PHYSICS

The following questions consist of two statements each, printed as Assertion and Reason. While answering these questions you are to choose any one of the following four responses.

(A) If both Assertion and Reason are true and the Reason is correct explanation of the Assertion.

(B) If both Assertion and Reason are true but Reason is not correct explanation of the Assertion.

(C) If Assertion is true but the Reason is false.

(D) If Assertion is false but Reason is true

Q.1 **Assertion :** The ionising power of β-particle is less compared α-particle but their penetrating power is more.
Reason : The mass of β-particles is less than the mass of α-particle. **[B]**

Q.2 **Assertion** : Electron capture occurs more often than positron emission in heavy element.
Reason : Heavy elements exhibit radioactivity. **[B]**

Q.3 **Assertion** : A certain radioactive substance has a half life period of 30 days. The disintegration constant is 0.0231 day^{-1}.
Reason : Decay constant varies inversely as half life. **[A]**

Q.4 **Assertion** : During radioactive disintegration an α particle and a β particle can be emitted simultaneously.
Reason : α, β are the products of radioactive decay. **[D]**

Q.5 **Assertion** : The units of decay constant are sec^{-1}.
Reason : It represents the rate of disintegration. **[C]**

Q.6 **Assertion** : Half life of a certain radio-active element is 100 days. After 200 days fraction left undecayed will be 50%
Reason : $\frac{N}{N_0} = \left(\frac{1}{2}\right)^{t/t_{1/2}}$, where symbols have usual meaning **[D]**

Q.7 **Assertion :** In beta decay, the velocity of the nucleus that emits an electron may not be directed along the line along which the electron velocity is directed.
Reason : If external force is zero, linear momentum of system is always conserved. **[A]**

Q.8 **Assertion :** β-particles emitted from radioactive nuclei has continuous energy ranging from zero to a certain maximum value.
Reason : In β-decay a neutron is converted into a proton, an electron and an antineutrino. The total energy emitted in β^- decay is shared by β^- particle and antineutrino. **[A]**

Q.9 **Statement I :** In β- decay, antinutrino is emitted.
Statement II : Antinutrino is emitted due to conservation of linear momentum. **[C]**

Q.10 **Statement I :** γ -photons are emitted during annihilation process of electron and positron.
Statement II : High energy photons are emitted due to conversion of mass into energy. **[A]**

Q.11 **Statement I :** Most of the heavy element emit α and β particles simultaneously.
Statement II : Heavy element contain comparatively larger number of neutrons then protons. **[D]**

Q.12 **Statement I :** Unit of decay constant is sec^{-1}.
Statement II : Decay constant represents rate of disintegration. **[C]**

Q.13 **Statement I :** 75% of radioactive nucleus remains active after 200 days for an element of half life 100 days.
Statement II : $N = N_o\,(1/2)^{t/T}$ where symbols have usual meaning. **[D]**

Q.14 **Assertion :** Half-life of a certain radioactive element is 10 days. After 200 days, fraction left undecayed will be 50%.

Reason : $\frac{N}{N_0} = \left(\frac{1}{2}\right)^n$, where symbols have standard meaning.

Sol. **[D]** Self explanatory

Q.15 **Assertion :** In β-decay an electron is emitted by the nucleus.

Reason : Electrons are not present inside the nucleus.

Sol. **[B]**

Q.16 **Assertion :** The ionisation power of β-particles is less as compared with α-particles.

Reason : The mass of β-particles is less than the mass of α-particles.

Sol. **[B]**

Both (A) and (R) are true but (R) is not the correct explanation of (A).

Q.17 **Assertion :** A free neutron is not a stable particle.

Reason : It decay spontaneously into a proton, an electron and an antineutrino.

Sol. **[A]**

Both (A) and (R) are true but (R) is the correct explanation of (A).

Q.18 **Statement I :** The activity of a radioactive sample decreases linearly with time.

Statement II : The number of active nuclei present in a radioactive sample decreases exponentially with time.

Sol. **[D]**

Q.19 **Statement-1 :** Amongst alpha, beta and gamma rays, α-particle has maximum penetrating power.

Statement-2 : The alpha particle is heavier than beta and gamma rays.

Sol. [D]

Q.20 **Statement-1 :** The ionising power of β-particle is less compared to α-particle but their penetrating power is more.

Statement-2 : The mass of β-particle is less than the mass of α-particle.

Sol.[B]

Q.1

Column-I	**Column-II**
(A) Alpha decay	(P) Monoenergetic particle are emitted
(B) Beta decay	(Q) Poly energetic particles are emitted
(C) Positron emission	(R) Angular momentum is conserved
(D) Electron capture	(S) Can take place in side and outside nucleus

Ans. **A → P,R ; B → Q,R,S ; C → Q,R ; D → P,R**

Q.2

Column- I	**Column-II**
(A) 1 Rutherford	(P) 1 disintegration/sec
(B) 1 Beequerel	(Q) 3.7×10^{10} dis/sec
(C) 1 curie	(R) 10^6 dis/sec
(D) Activity of 1 g Ra^{226}	(S) 10^{10} dis/sec

Ans. **A → R ; B → P ; C → Q ; D → Q**

Q.3

Column I	**Column II**
(A) Alpha Decay	(P) Monoenergetic particles
(B) Beta Decay	(Q) Poly energetic particles are emitted
(C) Positron emission	(R) Angular momentum is conserved
(D) Electron capture	(S) Can take place inside and outside nucleus

Sol. **A → P,R ; B → Q,R,S ; C → Q,R ; D → P,R,**

α - decay :

$${}^{A}_{z}X \to {}^{A-4}_{z-2}Y + {}^{4}_{2}He$$

$Q = K.E_Y + K.E_\alpha$

$K.E_Y << K.E_\alpha$

$Q = K.E_\alpha$

K.E. of all the emitted α-particles is equal to Q i.e., monoenergetic α- particles are emitted.

Angular momentum is conserved in α -decay

β-Decay : Neutron decays to proton

$${}^{A}_{z}X \to {}^{A}_{z+1}Y + \bar{\nu} + e^-$$

$Q = K.E_Y + KE_e + E_{\bar{\nu}}$

$K.E_Y << K.E_e$

$Q \simeq K.E_e + E_{\bar{\nu}}$

* $E_{\bar{\nu}}$ is the energy of anti-neutrions. $E_{\bar{\nu}}$ takes on values from zero to maximum. Hence poly energetic particles are emitted. i.e. poly energetic antineutrinos are emitted.
* Due to emission of antineutrions spin angular momentum is conserved.
* Neutron can decay in free space i.e., outside nucleus

Positron emission : - Proton decays to neutron

$${}^{A}_{Z}X \to {}^{A}_{Z-1}Y + \nu + e^+$$

Same explanation as above in case of Beta decay

Proton cannot decay in free space in i.e, outside nucleus because rest mass of proton is less than that of neutron.

Electron capture

$${}^{A}_{Z}X + e^- \to {}^{A}_{Z-1}Y + \nu$$

$Q \simeq K.E_Y + E_\nu$

$K.E_Y << E_\nu$

$Q \simeq E_\nu$

All the neutrinos emitted are of equal energies and their energies are approximately equal to Q. That is monoenergetic neutrinos are emitted.

- Angular momentum is conserved.
- Cannot takes placed outside nucleus. i.e, in free space

Q.4

Column I	**Column II**
(A) Alpha Decay	(P) Monoenergetic particles are emitted
(B) Beta Decay	(Q) Polyenergetic particles are emitted
(C) Positron emission	(R) angular momentum is conserved
(D) Electron capture	(S) Can take place inside and outside nucleus

Sol. **A → P,R, B → Q, R,S C → Q,R, D → P,R,**

α - decay :

$^{A}_{z}X \rightarrow ^{A-4}_{z-2}y + ^{4}_{2}He$

Q = $K.E_y + K.E_\alpha$

$K.E_y << K.E_\alpha$

Q = $K.E_\alpha$

K.E of all the emitted α-particles is equal to Q i.e., monoenergetic α- particles are emitted

Angular momentum is conserved in α -decay

β-Decay : Neutron decays to proton

$^{A}_{z}X \rightarrow ^{A}_{z+1}y + \bar{\nu} + e^-$

Q = $K.E_y + KE_e + E_{\bar{\nu}}$

$K.E_y << K.E_e$

Q $\simeq K.E_e + E_{\bar{\nu}}$

* $E_{\bar{\nu}}$ is the energy of anti-neutrions. $E_{\bar{\nu}}$ takes on values from zero to maximum. Hence poly energetic particles are emitted. i.e. poly energetic antineutrinos are emitted.

* Due to emission of antineutrions spin angular momentum is conserved.

* neutron can decay in free space i.e., out side nucleus

Positron emission : - Proton decays to neutron

$^{A}_{Z}X \rightarrow ^{A}_{Z-1}y + \nu + e^+$

Same explaination as above in case of Beta decay

Proton cannot decay in free space in i.e, outside nucleus because rest mass of proton is less than that of neutron.

Electron capture

$^{A}_{Z}X + e^- \rightarrow ^{A}_{Z-1}y + \nu$

Q $\simeq K.E_y + E_\nu$

$K.E_y << E_\nu$

Q $\simeq E_\nu$

All the neutrinos emitted are of equal energies & their energies are approximately equal to Q. That is monoenergetic neutrinos are emitted.

• Angular momentum is conserved.

Cannot takes placed outside nucleus. i.e, in free spa

Q.5 Match the process given in column-I with their characteristics in column-II.

Column I	**Column II**
(A) α - decay	(P) Atomic number of product nucleus decreases
(B) β^+ decay of	(Q) Atomic number product nucleus increases
(C) β^- decay of	(R) Atomic number product nucleus not necessarily changes
(D) Electron capture	(S) some mass is converted into energy

Sol. **A → P,S; B → P ; C → Q,S ; D → P**

Q.6 Match the following -

Column-I	***Column-II***
(A) α-decay	*(P) Mass number decreases*
(B) β^--decay	*(Q) Atomic number decreases*
(C) β^+-decay	*(R) Mass number does not change*
(D) *γ-decay*	*(S)Chemical symbol of nucleus changes*
	(T) Energy is released

Ans. **A → P, Q, S, T** **B → R, S, T**
C → Q, R , S, T **D → R, T**

Q.7 Match the column –

Column-I	**Column-II**
(A) Spontaneous radioactive decay of an uranium nucleus initially at rest as given by reaction $^{238}_{92}U \rightarrow ^{234}_{90}Th + ^{4}_{2}He + \ldots$	(P) Number of protons is increased
(B) Fusion reaction of two hydrogen nuclei as given by reaction $^{1}_{1}H + ^{1}_{1}H \rightarrow ^{2}_{1}H + \ldots.$	(Q) Momentum is conserved
(C) Fission of U^{235} nucleus initiated by a thermal neutron as given by reaction $^{1}_{0}n + ^{235}_{92}U \rightarrow ^{144}_{56}Ba + ^{89}_{36}Kr + 3\,^{1}_{0}n$	(R) Mass and energy are inter convertable
(D) β^- decay (negative beta decay)	(S)Charge is conserved
	(T)Angular momentum is conserved

Ans. **(A)** Q, R, S, T **(B)** Q, R, S, T
(C) Q, R, S, T **(D)** P, Q, R, S, T

Q.8 Match the following -

Column-I	**Column-II**
(A) α-decay	(P) Neutrino
(B) β-decay	(Q) Tunnel effect
(C) γ-decay	(R) Atomic number decreases by 1
(D) K-electron capture atomic	(S) No change in number

Sol. A → Q **B → P,R**
C → S **D → P, R**

Q.9 Match the column :

Column - I	**Column - II**
(A) α-rays	(P) stream of electrons or positrons
(B) β-rays	(Q) stream of double ionised helium atom
(C) γ-rays	(R) minimum penetrating power
	(S) maximum penetrating power
	(T) electromagnetic radiation
	(U) deflected by magnetic or electric field

Sol. (A) → (Q, R, U), (B) → (Q, U), (C) → (S, T)

PHYSICS

Q. 1 Energy released in Radioactive decay process

$$X \rightarrow Y + y$$

is given as –

(A) Sum of rest energy of Y and y minus rest energy of (X)

(B) Sum of Binding energy of Y and y minus binding of X

(C) Sum of rest energy of X minus sum of rest energy of Y and y

(D) Binding energy of X minus sum of binding energy of Y and y **[B,C]**

Q. 2 In the beta decay :

$${}^{A}_{Z}X \rightarrow {}^{A}_{Z+1}Y + e^-$$

(A) total energy is conserved

(B) mass number is conserved

(C) charge is conserved

(D) spin angular momentum is conserved

[B,C]

Q.3 In which of the following decays the atomic no. decreases ?

(A) α-decay (B) β^+-decay

(C) β^--decay (D) γ-decay

[A,B]

Q.4 A radioactive sample has initial concentration No. of nuclei–

(A) the number of undecayed nuclei present in the sample decays exponentially with time

(B) the activity (R) of the sample at any instant is directly proportional to the number of undecayed nuclie present in that sample at that time

(C) the no. of decayed nuclei grows exponentially with time

(D) the no. of decayed nuclei grow linearly with time **[A,B,C]**

Q.5 Magnetic field does cause deflection in–

(A) α-rays (B) β^+-rays

(C) β^--rays (D) γ-rays **[A,B,C]**

Q.6 Which of the following are correct ?

(A) a neutron can be decayed into a proton only inside a nucleus

(B) a proton can be changed into a neutron only inside a nculeus

(C) an isolated neutron can be changed into a proton

(D) an isolated proton can be changed into a neutron **[B,C]**

Q.7 A nuclide A undergoes α decay and another nuclide B undergoes β^- decay–

(A) All the α-particles emitted by A will have almost the same speed

(B) The α-particles emitted by A may have widely different speeds

(C) All the β-particles emitted by B will have almost the same speed

(D) The β-particles emitted by B may have widely different speeds **[A,D]**

Q.8 When the nucleus of an electrically neutral atom undergoes a radioactive decay process it will remain neutral after the decay if the process is–

(A) α-decay (B) β^--decay

(C) γ-decay (D) e^- capture process

[C,D]

Q.9 In the beta decay :

$${}^{A}_{Z}X \rightarrow {}^{A}_{Z+1}Y + e^-$$

(A) total energy is conserved

(B) mass number is conserved

(C) charge is conserved

(D) spin angular momentum is conserved

[A,B,C]

Sol. In beta decay neutron decays to proton

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

spin of p^+, e^- & ${}^{1}_{0}n$ is $\frac{1}{2}$

Therefore spin (R.H.S.) is either 0 or 1

spin (L.H.S.) in $\frac{1}{2}$

spin (R.H.S.) $\neq$ spin (L.H.S.)

Hence spin angular momentum is not conserved. Total energy, mass number and charge is conserved as can be seen by equation.

Q.10 In radioactivity decay according to law $N = N_0e^{-\lambda t}$ which of the following is/are true ?

(A) Probability that a nucleus will decay is $1 - e^{-\lambda t}$

(B) Probability that a nucleus will decay four half lives is 15/16

(C) Fraction nuclei that will remain after two half lives is zero

(D) Fraction of nuclei that will remain after two half-lives is ¼ **[A,B,D]**

Sol. $\frac{N}{N_0}$ ≡ fraction of nuclei that will not decay

$1 - N/N_0$ ≡ fraction of nuclei that will decay

$1 - N/N_0 \equiv 1 - e^{-\lambda t}$ ≡ Probability that a nucleus will decay

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

where n is the number of half lives

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

$1 - \frac{N}{N_0} = 1 - \frac{1}{16} = \frac{15}{16}$; Probability that a nucleus will decay

$\frac{N}{N_0} = \left(\frac{1}{2}\right)^2 = \frac{1}{4}$; fraction of nuclei that will remain after two half lives

Q.11 Energy released in Radioactive decay process

$X \to Y + y$

is given as –

(A) Rest energy of Y and y minus rest energy of (X)

(B) Sum of Binding energy of Y and y minus binding of X

(C) Rest energy of X minus sum of rest energy of Y and y

(D) Binding energy of X minus sum of binding energy of Y and y **[B,C]**

Sol. Conservation of energy gives

$m_Xc^2 + K.E_X = m_Yc^2 + K.E_Y + m_yc^2 + K.E_y$

$Q = (m_Xc^2 - m_Yc^2 - m_yc^2) = K.E_y + K.E_Y - K.E_X$

as 'X' is at rest

∴ Q ≡ Energy released is

$Q = (m_Xc^2 - m_Yc^2 - m_yc^2) = K.E_Y + K.E_y$

Q (energy released) is rest energy of X minus rest energy of Y and y.

* When binding energy of products is more than binding energy of initial nucleus then energy is released.

Q.12 In the beta decay :

${}^{A}_{Z}X \to {}^{A}_{Z+1}Y + e^-$

(A) total energy is conserved

(B) mass number is conserved

(C) charge is conserved

(D) spin angular momentum is conserved

[A,B,C]

Sol. In beta decay neutron decays to proton

${}^{1}_{0}n \to p^+ + e^-$

spin of p^+, e^- & ${}^{1}_{0}n$ is $\frac{1}{2}$

Therefore spin (R.H.S.) is either 0 or 1

spin (L.H.S.) in $\frac{1}{2}$

spin (R.H.S.) ≠ spin (L.H.S.)

Hence spin angular momentum is not conserved. Total energy, mass number & charge is conserved as can be seen by equation.

Q.13 In which of the following decays the atomic number decreases –

(A) α - decay (B) β^+ - decay

(C) β^- - decay (D) γ - decay **[A,B]**

Sol. **α decay :** ${}^{A}_{Z}X \to {}^{A-4}_{Z-2}\gamma + {}^{4}_{2}He$

β^+ decay : ${}^{A}_{Z}X \to {}^{A}_{Z-1}\gamma + \beta^+ + \nu$

β^- decay : ${}^{A}_{Z}X \to {}^{A}_{Z+1}\gamma + \beta^- + \bar{\nu}$

γ decay only the quantum state of nucleons change

Q.14 Energy released in radioactive decay process

$X \to Y + y$

is given as –

(A) Rest energy of Y and y minus rest energy of (X)

(B) Sum of Binding energy of Y and y minus binding of X

(C) Rest energy of X minus sum of rest energy of Y and y

(D) Binding energy of X minus sum of binding energy of Y and y **[B,C]**

Sol. Conservation of energy gives

$m_Xc^2 + K.E_X = m_Yc^2 + K.E_Y + m_yc^2 + K.E_y$

$Q = (m_Xc^2 - m_Yc^2 - m_yc^2) = K.E_y + K.E_Y - K.E_X$

as 'X' is at rest

∴ Q ≡ Energy released is

$Q = (m_Xc^2 - m_Yc^2 - m_yc^2) = K.E_Y + K.E_y$

Q (energy released) is rest energy of X minus rest energy of Y and y.

* When binding energy of products is more than binding energy of initial nucleus then energy is released.

Q.15 A nitrogen nucleus ${}^{14}_{7}N$ absorbs a neutron and can transform into lithium nucleus ${}^{7}_{3}Li$ under suitable conditions, after emitting –

(A) 4 protons and 4 neutrons

(B) 5 protons and 1 beta minus particles

(C) 2 alpha and 2 gama particles

(D) 1 alpha particle, 4 protons and 2 beta minus particles. **[A,C,D]**

Sol. ${}^{14}_{7}N + {}^{1}_{0}n \longrightarrow {}^{7}_{3}Li$

Diff in mass no. = 8

Diff. in atomic no = 4

(A) ${}^{14}_{2}N + {}^{1}_{0}n \longrightarrow {}^{7}_{3}Li + 4{}^{1}_{1}H + 4{}^{1}_{0}n$

above reaction is balanced hence (A) is correct.

(B) ${}^{14}_{7}N + {}^{1}_{0}n \longrightarrow {}^{7}_{3}Li + 5{}^{1}_{1}H + 1{}^{0}_{-1}e$

above reaction is not balanced

(C) ${}^{14}_{7}N + {}^{1}_{0}n \longrightarrow 2{}^{4}_{2}He + 2\gamma + {}^{7}_{3}Li$

above reaction is balanced

(D) ${}^{14}_{7}N + {}^{1}_{0}n \longrightarrow {}^{7}_{3}Li + {}^{4}_{2}He + 4{}^{1}_{1}H + 2{}^{0}_{-1}\beta$

above reaction is balanced.

Q.16 A nuclide A undergoes α-decay and another nuclide B undergoes β-decay -

(A) all the α-particles emitted by A will have almost the same speed

(B) the α-particles emitted by A may have widely different speed

(C) all the β-particles emitted by B will have almost same speed

(D) the β-particles emitted by B may have widely different speeds

Sol. **[A, D]**

Conceptual.

Q.17 Polonium ${}_{84}Po^{210}$ emits α-particles and is converted into ${}_{82}Pb^{206}$. This reaction is used for producing electric power in a space mission. Po^{210} has half life of 138.6 days. Assuming an efficiency of 10%. Now choose correct statement(s) -

Given : $M(Po^{210})$ = 209.98264 amu ; M(α) = 4.0026 amu

$M(Pb^{206})$ = 205.97440 amu ; 1 amu = 931 MeV energy

(A) 10 gm Po^{210} is required to produce 1.2×10^{7} Joule energy

(B) Decay constant of Po^{210} is 0.005 day^{-1}

(C) Q-value of α-decay process is 8.4×10^{-13} Joule

(D) None of these

Sol.[A,B,C] $Q = [M(Po^{210}) - M(Pb^{206}) - M(\alpha)]931$

$\lambda = \dfrac{0.693}{t_{1/2}}$

Q.18 For a certain radioactive substance, it is observed that after 4 hours, only 6.25% of the original sample is left undecayed. If follows that-

(A) the half life of the sample is 1 hour

(B) the mean life of the sample is $\dfrac{1}{\ln 2}$ hour

(C)the decay constant of the sample is ln 2 $hour^{-1}$

(D) after a further 4 hours, the amount of the substance left over would by only 0.39% of the original amount

Sol.[A,B,C,D] We have 6.25% = $\dfrac{6.25}{100} = \dfrac{1}{16}$

The given time of 4 hours thus equals 4 half-lives so that the half life is 1 hour.

Since half life $\dfrac{\ln 2}{\text{decay constant}}$ and

mean life = $\dfrac{1}{\text{deacy constant}}$

after further 4 hours, the amount left over would be $\dfrac{1}{2^4} \times \dfrac{1}{2^4}$ i.e. $\dfrac{1}{256}$ or $\dfrac{100}{256}$ or 0.39% of original amount.

Q.19 In radioactivity decay according to law $N = N_0 e^{-\lambda t}$ which of the following is/are true ?

(A) Probability that a nucleus will decay is $1 - e^{-\lambda t}$

(B) Probability that a nucleus will decay four half lives is 15/16

(C) Fraction nuclei that will remain after two half lives is zero

(D) Fraction of nuclei that will remain after two half-lives is ¼

Sol.[A,B,D]

$\frac{N}{N_0}$ ≡ fraction of nuclei that will not decay

$1 - N/N_0$ ≡ fraction of nuclei that will decay

$1 - N/N_0 \equiv 1 - e^{-\lambda t}$ ≡ Probability that a nucleus will decay

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

where n is the number of half lives

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

$1 - \frac{N}{N_0} = 1 - \frac{1}{16} = \frac{15}{16}$;

Probability that a nucleus will decay

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

fraction of nuclei that will remain after two half lives

Q. 1 ^{23}Ne decays to ^{23}Na by negative beta emission. Mass of ^{23}Ne is 22.994465 amu mass of ^{23}Na is 22.989768 amu. The maximum kinetic energy of emitted electrons neglecting the kinetic energy of recoiling product nucleus is ....MeV

Sol. **[0004]**

$$^{23}_{10}Ne \rightarrow {}^{23}_{11}Na + e^- + \bar{\nu}$$

$Q = [m(^{23}Ne) - m(^{23}Na)] \times 931.5$ MeV

A = 4.375 MeV = 4.4 MeV

$Q \simeq 4$ MeV

$Q = KE_y + KE_e + E\bar{\nu}$

KE_y is very very small

$A \approx KE_e + E\bar{\nu}$

when KE_e is maximum $E\bar{\nu}$ is negligible

$KE_e \simeq Q = 4$ MeV

Q.2 In U^{238} ore containing Uranium the ratio of U^{234} to Pb^{206} nuclei is 3. Assuming that all the lead present in the ore is final stable product of U^{238}. Half life of U^{238} to be 4.5×10^9 years and find the age of ore. (in 10^9 years) **[0002]**

Sol. $\frac{N}{N_0 - N} = \frac{3}{1} \quad \Rightarrow \quad \frac{N}{N_0} = \frac{3}{4}$

$$\frac{N}{N_0} = \frac{3}{4} = e^{-\lambda t}$$

$$\lambda t = \log_e 4/3 \Rightarrow \quad t = \left(\frac{\log_e 4/3}{0.693}\right) T_{1/2}$$

$$t = 4.5 \times 10^9 \left[\frac{.1249}{.3010}\right]$$

$= 1.8678 \times 10^9$ years $\approx 2 \times 10^9$ years

Q.3 The radioactivity of an old sample of whisky due to tritium (half life 12.5 years) was found to be only about 4% of that measured in a recently purchased bottle marked 10 years old. Find the age of sample in years. **[0068]**

Sol. $N_1 = N_0 e^{-\lambda.10}$

$N_2 = N_0 e^{-\lambda x}$

$$\frac{N_2}{N_1} = \frac{4}{100} = e^{\lambda(10-x)}$$

$$e^{\lambda(x-10)} = \frac{100}{4}$$

$\lambda(x - 10) = 2\,\ell n\, 10 - \ell n\, 4$

$\lambda(x - 10) = 2(2.3) - 2(0.693)$

$\lambda(x - 10) = 3.22$

Now $\lambda = \frac{0.693}{12.5}$ yr^{-1}

$$\therefore x - 10 = \frac{12.5}{0.693} \times 3.22 = 58.08$$

$x \simeq 68$ years

Q.4 The nuclei of two radioactive isotopes of same substance A^{236} and A^{234} are present in the ratio 4 : 1 in an ore obtained from Mars. Their half lives are 30 min and 60 min respectively. Both isotopes are alpha emitters and the activity of the isotope with half life 30 min is one Rutherford . Calculate after how much time (in min) their activities will become identical. **[0180]**

Sol.

	A^{236}	:	A^{234}
Nuclei	$4N_0$	:	N_0
Half life	30	:	60

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

$$\lambda_1 4N_0\, e^{-\frac{0.693}{30}t} = \lambda_2 N_0\, e^{-\frac{0.693}{60}t}$$

$$\frac{0.693}{30} \times 4N_0\, e^{-\frac{0.693}{30}t} = \frac{0.693}{60} \times N_0\, e^{-\frac{0.693}{60}t}$$

$$8 = e^{0.693t\left(\frac{1}{30} - \frac{1}{60}\right)}$$

$$8 = e^{+\frac{0.693}{60}t}$$

$$3 \times 0.693 = \frac{0.693t}{60}$$

t = 180 min

Q.5 An unstable element is produced in a nuclear reactor at a constant rate. If its half life is 100 years, how much time in years is required to produce 50% of the equilibrium quantity ? **[0100]**

Sol. Let rate of production = R

$\therefore \frac{dN}{dt} = R - \lambda N$

$\frac{dN}{dt} + \lambda N = R$

$e^{\lambda t}\frac{dN}{dt} + \lambda N e^{\lambda t} = Re^{\lambda t}$

$\frac{d(Ne^{\lambda t})}{dt} = Re^{\lambda t}$

$Ne^{\lambda t} = \frac{Re^{\lambda t}}{\lambda} + C$

At t = 0, N = 0 $\Rightarrow$ $C = -\frac{R}{\lambda}$

$\therefore N = \frac{R}{\lambda}(1 - e^{-\lambda t})$

At equilibrium quantity $N = \frac{R}{\lambda}$ for $t \to \infty$

$\therefore \frac{R}{2\lambda} = \frac{R}{\lambda}(1 - e^{-\lambda t})$

$\Rightarrow e^{-\lambda t} = \frac{1}{2}$

$t = \frac{\ell n2}{\lambda} = T_{1/2} = 100$ years

Q.6 Find the activity of 0.5 mg of radon-222 in curie. It is known that half-life of radon is 3.8 days. **[0077]**

Sol. $\left|\frac{dN}{dt}\right| = \lambda N_0$

$= \frac{\ell n2}{T_{1/2}} N_0$

$= \frac{0.693 \times 0.5 \times 10^{-3} \times 6.02 \times 10^{23}}{3.8 \times (24 \times 3600) \times 222 \times (3.7 \times 10^{10})}$

= 77.35 mg

$\simeq$ 77 mg

Q.7 A radioactive sample decays with a mean life of 20 millisecond. A capacitor of capacitance 100 μF is charged to some potential and then the plates are connected through a wire of resistance R. What should be the value of R in ohm so that the ratio of the charge on the capacitor to the activity of the radioactive sample remain constant in time ? **[0200]**

Sol. $\frac{Q}{A} = \frac{Q_0 e^{-t/RC}}{A_0 e^{-\lambda t}} = \frac{Q_0}{A_0} e^{(\lambda - \frac{1}{RC})t}$

$\lambda - \frac{1}{RC} = 0$

$\Rightarrow \lambda = \frac{1}{RC}$

$\lambda = \frac{1}{C\lambda} = \frac{T}{C} = \frac{20 \times 10^{-3}}{100 \times 10^{-6}} = 200\ \Omega$

Q.8 The mean lives of a radioactive substance are 1620 and 405 years for α-emission and β-emission respectively. Find out the time (in years) after which three fourth of a sample will decay if it is decaying both by α-emission and β-emission simultaneously. (Take ℓn 2 = 0.693) **[0449]**

Sol. $\frac{1}{T} = \frac{1}{T_\alpha} + \frac{1}{T_\beta}$

$\Rightarrow T = \frac{T_\alpha T_\beta}{T_\alpha + T_\beta} = 324$ years

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

$t = \frac{1}{\lambda}\ell n\frac{N_0}{N} = T\ \ell n\frac{N_0}{N}$

t = 324 × 2ℓn 2

t = 449 .06 years

t $\approx$ 449 years

Q.9 If 20 gm of a radioactive substance due to radioactive decay reduces to 10gm in 4 minutes, then in what time (in minutes) 80gm of the same substance will reduce to 20 gm -

Sol. **[8]**

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

$20 = 80\left(\frac{1}{2}\right)^n$

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

$t = nT_{1/2} = 2 \times 4 = 8$ minutes

Q.10 Equal masses of two samples of charcoal A and B are burnt separately and the resulting carbon dioxide are collected in two vessels. The radioactivity of ^{14}C is measured for both the samples. The gas from the charcoal A gives 2100 counts per week and gas from the charcoal B gives 1400 counts per week. Find the age difference between two samples. Half life of ^{14}C = 5730 years and [$\log_e\left(\frac{3}{2}\right)$ = 0.4055]

Sol. **[3352]**

Q.11 A polonium ($_{84}Po^{209}$) nucleus transforms into one of lead ($_{82}Pb^{207}$) by emitting an α-particle, then the kinetic energy of the α-particle in MeV is -

[m (P_0) = 209.98297u ; m (Pb) = 205.97446 m (α-particle) = 4.00260 u]

Q.12 The energy in MeV required to extract a neutron from a carbon nucleus with mass number 13 is -

[m ($_6C^{13}$) = 13.00335u ; m ($_6C^{12}$) = 12.0000u

m_n = 1.00867 u ; m_p = 1.00783u]

Sol. **[5]**

Energy required is equal to difference in binding energy of parent nucleus and daughter nucleus.

Q.13 A nucleus at rest undergoes a decay emitting an α-particle of de-Broglie wavelength 5.76×10^{-15} m. If the mass of daughter nucleus is 223.610 amu and that of α-particle is 4.002 amu. The mass of the parent nucleus is 22X amu then find X appearing in the number 22X.

(1 amu = 931.47 MeV/c^2)

Sol. **[8]**

$\lambda = \frac{h}{P}$ for α-particle

$(K.E.)_\alpha = \frac{P^2}{2m_\alpha}$ and $(K.E.)_{nucleus} = \frac{P^2}{2m_n}$

$E = \frac{P^2}{2}\left[\frac{1}{m_\alpha} + \frac{1}{m_n}\right]$ = 6.25 MeV

∴ mass of parent nucleus = $\left(m_n + m_\alpha + \frac{E}{c^2}\right)$

= 227.62 amu

Q.14 There are two radio nuclei A and B. A is an alpha emitter and B a beta emitter. Their disintegration constants are in ratio of 1 : 2. 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 is -

Sol. **[2]**

$\frac{\lambda_A}{\lambda_B} = \frac{1}{2}$ Probabilities of getting α and β particles are equal. Thus rate of disintegration are equal

∴ $\lambda_A N_A = \lambda_B N_B$

Q.15 Half life of radioactive substance A is two time that of B. Initially number of nuclei of A and B are N_A and N_B respectively. After three half lives of A number of nuclei of both are equal. Then the ratio $\frac{N_B}{N_A}$ is –

Sol. **[8]**

3 half lives of A is equivalent to 6 half lives of B.

∴ $N_A\left(\frac{1}{2}\right)^3 = N_B\left(\frac{1}{2}\right)^6$

Q.16 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 then the value of n is -

Sol. **[1]**

Let $\lambda_A = \lambda$ and $\lambda_B = 2\lambda$

Initially rate of disintegration of A is is λN_0 and that of B is $2\lambda N_0$.

After one half life of A, rate of disintegration of A will becomes $\frac{\lambda N_0}{2}$ and that of B would also be $\frac{\lambda N_0}{2}$ so after one half life of A or two half life of B. $\left(\frac{-dN}{dt}\right)_A = \left(\frac{-dN}{dt}\right)_B$

$\therefore$ n = 1

Q.17 Number of nuclei of a radioactive substance at t = 0 are 1000 and 900 at t = 2 sec. The number of nuclei at t = 4 sec will be x10, then the value of x in number x10 is -

Sol. **[8]**

In 2 sec only 90% of nuclei are left. Thus in next 2 sec. 90% of 900 or 810 nuclei will be left.

Q.18 If 20 gm of a radioactive substance due to radioactive decay reduces to 10 gm in 4 minutes, then in what time (in minutes) 80 gm of the same substance will reduce to 20 gm.

Sol.[4] $N = N_0\left(\frac{1}{2}\right)^n$

$20 = 80\left(\frac{1}{2}\right)^n$

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

$t = n\,T_{1/2} = 2 \times 4 = 8$ minutes

PHYSICS

Q.1 A radioactive material has a mean lives of 1620 year and 660 year for α and β emission respectively. The material decay by simultaneous α and β emission. The time in which 1/4th of the material remains intact is -

(A) 4675 year (B) 720 year
(C) 650 year (D) 324 year **[C]**

Sol. $\tau = \frac{\tau_1\tau_2}{\tau_1+\tau_2} = \frac{1620\times660}{2280} = 469$

$\frac{N}{4} = \frac{N}{2^{\frac{t}{T}}}$

$t = 2T = 2\,\tau\,\ell n\,2 = 2 \times 0.693 \times 469$

$= 650$ years.

Q.2 The ratio activity of an element becomes 1/64th of its original value in 60 sec. Then the half life period is -

(A) 5 sec (B) 10 sec
(C) 20 sec (D) 30 sec **[B]**

Sol. A.P $= \frac{1}{64} = \frac{1}{2^n}$ (n = 6)

$t = n\,T_{1/2} \Rightarrow T_{1/2} = \frac{t}{n} = \frac{60}{6} = 10$ sec

Q.3 The half life period of a radioactive substance is 140 days. After how much time, 15 gm will decay from a 16 gm sample of the substance ?

(A) 140 days (B) 560 days
(C) 420 days (D) 280 days **[B]**

Sol. $\frac{m}{m_0} = \frac{1\,gm}{16\,gm} = \left(\frac{1}{2}\right)^4 = \left(\frac{1}{2}\right)^{\frac{t}{T}}$

$\Rightarrow$ t = 4T = 4 × 140 days = 560 days

Q.4 In free space the intensity of 5 eV neutron beam is reduced by a factor of one half. Half life is $t_{1/2}$ = 12.8 min. The distance travelled by neutron beam is-

(A) 2800 km (B) 23800 km
(C) 28 km (D) 2 km **[B]**

Q.5 90 % of a radio active sample is left undecayed after time t has elapsed. what percentage of the initial sample will decay in a total time 2t. -

(A) 20 % (B) 19 %
(C) 40 % (D) 38 % **[B]**

Sol. $N = N_0\,(0.9)^2$

$N = 0.81\,N_0$

81% of initial value is left

hence % of the initial sample decayed

= 100 – 81 = 19 %

Q.6 The half life of ^{198}Au is 2.7 days. The probability that any ^{198}Au nucleus will decay in one second is -

(A) 10^{-6} (B) 3×10^{-6}
(C) 5×10^{-6} (D) 10^{-5}

Sol. **[B]**

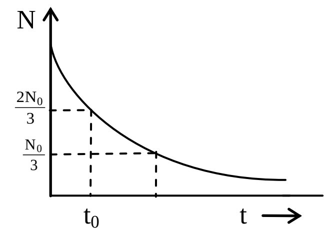
Decay probability per second is just the decay constant

$\lambda = \frac{0.693}{t_{1/2}} = \frac{0.693}{2.7\text{days}}$

$\lambda = \frac{0.693}{2.7\times24\times60\times60}$

$\lambda = 2.97 \times 10^{-6}$/sec

Q.7 Figure shows the variation of the number of radioactive atoms left undecayed with time. The time corresponding to $N = \frac{N_0}{3}$ is -



(A) $3\,t_0$

(B) $t_0\ \log_e 2$

(C) $\frac{t_0 \log_e 3}{\log_e\left(\frac{3}{2}\right)}$

(D) cannot be ascertained because it depends on the decay constant.

Sol. **[C]**

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

$\frac{2N_0}{3} = N_0 e^{-\lambda t_0}$ $\quad e^{-\lambda t_0} = \frac{3}{2}$ .... (1)

$\lambda t_0 = \log_e\left(\frac{3}{2}\right)$

Also $\frac{N_0}{3} = N_0\ e^{-\lambda t_1}$

$\lambda t_1 = \log_e 3$

$t_1 = \frac{1}{\lambda}\log_e 3 = \frac{t_0 \log_e 3}{\log_e\left(\frac{3}{2}\right)}$

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

Sol. **[A]** Let $\lambda_A = \lambda$ and $\lambda_B = 2\lambda$

Initially rate of disintegration of A is λN_0 and that of B is $2\lambda N_0$. After one half life time of A, the rate of disintegration of A becomes $\frac{\lambda N_0}{2}$ and that of B would also be $\frac{\lambda N_0}{2}$ [half-life of B = $\frac{1}{2}$ (half-life of A)]

So, after one half-life of A or two half-lives of B.

$$\left(-\frac{dN}{dt}\right)_A = \left(-\frac{dN}{dt}\right)_B$$

$\therefore$ n = 1

Q.9 The mean lives of a radioactive substance are 1620 year and 405 year for α-emission and β-emission respectively. Find the time during which three-fourth of a sample will decay if it is decaying both by α-emission and β-emission simultaneously.

(A) 249 years (B) 449 years

(C) 133 years (D) 99 years

Sol. **[B]**

The decay constant λ is the reciprocal of the mean life τ.

Thus, $\lambda_\alpha = \frac{1}{1620}$ per year

and $\lambda_\beta = \frac{1}{405}$ per year

$\therefore$ Total decay constant, $\lambda = \lambda_\alpha + \lambda_\beta$

or $\lambda = \frac{1}{1620} + \frac{1}{405} = \frac{1}{324}$ per year

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

When $\frac{3}{4}$ th part of the sample has disintegrated, $N = N_0/4$

$\therefore$ $\frac{N_0}{4} = N_0 e^{-\lambda t}$

or $e^{\lambda t} = 4$

Taking logarithm of both sides, we get

$\lambda t = \log_e 4$

or $t = \frac{1}{\lambda}\log_e 2^2 = \frac{2}{\lambda}\log_e 2$

$= 2 \times 324 \times 0.693 = 449$ year

Q.10 The example of radioactive substance is

(A) Na (B) Mg

(C) He (D) Np **[D]**

Q.11 Radioactivity is not influenced by

(A) pressure

(B) electronic configuration

(C) temperature

(D) all of these **[D]**

Q.12 The parent and the stable product of the Uranium series are respectively, $^{238}_{92}U$ and $^{206}_{82}Pb$. How many α and β- particles respectively are emitted from the parent nucleus to become the stable end product ?

(A) 8, 8 (B) 6, 6

(C) 8, 6 (D) 16, 8 **[C]**

Q.13 In which of the following decays the element does not change ?

(A) α-decay (B) β^+-decay

(C) β^--decay (D) γ-decay **[D]**

Q.14 One of the incomplete nuclear decay process is

$^{228}Th \longrightarrow {}^{224}Ra^* + ...$

The term in the place of blank may be

(A) α (B) β^-

(C) β^+ (D) γ **[A]**

Q.15 The phenomenon in which the masses of a particle and an antiparticle disappear to reappear as energy is called -

(A) Pair production (B) Annihilation

(C) Cerenkov radiation (D) Compton scattering

[B]

Q.16 Which one of the following is not a mode of radioactive decay -

(A) Electron emission (B) Alpha decay

(C) Fusion (D) Gamma emission

[C]

Q.17 In a radioactive decay, neither the atomic number nor mass number changes. Which of the following particles is emitted in the decay ?

(A) proton (B) neutron

(C) electron (D) photon **[D]**

Q.18 The rate of disintegration of fixed quantity of a radioactive element can be increased by -

(A) Increasing the temperature

(B) Increasing the pressure

(C) Chemical reaction

(D) It is not possible **[D]**

Sol. Not change with temperature, pressure or any other chemical reactions

Q.19 An α particle is bombarded on ^{14}N. As a result a ^{17}O nucleus is formed and a particle is emitted. This particle is a–

(A) neutron (B) proton

(C) electron (D) positron **[B]**

Q.20 A radioactive substance X decays into another radioactive substance Y. Initially only X was present. λ_x and λ_y are the disintegration constants of X and Y. N_x and N_y are the number of nuclei of X and Y at any time t. Number of nuclei N_y will be maximum when:

(A) $\frac{N_y}{N_x - N_y} = \frac{\lambda_y}{\lambda_x - \lambda_y}$

(B) $\frac{N_x}{N_x - N_y} = \frac{\lambda_x}{\lambda_x - \lambda_y}$

(C) $\lambda_y N_y = \lambda_x N_x$

(D) $\lambda_y N_x = \lambda_x N_y$ **[C]**

Sol. Net rate of formation of Y at any time t is:

$$\frac{dN_y}{dt} = \lambda_x N_x - \lambda_y N_y$$

N_y is maximum when $\frac{dN_y}{dt} = 0$

or $\lambda_y N_y = \lambda_x N_x$

Q.21 When an electron and positron with equal speeds in opposite direction annihilate each other, they cannot produce just one gamma ray, because that will violate law of–

(A) conservation of charge

(B) conservation of energy

(C) conservation of momentum

(D) conservation of nucleon number **[C]**

Q.22 A radioactive decay counter is switched on at t = 0. A β-active sample is present near the counter. The counter registers the number of β-particles emitted by the sample. The counter registers 1×10^5 β-particles at t = 36 sec and 1.11×10^5 β-particles at t = 108 sec. $T_{1/2}$ of this sample is -

(A) 5.2 sec (B) 10.8 sec

(C) 15.4 sec (D) 20.6 sec **[B]**

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

Decay $= N_0 - N$

$10^5 = N_0 (1 - e^{-36\lambda})$

$1.11 \times 10^5 = N_0(1 - e^{-108\lambda})$

$\Rightarrow \frac{1-e^{-108\lambda}}{1-e^{-36\lambda}} = 1.11$

$\Rightarrow e^{-36\lambda} = 0.1 \Rightarrow \lambda = \frac{\ell n10}{36}$

$T_{1/2} = \frac{\ell n2}{\lambda} = \frac{36\,\ell n 2}{\ell n10} \simeq 10.8$

Q.23 The compound unstable nucleus $^{236}_{92}U$ often decays in accordance with the following reaction

$^{236}_{92}U \rightarrow {}^{140}_{54}Xe + {}^{94}_{38}Sr +$ other particles. Here the other particles are–

(A) An alpha particle

(B) Two protons

(C) One proton and one neutron

(D) Two neutrons **[D]**

Q.24 Tritium $\left({}_1^3H\right)$ has a half-life of 12.5y against beta decay. What fraction of a sample of tritium will remain undecayed after 25y ?
(A) 1/4 (B) 3/4
(C) 1/2 (D) 3/8 **[A]**

Q.25 The activity of a certain radionuclide decreases to 15 percent of its original value in 10 days. Find its half-life. [ln (0.15) = – 0.19].
(A) 3.00 days (B) 3.50 days
(C) 3.65 days (D) 3.8 days **[C]**

Q.26 The half life of ^{24}Na is 15.0 h. How long does it take for 80 percent of a sample of this nuclide to decay ?
(A) 30 h (B) 34.8 h
(C) 40 h (D) 32.2 h **[B]**

Q.27 One g of ^{226}Ra has an activity of nearly 1Ci. Determine the half-life of ^{226}Ra.
(A) 1.6×10^2 y (B) 1.6×10^3 y
(C) 1.6 y (D) 8 y **[B]**

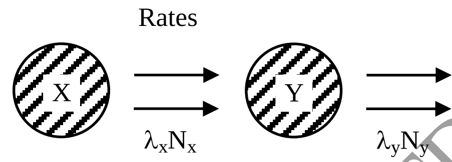
Q.28 The half-life of ${}_{92}^{238}U$ against alpha decay is 4.5×10^9y. Find the activity of 1.0g of ^{238}U.
(A) 1.2×10^4 Bq (B) 1.2×10^3 Bq
(C) 1.2×10^2 Bq (D) 1.2×10^1 Bq **[A]**

Q.29 The activity of a sample of an unknown radionuclide is measured in daily intervals. The results, in MBq, are 33.0, 27.7, 23.3, 19.6 and 16.5. Find the half life of the radionuclide.
(A) 8 days (B) 2 days
(C) 16 days (D) 4 days **[D]**

Q.30 Two radioactive sources A and B of half lives of 1 hour and 2 hours respectively initially contain the same number of radioactive atoms. At the end of two hours, their rates of disintegration are in the ratio of -
(A) 1 : 4 (B) 1 : 3
(C) 1 : 2 (D) 1 : 1 **[D]**

Q.31 A radioactive isotope is being produced at a constant rate X. Half-life of the radioactive substance is Y. After some time the number of radioactive nuclei become constant. The value of this constant is:
(A) $\frac{XY}{\ln(2)}$ (B) XY
(C) (XY) ln (2) (D) $\frac{X}{Y}$ **[A]**

Sol. Number of radio-nuclei become constant, when



$X = \lambda N$

or $N = \frac{X}{\lambda}$

$= \frac{X}{\frac{\ln 2}{Y}} = \frac{XY}{\ln(2)}$

Q.32 In one average life –
(A) half the active nuclei decay
(B) less than half the active nuclie decay
(C) more than half the active nuclie decay
(D) all the nuclie decay **[C]**

Q.33 A freshly prepared radio active source of half life 2 hours 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 **[B]**

Q.34 The decay constant of a radioactive sample is λ. The half life and the average life of the sample are respectively.
(A) $\frac{1}{\lambda}$ & $\frac{\ell n2}{\lambda}$ (B) $\frac{\ell n2}{\lambda}$ & $\frac{1}{\lambda}$
(C) $\lambda\ \ell n2$ & $\frac{1}{\lambda}$ (D) $\frac{\lambda}{\ell n2}$ & λ **[B]**

Q.35 The mean free path of a 5 eV neutron in vacuum is closest to (Life time of neutron is about 10^3 sec) –
(A) 10 km (B) 100 km
(C) 1,000 km (D) 10,000 km **[D]**

Sol. The mean free path in vacuum is the distance the neutron travels in its lifetime, from generation to decay. Lifetime of the neutron is about 10^3 s. As its energy 5 eV is much less than its rest energy 940 MeV, non-relativistic approximation may be used and its velocity is

$$v = \sqrt{\frac{2E}{m}} = c\sqrt{\frac{2E}{mc^2}} = \sqrt{\frac{2\times5\times10^{-6}}{940}} \times 3 \times 10^8 =$$

10^4 m/s.

Thus S = vt = 10^4 km.

Q.36 The activity of a sample of radioactive material is A_1 at time t_1 and A_2 at time $t_2(t_2 > t_1)$. Its mean life is T then which of the following is correct ?

(A) $A_1t_1 = A_2t_2$ (B) $\frac{A_1 + A_2}{t_2 - t_1}$ = constant

(C) $A_2 = A_1e^{(t_1-t_2)/T}$ (D) $A_2 = A_1e^{(t_1/Tt_2)}$

Sol. **[C]**

$A_1 = A_0e^{-t_1/T}$

$A_2 = A_0e^{-t_2/T}$

$\frac{A_1}{A_2} = e^{(t_1-t_2)/T}$

$A_2 = A_1e^{(t_1-t_2)/T}$

Q.37 Probability that a radioactive nucleus will not decay in time t will be: (given decay constant = λ)

(A) $e^{-\lambda t}$ (B) $1- e^{-\lambda t}$

(C) $e^{\lambda t}$ (D) $1- e^{\lambda t}$ **[A]**

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

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

Q.38 Half-life of a radioactive substance A is two times the half-life of another radioactive substance B. Initially the number of nuclei of A and B are N_A and N_B respectively. After three half lives of A number of nuclei of both are equal. Then the ratio N_A/N_B is:

(A) 1/4 (B) 1/8

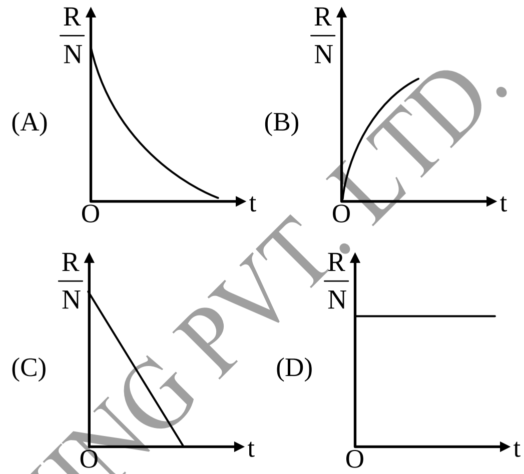
(C) 1/3 (D) 1/6 **[B]**

Sol. Three half-lives of A is equivalent to six half-lives of B.

Hence, $N_A\left(\frac{1}{2}\right)^3 = N_B\left(\frac{1}{2}\right)^6$

or $\frac{N_A}{N_B} = \frac{1}{8}$

Q.39 A radioactive sample has N_0 active atoms at t = 0. If the rate of disintegration at any time is R the number of atoms is N, then the ratio R/N varies with time as -



[D]

Q.40 In free space the intensity of 5 eV neutron beam is reduced by a factor of one half. Half life is $t_{1/2}$ = 12.8 min. The distance travelled by neutron beam is-

(A) 2800 km (B) 23800 km

(C) 28 km (D) 2 km **[B]**

Sol. Speed of the neutrons in beam is

$\frac{1}{2}mv^2 = K = 5eV$

$$v = \sqrt{\frac{2(5)\times1.6\times10^{-19}}{1.67\times10^{-27}}}$$

Q.41 A sample contains large number of nuclei. The probability that a nucleus in sample will decay after four half lives is-

(A) $\frac{1}{4}$ (B) $\frac{3}{4}$

(C) $\frac{15}{16}$ (D) $\frac{7}{16}$ **[C]**

Sol. Probability that a nucleus will not decay is-

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

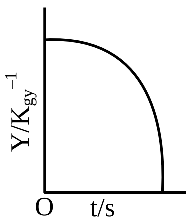
When n is the number of half lives

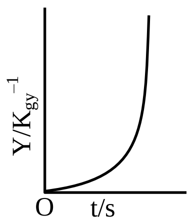
$$q = \left(\frac{1}{2}\right)^4 = \frac{1}{16}$$

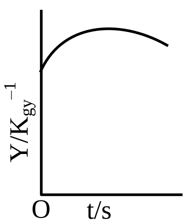
Probability that a nucleus will decay is

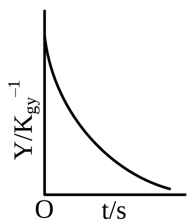
$$p = 1 - q = 1 - \frac{1}{16} = \frac{15}{16}$$

Q.42 The radioactive nucleus of an element X decays to a stable nucleus of elements Y. A graph of the rate of formation of Y against time would look like -

(A) 

(B) 

(C) 

(D) 

[D]

Q.43 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 **[A]**

Sol. Let $\lambda_A = \lambda$ and $\lambda_B = 2\lambda$

Initially rate of disintegration of A is λN_0 and that of B is $2\lambda N_0$.

After one half-life of A, rate of disintegration of A will becomes $\frac{\lambda N_0}{2}$ and that of B would also be $\frac{\lambda N_0}{2}$ (half-life) of B = $\frac{1}{2}$ (half-life of A)

So, after one half-life of A or two half-lives of B.

$$\left(-\frac{dN}{dt}\right)_A = \left(-\frac{dN}{dt}\right)_B$$

$\therefore$ n = 1

Q.44 How would the radio isotope of magnesium with atomic mass 27 undergo radioactive decay ?

(A) Electron capture

(B) Alpha decay

(C) Beta decay

(D) Gamma ray emission **[C]**

Sol. $^{27}_{12}\text{Mg} \rightarrow ^{27}_{13}\text{A}\ell + e^- + \bar{\nu}$

Beta decay in which isotope $^{27}_{12}\text{Mg}$ is converted to an isotope of aluminum $^{27}_{13}\text{A}\ell$.

Q.45 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) $\frac{1}{\ln(2)}$ s

(C) ln (2) s (D) 2 s **[C]**

Sol. Let N be the number of nuclei at any time t. Then

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

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

or $N = \frac{200}{\lambda}(1 - e^{-\lambda t})$

Given that N = 100 and $\lambda = 1\ s^{-1}$

$\therefore$ 100 = 200 $(1 - e^{-t})$

or $e^{-t} = \left(\frac{1}{2}\right)$

$\therefore$ t = ln (2) sec.

Q.46 The mean lives of a radioactive material for α and β radiations are 1620 years and 520 years respectively. The material decays simultaneously for α and β decay. The time after which one fourth of the material remains undecayed is -

(A) 540 years (B) 324 years

(C) 720 years (D) 840 years **[A]**

Sol. $\tau = \dfrac{\tau_\alpha \tau_\beta}{\tau_\alpha + \tau_\beta} = \dfrac{1620\times520}{1620+520}$

= 394 years

t = time of decay = $2.303 \log_{10} \dfrac{N_0}{N} \times \tau$

$= 2.303 \times \log_{10} 4 \times 394$

= 540 years

Q.47 Number of nuclei of a radioactive substance at time t = 0 are 1000 and 900 at time t = 2 s. Then number of nuclei at time t = 4 s will be:

(A) 800 (B) 810

(C) 790 (D) 700 **[B]**

Sol. In 2s only 90% nuclei are left behind. Thus, in next 2s 90% of 900 or 810 nuclei will be left.

Q.48 In a sample of a radioactive substance what fraction of the initial number of nuclei will remain undecayed after a time $t = \dfrac{T}{2}$, where T = half-life of radioactive substance:

(A) $\dfrac{1}{\sqrt{2}}$ (B) $\dfrac{1}{2\sqrt{2}}$

(C) $\dfrac{1}{4}$ (D) $\dfrac{1}{\sqrt{2}-1}$ **[A]**

Sol. Fraction of nuclei which remain undecayed is

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

$= e^{-\left(\frac{\ln 2}{T}\right)\left(\frac{T}{2}\right)}$

$= \dfrac{1}{e^{\ln\sqrt{2}}} = \dfrac{1}{\sqrt{2}}$

Q.49 β decays, the number of α and β decays undergone is:

(A) 7 and 5 (B) 7 and 7

(C) 5 and 7 (D) 7 and 9 **[B]**

Sol. Let number of α decays are x and number of β decays are y. Then

$92 - 2x + y = 85$

or $2x - y = 7$ … (1)

and $238 - 4x = 210$

$\therefore x = 7$

Substituting this value in Eq. (1), we get

$y = 7$

Q.50 The half-value period of a radioactive element is 20 seconds. At any instant the number of radioactive nuclei is one million. Ten seconds later, the number of radioactive nuclei left are -

(A) $10^6\sqrt{2}$ (B) $\dfrac{10^6}{\sqrt{2}}$

(C) 5×10^5 (D) 2.5×10^5 **[B]**

PHYSICS

Q.1 The decay constant of $^{197}_{80}Hg$ (electron capture to $^{197}_{79}Au$) is $1.8 \times 10^{-4}\ s^{-1}$. (a) What is the half-life ? (b) What is the average-life ? (c) How much time will it take to convert 25% of this isotope of mercury into gold ? ln (4/3) = 0.288

Ans. (a) 64 min (b) 92 min (c) 1600 s

Q.2 A certain sample of a radioactive material decays at the rate of 500 per second at a certain time. The count rate falls to 200 per second after 50 minutes. (a) What is the decay constant of the sample ? (b) What is its half-life ? ln (2.5) = 0.916

Ans. (a) $3.05 \times 10^{-4}\ s^{-1}$ (b) 38 min

Q.3 The count rate from a radioactive sample falls from 4.0×10^6 per second to 1.0×10^6 per second in 20 hours. What will be the count rate 100 hours after the beginning ? $(1/2)^{10} = 9.8 \times 10^{-4}$

Ans. 3.9×10^3 per second

Q.4 What fraction of the radioactive cobalt nuclei whose half-life is 71.3 day decays during a month ? $(1/2)^{0.42} \approx 0.747$

Ans. 0.252 i.e. about 1/4

Q.5 How many beta-particles are emitted during one hour by 1.0 μg of Na^{24} radionuclide whose half-life is 15 hour ?

Ans. 1.13×10^{15} β- particles

Q.6 A piece of timber recovered from an archaeological excavation has $_6C^{14}$ about 6.25% of its expected value. How old the sample is ? [Half life of $_6C^{14}$ = 5600 year]

Ans. 22,400 year

Q.7 The half value period of radium is 1590 year. In how many years will one gram of pure element,
(i) lose one centigram
(ii) be reduced to one centigram.

Ans. (i) 23.06 year (ii) About10560 year

Q.8 Determine the age of ancient wooden items if it is known that the specific activity of C^{14} nuclide in them amounts to 3/5 of that in lately felled trees. The half-life of C^{14} nuclei is 5570 year.

Ans. 4.1×10^3 year

Q.9 The half-life of ^{198} Au is 2.7 days. (a) Find the activity of a sample containing 1.00 μg of ^{198}Au. (b) What will be the activity after 7 days ? Take the atomic weight of ^{198}Au to be 198 g/mol.

Ans. (a) 0.244 Ci (b) 0.040 Ci

Q.10 Find the probability that a particular nucleus of ^{38}Cl will undergo β-decay in any 1.00-s period. The half-life of ^{38}Cl is 37.2 min.

Ans. 3.10×10^{-4}

Q.11 Radon is a monatomic gas having mass number 222 and with a radioactive constant equal to $2.1 \times 10^{-6}\ s^{-1}$. Calculate the number of alpha-particles emitted per second by 1 gram of radon at S.T.P. when free from any impurity.

Ans. $5.7 \times 10^{15}\ s^{-1}$

Q.12 At the initial moment the activity of a certain radionuclide totalled 650 particles per minute. What will be the activity of the preparation after half of its half-life period ?

Ans. 4.6×10^2 particles/min.

Q.13 The atomic ratio between the uranium isotopes U^{238} and U^{234} in a mineral sample is found to be 1.8×10^4. The half-life of U^{234} is 2.5×10^5 year. What is the half life of U^{238} ?

Ans. 4.5×10^9 year

Q.14 Given that the period of radon is 3.82 day and that the volume at normal temperature and pressure, of radon in equilibrium with 1 g of radium is $0.63\ mm^3$, deduce the half value period of radium. Gram-molecular volume = 22.4 litre, atomic weight of radium = 226.

Ans. 1640 years.

Q.15 Calculate the percentage of radium contained in uranium mineral (of half life period = 4560 year) which have reached a state of secular equilibrium.

(Take half life period of radium = 1590 year).

Ans. 26 %

Q.16 The selling rate of a radioactive isotope is decided by its activity. What will be the second hand rate of a one month old ^{32}P ($t_{1/2}$ = 14.3 day) source if it was originally purchased for 800 rupees ?

Ans. 187 rupees

Q.17 A radon $_{86}Rn^{222}$ nucleus of mass 3.6×10^{-25} kg decays by emission of an α-particle of mass 6.7×10^{-27} kg and energy 8.8×10^{-13} J. Calculate (a) the momentum of the emitted α-particle (b) the velocity of recoil of resulting nucleus.

Ans. (a) 1.08×10^{-19} kg ms^{-1} (b) 3.1×10^{5} ms^{-1}

Q.18 (a) What isotope is produced from the alpha-radioactive $_{88}Ra^{226}$ as a result of five alpha-disintegrations and four β^--disintegrations ?

$$_{88}Ra^{226} \xrightarrow{5\alpha} {}^{206}_{78}Pt \xrightarrow{4\beta^-} {}^{206}_{82}Pb$$

(b) How many alpha and β^--decays does $_{92}U^{238}$ experience before turning finally into the stable $_{82}Pb^{206}$ isotope ?

Ans. (a) Pb^{206}; (b) 8 α decays and 6 β decays

Q.19 An experiment. is done to determine the half-life of a radioactive substance that emits one beta-particle for each decay process. Measurements show that an average of 8.4 beta-particles are emitted each second by 2.5 milligram of the substance. The atomic weight of the substance is 230. Find the half-life of the substance.

Ans. 1.7×10^{10} year

Q.20 A radioactive element contains 10^{12} atoms at a certain instant. If the half-life period of element is 30 day, calculate (i) the number of disintegrations in the first second, (ii) how long will it take 3/4th of the atoms originally present to disintegrate ?

Ans. (i) 2.7×10^{5} (ii) 60 day