{2}\right)^{t/2hr} \Rightarrow \left(\frac{1}{2}\right)^6 = \left(\frac{1}{2}\right)^{t/2}$

(a) 6 h (b) 12 h (c) 24 h (d) 128 h

$t/2 = 6$

$t = 12\,hr$

Q3) The count rate of activity of a radioactive sample of a very large population decreased from 1024 to 128 in 3 minutes. Then the rate of disintegration at the end of 5 minutes is -

$\frac{1}{8}$ times $= \left(\frac{1}{2}\right)^3$ times

$\Rightarrow 3\, t_{1/2} = 3$ min

$t_{1/2} = 1$ min

Activity at $t = 5$

$= \frac{1}{4} \times$ activity at $t = 3$

$= \frac{128}{4} = 32$

(a) 96 (b) 64 (c) 48 (d) 32

Q4) If 10% of a radioactive substance decays in every 5 years, then the percentage of the substance that will have decayed in 20 years will be -

$t_{.9} = 5$ years

$N = N_0 \left(\frac{9}{10}\right)^{t/t_{.9}}$

$N = N_0 \left(\frac{9}{10}\right)^4 = .656 N_0$

decay $= N_0 - N = .344 N_0$

(a) 40%　　(b) 50%　　(c) 65.6 %　　(d) 34.4 % ✓

% decay $= .344 \times 100$
$= 34.4\%$

Q5) A radioactive material of half-life T was produced in a nuclear reactor at different instants, the quantity produced second time was twice of that produced first time. If now their present activities are A1 and A2 respectively then their age difference equals -

$A_0 \rightarrow$ initial activity of first

$2A_0 \rightarrow$ " " " second

$t_{1/2} = \frac{\ln 2}{\lambda}$

$A_1 = A_0 e^{-\lambda t_1}$

$A_2 = 2A_0 e^{-\lambda t_2}$

$\frac{A_1}{A_2} = \frac{1}{2} e^{-\lambda(t_1 - t_2)}$

$\ln\left(\frac{2A_1}{A_2}\right) = -\lambda(t_1 - t_2)$

$t_1 - t_2 = \frac{1}{\lambda} \ln\left(\frac{A_2}{2A_1}\right)$

$= \frac{T}{\ln 2} \ln\left(\frac{A_2}{2A_1}\right)$

(a) $\frac{T}{\ln 2}\left|\ln\frac{2A_1}{A_2}\right|$

(b) $T\left|\ln\frac{A_1}{A_2}\right|$

(c) $\frac{T}{\ln 2}\left|\ln\frac{A_2}{2A_1}\right|$ ✓

(d) $T\left|\ln\frac{A_2}{2A_1}\right|$

Q6) The half life period of a radioactive element X is same as the mean life time of another radioactive element Y. Initially both of them have the same number of atoms. Then -

$t_{1/2\,x} = \frac{.6932}{\lambda_x}$ $t_{mean(y)} = \frac{1}{\lambda_y}$

(a) X & Y have the same decay rate initially

(b) X & Y decay at the same rate always

(c) Y will decay at a faster rate than X ✓

(d) X will decay at a faster rate than Y

$\frac{.6932}{\lambda_x} = \frac{1}{\lambda_y}$

$\lambda_x = .6932\,\lambda_y$

$\lambda_x < \lambda_y$

$R = \lambda N$ → same for both; λ ↓ greater for y.

Q7) A radioactive substance is being produced at a constant rate of 200 nuclei/s. The decay constant of the substance is 1 s-1. After what time the number of radioactive nuclei will become 100. Initially there are no nuclei present?

$$\xrightarrow{200/\text{sec}} A \xrightarrow{\lambda = 1} B$$

$t = 0$: $A = 0$, $B = 0$

$t = t$: $A = N$

$$\frac{dN}{dt} = 200 - \lambda N = 200 - N$$

$$\int_0^{100} \frac{dN}{200 - N} = \int_0^t dt$$

(a) 1 s

(b) 1/(In(2))s

(c) In (2) s ✓

(d) 2 s

$$-\left[\ln(200 - N)\right]_0^{100} = t$$

$$-\left[\ln 100 - \ln 200\right] = t = \ln 2$$

Q8) There are two radioactive substances A and B. Decay constant of B is two times that of A. Initially both have equal number of nuclei. After n half lives of A rate of disintegration of both are equal. The value of n is:

$t_{1/2} \propto \frac{1}{\lambda}$

A	B
λ	2λ
N_0	N_0
n half lives	2n half lives

$R = \lambda N \Rightarrow \lambda_1 N_1 = \lambda_2 N_2$

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

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

(a) 1 (b) 2 (c) 4 (d) all of these

$2n - 1 = n$

$n = 1$

Q9) A radioactive isotope A decays into another isotope B which has a half-life equal to 1/2 of that of A. Both isotopes emit α-particles during their decay, and B decays into a stable nucleus. If a sample consists initially of atoms of A only, then the net activity of the sample initially:

$A \xrightarrow{\lambda} B \xrightarrow{2\lambda} C$ (stable)

t = 0: N_0, 0

just after t = 0: $N_0 - \Delta N$, ΔN (small)

(a) increases with time ✓

(b) decreases with time

(c) remains constant

(d) any of the above may be true

at t = 0, total disintegration/sec $= \lambda N_0$

just after t = 0, total disintegration/sec $= \lambda(N_0 - \Delta N) + 2\lambda\Delta N$

$= \lambda(N_0 + \Delta N)$

Q10) There are two radio nuclei A and B. A is an alpha emitter and B a beta emitter. Their disintegration constants are in the ratio of 1: 2. What should be the ratio of number of atoms of A and B at any time t so that probabilities of getting alpha and beta particles are same at that instant ?

(a) 2 : 1 (b) 1 : 2 (c) e (d) e^{-1}

Q11) After 280 days, the activity of a radioactive sample is 6000 dps. The activity reduces to 3000 dps after another 140 days. The initial activity of the sample in dps is:

$t_{1/2} = 140$ days

$A = A_0 \left(\frac{1}{2}\right)^n$

$6000 = A_0 \left(\frac{1}{2}\right)^2$

$A_0 = 4 \times 6000$

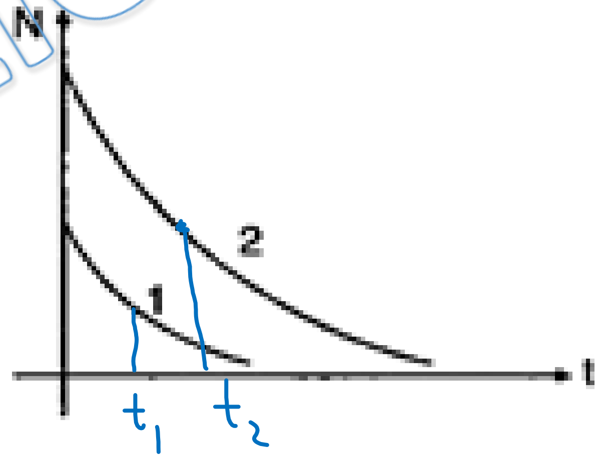
(a) 6000 (b) 9000 (c) 3000 (d) 24000

Q12) In radioactivity number of nuclei of two radioactive substances 1 and 2 are shown in figure. Match the following

$A = \lambda N$ → greater for 2

λ → greater for 1

Table-1		Table-2	
(A)	Initial activity of	(P)	1 is more
(B)	Half-life of	(Q)	2 is more
(C)	Decay constant of	(R)	nothing can be said



COMPREHENSION (Q13 to Q15)

We have two radioactive nuclei A and B. Both convert into a stable nucleus C. Nucleus A converts into C after emitting two α-particles and three β-particles. Nucleus B converts into C after emitting one α -particle and five β particles. At time t = 0, nuclei of A are 4 N_0 and that of B are N_0. Half-life of A (into the conversion of C) is 1min and that of B is 2 min. Initially number of nuclei of C are zero.

(Q13) If atomic numbers and mass numbers of A and B are Z_1, Z_2, A_1 and A_2 respectively. Then:

(a) $Z_1 - Z_2 = 6$

(b) $A_1 - A_2 = 4$

(c) both (a) and (b) are correct

(d) both (a) and (b) are wrong

$(4N_0)\ A \xrightarrow[t_{1/2} = 1\text{min}]{2\alpha,\ 3\beta} C$

$(N_0)\ B \xrightarrow[1\alpha,\ 5\beta]{t_{1/2} = 2\text{min}} C$

$A(C) = A_1 - 2\times4 = A_2 - 4 \Rightarrow A_1 - A_2 = 4$

$Z(C) = Z_1 - 4 + 3 = Z_2 - 2 + 5 \Rightarrow Z_1 - Z_2 = 4$

Q14) What are number of nuclei of C, when number of nuclei of A and B are equal?

$N_A = N_B$

$\Rightarrow 4N_0\left(\frac{1}{2}\right)^{t/1} = N_0\left(\frac{1}{2}\right)^{t/2}$

$\left(\frac{1}{2}\right)^{t-t/2} = \frac{1}{4} = \left(\frac{1}{2}\right)^2$

(a) $2N_0$ (b) $3N_0$ (c) $\frac{9N_0}{2}$ (d) $\frac{5N_0}{2}$

$t/2 = 2$

$t = 4 \Rightarrow N_A = 4N_0\left(\frac{1}{2}\right)^4 = N_0/4$

$N_B = N_0\left(\frac{1}{2}\right)^2 = N_0/4$

$N_A + N_B = \frac{N_0}{2}$ at $t = 4$ min

Initial $N_A + N_B = 5N_0 \Rightarrow N_C = 5N_0 - \frac{N_0}{2} = \frac{9N_0}{2}$

Q15) At what time rate of disintegrations of A and B are equal.

$A_A = A_B$

$\Rightarrow \lambda_A 4 N_0 \left(\frac{1}{2}\right)^{t/1\,min} = \lambda_B N_0 \left(\frac{1}{2}\right)^{t/2\,min}$

$\Rightarrow 4 \frac{\lambda_A}{\lambda_B} \left(\frac{1}{2}\right)^{t} = \left(\frac{1}{2}\right)^{t/2}$

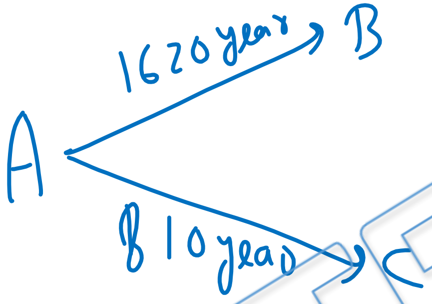
(a) 4 min (b) 6 min (c) 8 min (d) 2 min

$\Rightarrow 4 \frac{t_B}{t_A} \left(\frac{1}{2}\right)^{t/2} = 1$

$\Rightarrow \left(\frac{1}{2}\right)^{t/2} = 1/8 = \left(\frac{1}{2}\right)^{3} \Rightarrow t/2 = 3$

$t = 6$

Q16) A radioactive material decays by simultaneous emission of two particles with respective half-lives 1620 and 810 years. The time, in years, after which one-fourth of the material remains is



effective $\lambda = \lambda_1 + \lambda_2$

$$\frac{.693}{t_{1/2}} = \frac{.693}{t_1} + \frac{.693}{t_2}$$

$$t_{1/2} = \frac{t_1 t_2}{t_1 + t_2} = \frac{1620 \times 810}{2430} = 540$$

(a) 1080 (b) 2430 (c) 3240 (d) 4860

$t_{1/2} = 540$ year

$$\frac{N}{N_0} = \left(\frac{1}{2}\right)^{t/t_{1/2}}$$

$$\Rightarrow \left(\frac{1}{2}\right)^2 = \left(\frac{1}{2}\right)^{t/540} \Rightarrow t = 540 \times 2 = 1080 \text{ years}$$

Q17) Equal masses of two samples A and B of charcoal are burnt and the activity of resulting carbon-di-oxide from two samples is measured. The gas from sample A gives 10^4 counts per month and that from sample B gives 2.5×10^3 counts per month. The age difference of two samples is - (Half life of C^{14} is 5730 years) -

(a) 5730 Y

(b) 11460 Y

(c) 17190 Y

(d) 22920 Y

$t_{1/2} = 5730$ years

$C^{14} \longrightarrow C^{12}$

$t = \frac{2.303}{\lambda} \log\left(\frac{A_0}{A}\right) \Rightarrow t_A = \frac{2.303}{\lambda} \log\left(\frac{A_0}{10^4}\right)$

$t_B = \frac{2.303}{\lambda} \log\left(\frac{A_0}{2.5 \times 10^3}\right)$

$t_B - t_A = \frac{2.303}{\lambda} \log\left(\frac{A_0}{2.5 \times 10^3} \times \frac{10^4}{A_0}\right) = \frac{2.303 \times 2 \log 2}{\lambda}$

$= 2 t_{1/2} = 11460$ years

Q18) The radioactive carbon gets produced by the process of -

(a) reaction of radium rays on simple carbon

(b) reaction of cosmic rays on simple carbon

(c) reaction of high energy neutrons on nitrogen

(d) reaction of cosmic rays on oxygen.

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