2. NUCLEAR PHYSICS

SYNOPSIS

NUCLEUS, PROPERTIES OF NUCLEUS, (SIZE, DENSITY, RADIUS...)

Nucleus consists of neutrons and protons	**Radius:** $r = r_0 A^{1/3}$ (**where r_o = 1.1to 1.4 fermi**)
Nucleons = Neutrons + Protons	**Mass number**(A): $A = N_n + N_p$
Forces Inside nucleus Columbic and Non-columbic forces	N_n : number of neutrons inside nucleus N_p : number of protons inside nucleus
Non-columbic forces: Short-Range forces exists between p-p, n-p, n-n (which are charge independent)	Mass of Nucleus: Unlike macroscopic material, $M_{nucleus}$ is not same as that of $M_{nucleons}$ $\{M_{nucleus} < M_{nucleons}\}$
Columbic forces : Charge dependent Repulsive in nature.	$M_{nucleons} = N_n(m_{neutron}) + N_p(m_{proton})$ $N_p = Z$ & $N_n = A - Z$
Gravitational forces : are very small when compared to the Columbic and Non-columbic forces and hence neglected.	**Binding energy:** $BE = (\Delta m)C^2$ measured in MeV 1 MeV = Million electron volt = 1.6×10^{-13}J
Nucleus may be stable or unstable depending on Columbic and Non-columbic forces.	**Mass defect:** (Δm) $\Delta m = M_{nucleons} - M_{nucleus}$ **Measured in amu or "u"** $1amu = 931.5 MeV/C^2$
$F_{columbic} >> F_{non\text{-}columbic}$ nucleus tends to disintegrate spontaneously $F_{columbic} << F_{non\text{-}columbic}$ does not disintegrate spontaneously	**Density of Nucleus:** Almost 10^{15} times that of ordinary matter (Earth's crust) $\rho = \frac{M_{nucleus}}{Volume} = \frac{A}{(\frac{4}{3}\pi r^3)} = \frac{3}{4\pi r_0^3}$
Stability of nucleus More $\frac{BE}{A}$, more the stability — $\frac{BE}{A}$ is binding energy per nucleon More $\frac{N}{P}$ ratio More stability — $\frac{N}{P}$ is the ratio of number of neutrons of protons inside the nucleus **Packing fraction** $PF = \frac{A-M}{M}$ (A: mass number & M: mass of nucleus)	**Short- Range Forces** Charge independent Attractive in nature Not gravitational Extended up to few femto Can attract any particle, when they are very close to the nucleus Not indfluenced by external factors like pressure electric field, magnetic field,...... can attract incoming neutron, if they have less KE and come close to the nucleus. which is the principle of neutron-capture **Atom is open to a neutron**

Nuclear forces (properties / characteristics ......)

BE, BE curve, line of stability curve

Nuclear Reactions (exothermic/exotherimic)

(a) conservation laws involved in reaction

(b) Application of COLM

(c) Calculation of Q-value (exothermic)

(d) Endo-thermic : Calculation of KE_{min} of bombarding particle

Nuclear Decays:

For nucleus stability

A) Negative $\beta-$ decay takes if $\left(\frac{N}{Z}\right)$ value morethan, required value

B) Positive β – decay, $\alpha-$decay and k-capture takes if $\left(\frac{N}{2}\right)$ value less than, required value

$\alpha-$decay (release of helium nucleus) $^{4}_{2}He$	β^- decay (release of electron) Conversion of $n\rightarrow p$	β^+ decay (release of positron) Conversion of $p\rightarrow n$ Positron = Positive electron
$^{A}_{Z}X \rightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}He+Q$ All Conservation Laws are valid Mass [A = A-4 + 4] Charge [Z = Z +2] Energy $TE_{final} = TE_{initial}$ Linear Momentum $\overline{p}_{final} = \overline{p}_{initial}$ Linear Momentum $\overline{L}_{final} = \overline{L}_{initial}$ **COLM & COE** **Initially X is at rest:** **Apply COLM** $\overline{0} = \overline{p}_Y + \overline{p}_\alpha$ $\Rightarrow \lvert\overline{p}_Y\rvert = \lvert\overline{p}_\alpha\rvert$ Apply COE $KE_Y + KE_\alpha = Q$ $\Rightarrow \frac{\lvert\overline{p}_Y\rvert^2}{2m_Y} + \frac{\lvert\overline{p}_\alpha\rvert^2}{2m_\alpha} = Q$ $\Rightarrow KE_Y = [\frac{m_\alpha}{m_\alpha + m_Y}]Q$ $KE_\alpha = [\frac{m_Y}{m_\alpha + m_Y}]Q$	β^- decay (negative dacay) β^- decay (release of electron) $^{1}_{0}n \rightarrow {}^{1}_{1}p + {}^{0}_{-1}e + Q$ In the above reaction, only conservation of charge is valid. Conservation of Mass, Energy, Linear Momentum, Angular Momentum are invalid. Hence, extensive studies by Pauli & others have suggested an existence of a particle, which make the other conservation laws valid too. Fermi has named the released particle as neutrino (which has an anti-particle known as anti neutrino β^- decay (release of electron) $^{1}_{0}n \rightarrow {}^{1}_{1}p + {}^{0}_{-1}e + \overline{v} + Q$ release of electron is accom-pained with anti-neutrino v : neutrino with the emission of β^- a new element whose place is one to the right of the parent element in the periodic table	β^- decay (positive dacay) β^+ decay (released of positron) $^{1}_{1}p \rightarrow {}^{1}_{0}n + {}^{0}_{1}e + v + Q$ β^+ decay release of positron is accompanied with neutrino v : neutrino **Properties of neutrino** It has as anti-particle known as antoneutrino It has almost negligible mass (<7MeV/C²) It has no charge It has a spin +1/2 or -1/2 with the emission of β^+ a new element whose place is one to the left of the parent element

Due to release of a α – particle: A new element whose position is 2 places left of the parent element in periodic table & with new atomic number is formed	${}_{Z}^{A}X \rightarrow {}_{Z+1}^{A}Y + {}_{-1}^{0}e + \overline{\nu} + Q$ Here, all conservation laws are valid	in the periodic table ${}_{Z}^{A}X \rightarrow {}_{Z-1}^{A}Y + {}_{+1}^{0}e + \overline{\nu} + Q$ Here all conservation laws are valid

Substance emits α and β particles simultaneously	
α and β^- particles are emitted ${}_{Z}^{A}X \rightarrow {}_{Z+1}^{A-4}Y + {}_{2}^{4}He + {}_{-1}^{0}e + \overline{\nu} + Q$ with an electron, anti-neutrino is emitted	α and β^+ particles are emitted ${}_{Z}^{A}X \rightarrow {}_{Z-3}^{A-4}Y + {}_{2}^{4}He + {}_{+1}^{0}e + \nu + Q$ with an positron, neutrino is emitted
Here all the conservation laws are valid	Here all the conservation laws are valid

Laws of Radioactivity and Applications

Termiology involved in radioactivity

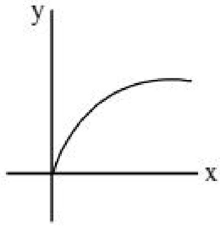
Terminology	Application of law of radioactivity	Useful data (OR) Information	
Production rate (α)	Only production and no decay	1 curie = 3.7×10^{10} di sintegra	
Disintegration constant (λ)	Number of half - lives,	1 Becquerel = 1 dps	
N_0: Initial number of atoms undecayed	Number of atoms left undecayed, decayed, probability	1Rd = 10^6 dps	
N: Number of atoms un -decayed at any time t	of decay, probability of un-decay graphs	Natural logarithms	Common logarithms
		$ln\ 2 = 0.693$	$\log 2 = 0.3010$
Initial activity ($R_0 = \lambda N_0$)	Parallel Decay or simultaneous	$ln\ 3 = ...$	$\log 3 = ...$
Activity ($R = \lambda N$)	decay	$ln\ 4 = 2(0.693)$	$\log 4 = ...$
	Simultaneous production and decay	$ln\ 5 = ...$	$\log 5 = ...$
	Successive radioactive disintegration		

No Production of radioactive nuclei, only decay of exisisting substance

N_0: initial number of atoms (at t = 0)	n: number of moles; $n = \frac{m}{M} = \frac{N}{N_A}$
N : Number of atoms un-decayed (any time t)	m: mass of the substance
N': Number of atoms decayed (any time t)	M: Molecular mass/weight
m_0 : initial mass (at t = 0)	N_A = Avogadro Number
R_0 : initial activity (at t = 0) $\Rightarrow \lambda N_0$	Note: The activity per unit mass called specific activity
τ: Mean life or average life $\tau = \frac{1}{\lambda}$	Note: The number of atoms disintegrated per unit volume is constant

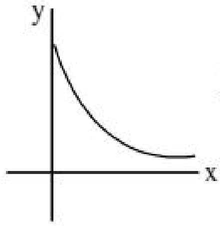
Law of radioactivity	$\frac{dN}{dt} = -\lambda N$
Separation of variable & integration	$\Rightarrow N = N_0 e^{-\lambda t}$ or $N = N_0(2^{-t/\tau})$
We have N + N' = N_0	$\Rightarrow N' = N_0(1 - e^{-\lambda t})$
Mass at any instant	$\Rightarrow m = m_0 e^{-\lambda t}$
Activity at nay instant	$\Rightarrow R = R_0 e^{-\lambda t}$
Probability of decay (p)	$p = e^{-\lambda t}$
Probability of decay (p')	$p = 1 - e^{-\lambda t}$
But p + p' = 1	

Exponential increase function



$y = N^1 : x = t$
$y = p^1 : x = t$

Exponential decrease function



$y = N : x = t$
$ty = p : x = t$

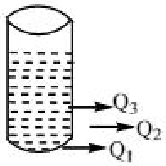
Number of half - lives (x)

number of Half - lives (x)	Time (t) $t = x(T_{1/2})$	Un-decayed atoms (N)
-	0	N_0
1	$t = (T_{1/2})$	$N = \frac{N_0}{2}$
2	$t = 2(T_{1/2})$	$N = \frac{N_0}{2^2}$
3	$t = 3(T_{1/2})$	$N = \frac{N_0}{2^3}$
4	$t = 4(T_{1/2})$	$N = \frac{N_0}{2^4}$
x	$t = x(T_{1/2})$	$N = \frac{N_0}{2^x}$

activity: $R = \frac{R_0}{2^x}$

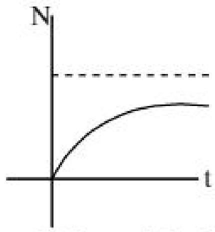
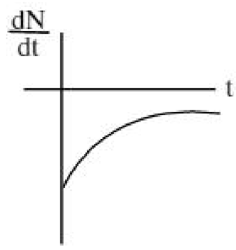
number of Half - mer (x)	Time (t) $t = x(T_{1/2})$	Un-decayed mass (m)
-	0	m_0
1	$t = (T_{1/2})$	$m = \frac{m_0}{2}$
2	$t = 2(T_{1/2})$	$m = \frac{m_0}{2^2}$
3	$t = 3(T_{1/2})$	$m = \frac{m_0}{2^3}$
4	$t = 4(T_{1/2})$	$m = \frac{m_0}{2^4}$
x	$t = x$	$m = \frac{m_0}{2^x}$

Simultaneous decay (or) parallel decay

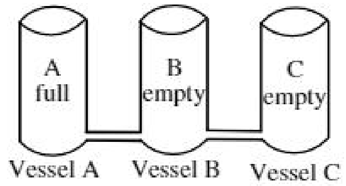
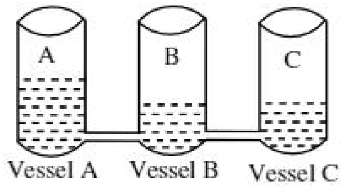
Mechanical Analogue	Mechanical Analogue
A full vessel being emptied with multiple orifices, simultaneously **Net rate flow:** $Q_{eq} = Q_1 + Q_2 + Q_3 + ...$ **where Q = Av** **Note : No filling only emptied** 	**A nuclear radioactive material having multiple decays, simultaneously** **Net Activity:** $R_{eq} = R_1 + R_2 + R_3 + R_4 +$ **where** $R = \lambda N$ $\lambda_{eq} = \lambda_1 + \lambda_2 + \lambda_3 + \lambda_4 + ...$ $\frac{1}{T_{eq}} = \frac{1}{T_1} + \frac{1}{T_2} + \frac{1}{T_3} + \frac{1}{T_4} + ...$ **Note : No production only decay**

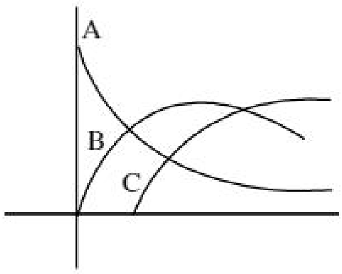
Simultaneous Production & decay (production rate α nuclei per sec & constant)

N_0 : initial number of atoms (at t = 0)	n : number of moles; $n = \frac{m}{M} = \frac{N}{N_A}$
N : Number of atoms un-decayed (any time t)	m : mass of the substance
N: Number of atoms decayed (any time t)	M: Molecular mass/weight
m_0: initial mass (at t = 0)	N_A : Avogadro Number
R_0 : initial activity (at t = 0) $\Rightarrow \lambda_0$	
τ : Mean life or average life $\tau = \frac{1}{\lambda}$	

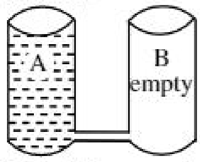
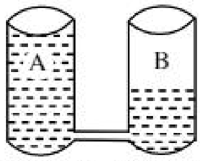
Law of radioactivity ** for N_{max}, $\frac{dN}{dt} = 0$	$\frac{dN}{dt} = \alpha - \lambda N$ $N_{max} = \frac{\alpha}{N}$	
Separation of variables & integration	$\Rightarrow N = N_{max} - (N_{max} - N_0)\ e^{-\lambda t}$ Where $N_{max} = \frac{\alpha}{\lambda}$	Similar graph for activity λN versus t.
Rate of disintegration at any time "t"	$\frac{dN}{dt} = -(\alpha - \lambda N_0)e^{-\lambda t}$	
Mass at any instant	We have $m = \left(\frac{N}{N_A}\right)M$	
Activity at any instant	$R = \lambda N$	

Successive radioactive disintegration

Mechanical analogue at t = 0	**Mechanical analogue at any time "t:**
 * Initially vessel A is completely filled, B, C are empty	

Parent nucleus (A) **Daughter Nuclide: B,C,D** **Decay constants:** $\lambda_A, \lambda_B, \lambda_C, \lambda_D$ Half-lives: T_A, T_B, T_C, T_D,.........	**Successive disintegration into daughter nuclides:** At " t = 0" A $\rightarrow$ B $\rightarrow$ C $\rightarrow$ D N_0 zero zero zero At "t" A $\rightarrow$ B $\rightarrow$ C $\rightarrow$ D N_A N_B N_C N_D
Equations for decay and formation of A,B,C,D,.......	Net activity = (Rate of formation) - (Rate of decay)
$\frac{dN_A}{dt} = -\lambda N_A$	$N_A = N_0 e^{-\lambda t}$ un-decayed at any instant "t"
$\frac{dN_B}{dt} = \lambda_A N_A - \lambda_B N_B$	$N_B = \frac{\lambda_A N_0}{\lambda_B - \lambda_A}\left\{e^{-\lambda A^t} - e^{-\lambda B^t}\right\}$
$\frac{dN_c}{dt} = \lambda_B N_B - \lambda_C N_C$	N_C = ...
Secular equilibrium $\lambda_A . N_A = \lambda_B . N_B = ...$ **Transient equilibrium** $\frac{N_B}{N_A} = \frac{\lambda_A}{\lambda_B - \lambda_A}$	

Successive radioactive disintegration & daughter product is a stable nucleus:

Mechanical analogue at t = 0	Mechanical analogue at any time "t" Volume(total) = Volume(A) + Volume(B) = Constant
Vessel A  No leak for vessel - B	 Vessel A Vessel B

Nuclear disintegration ; one daughter nuclide	Results
1. At t = 0 At "t" A $\rightarrow$ B A $\rightarrow$ B N_0 zero N_A N_B B is a stable product	$N_A + N_B = N_0$; $N_A = N_0 e^{-\lambda t}$ $N_B = N_0 - N_A$
2. At t = 0; two daughter nuclide A $\rightarrow$ B $\rightarrow$ C N_0 zero zero	$N_A + N_B = N_0$ (only decay, no formation)
3. At time "t" ; three daughter nuclide A $\rightarrow$ B $\rightarrow$ C N_A N_B N_C C is a stable product	$\frac{dN_A}{dt} = -\lambda N_A \Rightarrow N_A = N_0 e^{-\lambda t}$ (simultaneous decay and formation) $\frac{dN_B}{dt} = \lambda_A N_A - \lambda_B N_B$ $\Rightarrow N_B = \frac{\lambda_A N_0}{\lambda_B - \lambda_A}\{e^{-\lambda_A t} - e^{-\lambda_B t}\}$ $N_C = N_0 - N_A - N_B$
4. At t = 0; four daughter nuclide A $\rightarrow$ B $\rightarrow$ C $\rightarrow$ D N_0 zero zero zero At any time "t" A $\rightarrow$ B $\rightarrow$ C $\rightarrow$ D N_A N_B N_C N_D D is a stable product	$N_A + N_B + N_C + N_D = N_0$ For A $\frac{dN_A}{dt} = -\lambda N_A \Rightarrow N_A = N_0 e^{-\lambda t}$ For B $\frac{dN_A}{dt} = \lambda_A N_A - \lambda_B N_B$ $= N_B = \frac{\lambda_A N_0}{\lambda_B - \lambda_A}\{e^{-\lambda_A t} - e^{-\lambda_B t}\}$

Nuclear fission

Nuclear fission (Neutron capture)

a) Fission reaction

b) Energy calculation & power output of a reactor

c) Nuclear reactor(construction & theory)

$$\left[\text{key point, } P_{output} = \left(\frac{\text{no.of fissions}}{\text{second}}\right)\text{Energy}\right]$$

$$n = \frac{N}{N_A} = \frac{m}{M}$$

In the process of fission of one uranium nucleus release average energy about 200 MeV.

In number reactor

$$\text{Re production factor}(k) = \frac{\text{No.of neutrons participate in any generation}}{\text{No.of neutrons participate immediately preceeding generation}}$$

A) If $K > 1$ is said to be super critical

B) If $K = 1$ is said to be critical

C) If $K < 1$, is said to be sub critical

The average number of neutrons released in nuclear reactor is 2.5

Terminology Involved		**useful data or information**
Slow neutrons (bombarding)	**Energy of reactor**	**standard values** M(uranium) = 235 gm a) $1\text{a.m.u} = 1.6603\times10^{-27}$ kg = 931.5MeV b) $m_{electron} = 9.1095\times10^{-31}$ kg $\simeq$ 0.511 MeV c) $m_{proton} = 1.6726\times10^{-24}$ kg $\approx$ 938.28 MeV d) $m_{neutron} = 1.6750\times10^{-27}$ kg $\simeq$ 939.57 MeV
Thermal neutrons	Number of fissions per second	
Uranium Ore Nuclear Fuel ^{235}U	power output Power of Reactor	
Liquid drop model	Chain reaction	
Heavy nucleus	Uncontrolled chain reaction	
Smaller fragments	Released neutron	
Energy released per fission	Mass of nuclear fuel	

LECTURE SHEET

EXERCISE-I

(Nucleus & properties; Nuclear decays (α, β, γ, K capture))

LEVEL-I (MAIN)

Straight Objective Type Questions

1. If radius of $^{27}_{13}A\ell$ nucleus is estimated to be 3.6 fermi, then the radius of $^{125}_{52}X$ nucleus be nearly
   1) 4 fermi 2) 5 fermi 3) 6 fermi 4) 8 fermi

2. The nuclear radius of $_8O^{16}$ is 3×10^{-15} metre. If an atomic mass unit is 1.67×10^{-27} kg, then the nuclear density is approximately:
   1) 2.35×10^{17} gm per cm^3 2) 2.35×10^{17} kg per metre^3
   3) 2.35×10^{17} gm per metre^3 4) 2.35×10^{17} kg per cm^3

3. The nuclei of ^7_3Li and ^7_4Be are
   1) Isotopes 2) Isobars 3) Isotones 4) Mirror nuclei

4. In $_{88}Ra^{226}$ nucleus there are
   1) 138 protons and 88 neutrons 2) 138 neutrons and 88 protons
   3) 226 protons and 88 electrons 4) 226 neutrons and 138 electrons

5. An atomic nucleus contains neutrons and protons. The sum of the masses of these neutrons and protons in free space is
   1) equal to the mass of nucleus 2) less than the mass of nucleus
   3) greater than the mass of nucleus 4) sometimes less and sometimes more

6. A nucleus ^A_ZX has mass represented by M (A,Z). If M_p and M_n denote the mass of proton and neutron respectively and BE the binding energy in MeV, then
   1) $BE = [ZM_p + (A-Z)M_n - M(A-Z)]c^2$ 2) $BE = [ZM_p + AM_n - M(A-Z)]c^2$
   3) $BE = [M(A,Z) - ZM_p - (A-Z)]M_n$ 4) $BE = [M(A,Z) - ZM_p - (A-Z)M_n]c^2$

7. Find the binding energy of an α – particle from the following data.
   Mass of He nucleus=4.001265 amu; Mass of proton=1.007277 amu; Mass of neutron=1.00866 amu (Take one amu = 931.5MeV)
   1) 1850 MeV 2) 296 MeV 3) 28.512 MeV 4) None of these

8. Nuclear of forces are:
   1) short range and charge dependent 2) short range and charge independent
   3) long range and charge dependent 4) long range and charge independent

9. If the nuclear force between two protons, two neutrons and between proton and neutron is denoted by F_{pp}, F_{nn} and F_{pn} respectively then:
   1) $F_{pp} \approx F_{np} \approx F_{nn}$ 2) $F_{pp} \neq F_{np}$ but $F_{pp} = F_{pn}$ 3) $F_{pp} = F_{nn} \neq F_{nn}$ 4) $F_{pp} \neq F_{nn} \neq F_{pn}$

10. Of the three basic forces, gravitational, electrostatic and nuclear, which two are able to provide an attractive force between two neutrons?
    1) electrostatic and gravitational 2) electrostatic and nuclear
    3) gravitational and nuclear 4) some other force like van der Waals' force

11. Which of the following statements is correct?
    1) β – radioactivity is the process in which an electron is emitted from an unstable atom whose atomic number Z remains uncharged
    2) γ – radioactivity is the process in which the daughter nucleus has atomic number 1 unit more than that of the parent nucleus
    3) α – radioactivity is the process in which an unstable atom emits the nucleus of helium atom
    4) α – radioactivity is the process in which a heavy atom emits electromagnetic radiations of very high frequency

12. The decay constant λ of a radioactive sample is the probability of decay of an atom in unit time:
    1) λ decreases as the atoms become older
    2) λ decreases as the age of atoms increases
    3) λ is independent of the age of atoms
    4) behaviour of λ with time depends on the nature of the activity

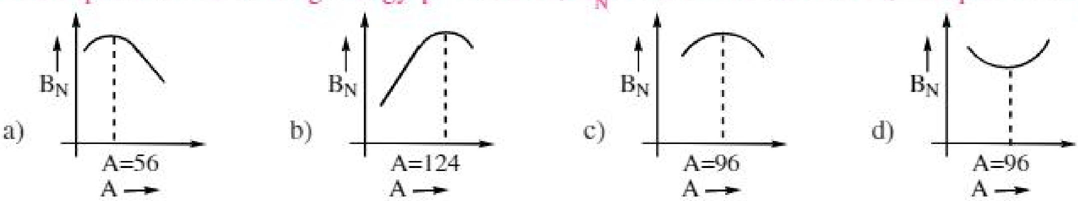
13. When a β – particle is emitted from a nucleus, the effect on its neutron–proton ratio is:
    1) increased 2) decreased 3) remains same 4) first (1) and then (2)

14. A nucleus with an excess of neutrons may decay radioactively with the emission of:
    1) a neutron 2) a proton 3) an electron 4) a positron

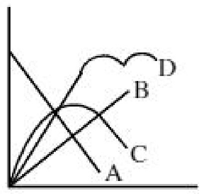
LEVEL-II (ADVANCED)

Straight Objective Type Questions

1. The dependence of binding energy per nucleon, B_N on the mass number A, is represented by:

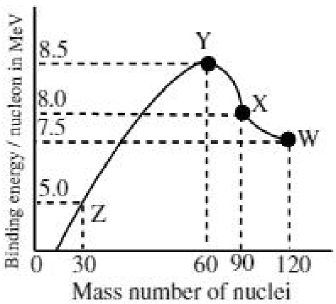


2. Binding energy per nucleon plot against the mass number for stable nuclei is shown in the figure. Which curve is current?

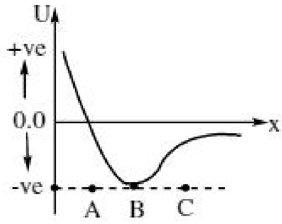


a) A b) B c) C d) D

3. Binding energy per nucleon versus mass number curve for nuclei is shown in the fig. W, X, Y and Z are four nuclei indicated on the curve. The process that would release energy is
    a) Y→ 2Z
    b) W → X + Z
    c) X→ Y + Z
    d) W→ 2Y



4. The potential energy U between two molecules as a function of the distance X between then has been shown in the following figure. The two molecules are:



a) attracted when X lies between A and B are repelled when X lies between B and C

b) attracted when X lies between B and C and are repelled when X lies between A and B

c) attracted when they reach B

d) repelled when they reach B

5. Energy equivalence of masses of $^{40}_{20}Ca$ and $^{41}_{20}Ca$ are 37225.154 MeV and 38156.362 MeV respectively. Energy equivalence of mass of a neutron is 939.57145 MeV. From the given data, we can conclude that

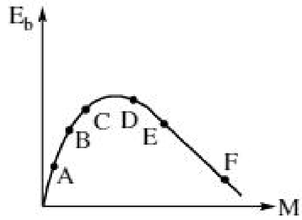
a) energy required to seaparate a neutron from $^{41}_{20}Ca$ is 939.57145 MeV

b) energy required to separate a neutron from $^{41}_{20}Ca$ is 37216.791 MeV

c) energy required to separate a neutron from $^{41}_{20}Ca$ 931.208 MeV

d) energy required to separate a neutron from $^{41}_{20}Ca$ is 8.36 MeV

6. Fig. is a plot of binding energy per nucleon E_b against the nuclear mass M, A, B, C, D, E and F correspond to different nuclei. Consider four reactions:



i) $A + B \rightarrow C + Q$ ii) $C \rightarrow A + B + Q$

iii) $D + E \rightarrow F + Q$ iv) $F \rightarrow D + E + Q$

Where Q is the energy released. In which reactions is Q positive

a) (i) and (iv) b) (i) and (iii) c) (ii) and (iv) d) (ii) and (iii)

7. The binding energies per nucleon for a deuteron and an α – particle are x_1 and x_2 respectively. The energy Q released in the reaction $^2_1H + ^2_1H \rightarrow ^4_2He + Q$ is:

a) $4(x_1 + x_2)$ b) $4(x_1 - x_2)$ c) $2(x_2 - x_1)$ d) $2(x_1 + x_2)$

8. A nucleus disintegrates into two nuclear parts, which have their velocities in the ratio 2:1. The ratio of their nuclear sizes will be:

a) $2^{1/3}:1$ b) $1:3^{1/2}$ c) $3^{1/2}:1$ d) $1:2^{1/3}$

9. In the options given below, let E denote the rest mass energy of a nucleus and n a neutron. The correct option is

a) $E\left(^{236}_{92}U\right) > E\left(^{137}_{53}I\right) + E\left(^{97}_{39}Y\right) + 2E(n)$ b) $E\left(^{236}_{92}U\right) < E\left(^{137}_{53}I\right) + E\left(^{97}_{39}Y\right) + 2E(n)$

c) $E\left(^{236}_{92}U\right) < E\left(^{140}_{56}I\right) + E\left(^{94}_{36}Y\right) + 2E(n)$ d) $E\left(^{236}_{92}U\right) = E\left(^{140}_{56}I\right) + E\left(^{94}_{36}Y\right) + 2E(n)$

10. If the mass of a proton, $m_p = 1.008u$, mass of a neutron $m_n = 1.009u$, then the binding energy of an α -particle of mass 4.003u will be

a) 28.8 MeV b) 21.4 MeV c) 8.2 MeV d) 32 MeV

11. Which of the following processes represents a γ - decay?

a) ${}_{Z}^{A}X+\gamma \rightarrow {}_{Z-1}^{A}X+a+b$ b) ${}_{Z}^{A}X+{}_{0}^{1}n \rightarrow {}_{Z-2}^{A-3}X+c$

c) ${}_{Z}^{A}X \rightarrow {}_{Z}^{A}X+f$ d) ${}_{Z}^{A}X+{}_{-1}e \rightarrow {}_{Z-1}^{A}X+g$

12. Statement-I: A nucleus having energy E_1 decays by β^- emission to a daughter nucleus having energy E_2 but the β^- rays are emitted with a continuous energy spectrum having end point energy E_1-E_2.

Statement-II: To conserve energy and momentum in β – decay, at least three particles must take part in transformation.

a) S-I and S-II both are correct and S-II is the correct explanation of S-I

b) S-I is correct, S-II is correct and S-II is not the correct explanation of S-I

c) S-I is incorrect, S-II is correct

d) S-I correct but S-II is not correct

13. An alpha nucleus of energy $\frac{1}{2}m\upsilon^2$ bombards a heavy nuclear target of charge Ze. The distance of closest approach for the alpha nucleus will be proportional to:

a) $1/\upsilon^4$ b) 1/Ze c) υ^2 d) 1/m

14. M_x and M_y denote the atomic masses of the parent and the daughter nuclei respectively in a radioactive decay. The Q-value of a β^- decay is Q_1 and that for a β^+ decay is Q_2. If m_e denotes the mass of an electron, then when of the following statements is correct?

a) $Q_1 = (M_x - M_y)c^2$ and $Q_2 = (M_x - M_Y - 2m_e)c^2$

b) $Q_1 = (M_x - M_y)c^2$ and $Q_2 = (M_x - M_y)c^2$

c) $Q_1 = (M_x - M_y - 2m_e)^2$ and $Q_2 = (M_x - M_y + 2m_e)c^2$

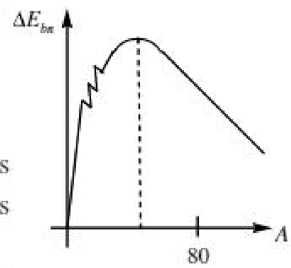
d) $Q_1 = (M_x - M_y + 2m_e)c^2$ and $Q_2 = (M_x - M_y + 2m_e)c^2$

15. In radioactive element, β – rays emits from

a) nucleus b) outer orbit c) inner orbit d) none of these

More than One correct answer Type Questions

16. Which of the following are correct for binding energy per uncleon (ΔE_{bn}) curve plotted as a function of mass number (A)?



a) Maximum occurs $A \sim 50$

b) When A increases from 0 to 30, there are considerable fluctuations as internucleon interaction is largely affected by pairing and symmetry effects

c) For $A>30, \Delta E_{bn}$ varies only about 10%. This shows nucleus interacts with their neighbours only

d) For $A>50$, the mean binding energy per nucleon decreases because of coulombic repulsion

17. For nuclei with A > 100,

a) the binding energy of the nucleus decreases on an average as A increases

b) the binding energy per nucleon decreases on an average as A increases

c) if the nucleus breaks into two roughly equal parts, energy is released

d) if two nuclei fuse to form a bigger nucleus, energy is released.

18. For a sample of β – active material, which of the following is incorrect?
    a) The Beta particles emitted have same energy
    b) The antineutrino emitted in a β – decay has zero momentum
    c) The active nucleus changes into one of its isobars after the Beta–decay
    d) The atomic number of the active nucleus remain same in β – decay

19. 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

20. During a β^--decay which of the following statements are correct?
    a) The daughter nucleus has one proton less than the parent nucleus
    b) The daughter nucleus has one proton more than the parent nucleus
    c) An electron which is already present with in the nucleus si ejected
    d) A neutron in the nucleus decays emitting an electron

21. Which of the following statement(s) is/are correct for a β-decay?
    a) when there is imblanace of number of neutrons and protons for stability, a β-particle is emitted
    b) when the number of protons is more than that required for stability, β^+ decay occurs
    c) in a β^+ deay a proton becomes a neutron at the expense of the binding energy of the parent nucleus releasing a positron and neutrino
    d) when a nucleus undergoes β^- decay the total nucleon number remains constant

Linked Comprehension Type Questions

Passage-I:

A nucleus X is intially at rest. It undergoes α – decay according to the equation ${}^{A}_{92}X \rightarrow {}^{238}Y_Z + \alpha$. The α-particle produced in the above decay moves in a circular track of radius R in a uniform magnetic field (B). We are given that: m(Y) = 228.03u, $m\left({}^1_0 n\right) = 1.009u$, $m\left({}^4_2 He\right) = 4.003u$, $m\left({}^1_1 H\right) = 1.008u, r = 0.11m, B = 3T$. With the help of the comprehension given above, choose the most appropriate alternative to each of the following questions.

22. Kinetic energy of the α – particle (in MeV) is approximately:
    a) 6.3 b) 5.24 c) 7.4 d) 8.71

23. Total energy released (in MeV) during the process of α – decay is:
    a) 5.33 b) 6.38 c) 7.47 d) 6.32

24. Binding energy (in MeV) per nucleon of the parent nucleus is
    a) 8.1 b) 6.4 c) 7.86 d) 7.47

Passage-II:

The β – decay process, discovered around 1900, is basically the decay of a neutron(n). In the laboratory a proton (p) and an electron (e^{-1}) are observed as the decay products of the neutron therefore, considering the decay products of the neutron therefore, considering the decay of a neutron as a two-body decay process, it was electron should be constant. But experimentally, it was observed that the electron kinetic energy has a continuous spectrum. Considering a three-body decay process, i.e., $n \rightarrow p + e^- + \bar{\upsilon}_e$, around 1930. Pauli explained the observed electron energy *spectrum. Assuming the anti-neutrino $(\overline{\upsilon}_e)$ to be massless and processing negligible energy and neutron to be at rest, momentum and energy conservation principles are applied. From this calculatiion, the maximum kinetic energy of the electron is 0.8×10^6 eV. The kinetic energy carried by the proton is only the recoil energy.*

25. What is the maximum energy of the anti-neutrino?

a) zero
b) Much less than 0.8×10^6eV
c) Nearly 0.8×10^6 eV
d) Much larger than 0.8×10^6 eV

26. If the anti-neutrino hand a mass of 3 eV/c^2 (where c is the speed of light) instead of zero mass, what should be the range of the kinetic energy, K of the electron

a) $0 \le K \le 0.8\times10^6$eV
b) $3.0eV \le K \le 0.8\times10^6$eV
c) $3.0eV \le K \le 0.8\times10^6$ eV
d) $0 \le K \le 0.8\times10^6$ eV

Matrix Matching Type Questions

27. **Column-I (Nucelar processes)** — **Column-II (Particles emitted)**

A) α – decay
B) β – decay
C) Total binding energy in a process is increased
D) Electron capture

p) He^{++}
q) e^{-1}
r) e^{+}
s) v
t) $\overline{v}$

28. **Column-I (Decay)** — **Column-II (Phenomenon/particle emitted)**

A) α decay
B) β decay
C) γ decay
D) K-electrons capture

p) Neutrino
q) Tunnel effect
r) Atomic number of parent nucleus decreases by 1
s) No change in atomic number
t) Atomic number of parent nucleus decreases by 2

EXERCISE-II

(Radioactive Laws & Application)

LEVEL-I (MAIN)

Straight Objective Type Questions

1. A sample of radio active substance has 10^6 radioactive nuclei. It's half-life is 20 sec. How many nuclei will remain after 10 seconds?

1) 7×10^5 2) 8.5×10^5 3) 8×10^5 4) 7.5×10^5

2. One mole of radium has an activity of 1/3.7 kilo curie. Its decay constant will be

1) $\frac{1}{6}\times10^{10}$ s^{-1} 2) $10^{-10}s^{-1}$ 3) 10^{-11} s^{-1} 4) 10^{-8} s^{-1}

3. The half life of radium is 1600 years. The mean life of radium is

1) 800 years 2) 2309 years 3) 3209 years 4) 2903 years

4. The half life of Pa-218 is 3 minutes. What mass of a 16g sample of Pa-218 will remain after 15 minutes.

1) 3.2g 2) 2.0 g 3) 1.6 g 4) 0.5 g

5. In a sample of radioactive material, what fraction of the initial number of active nuclei will remain undisintegrated after half of a half-life of the sample ?

1) $\frac{1}{4}$ 2) $\frac{1}{2\sqrt{2}}$ 3) $\frac{1}{\sqrt{2}}$ 4) $\sqrt{2}-1$

6. Let T be the mean life of a radioactive sample. 75% of the active nuclei present in the sample initially will decay in time

1) 2T 2) $\frac{1}{2}(ln2)T$ 3) 4T 4) $2(ln2)T$

7. In a sample of radio active material, what percentage of the initial number of active nuclei will decay during one mean life ?

1) 37% 2) 50% 3) 63% 4) 69%

8. A radio active sample with a half life of 1 month has activity $2\mu ci$. Its activity 2 months earlier was

1) $1\mu ci$ 2) $0.5\mu ci$ 3) $4\mu ci$ 4) $8\mu ci$

9. The probability of survival of a radioactive nucleus for one mean life, is

1) $\frac{1}{e}$ 2) $1-\frac{1}{e}$ 3) $\frac{\ell n2}{e}$ 4) $1-\frac{\ell n2}{e}$

10. There are two radio nuclei A and B. A is an alpha emitter and B is 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

1) 2 : 1 2) 1 : 2 3) e 4) e^{-1}

11. A radio active material decreases by simultaneous emissions of two particles with half lifes 1620 and 810 years. The time after which $(1/4)^{th}$ of the material remained is

1) 1080 years 2) 2000 years 3) 1500 years 4) 1200 years

12. Two radio active sources A and B initially contain equal number of radio active atoms. Source A has a half life of 1 hour and source B has a half life of 2 hours. At the end of 2 hours, the ratio of rate of disintegration of A to that of B is

1) 1 : 2 2) 2 : 1 3) 1 : 1 4) 1 : 4

13. A radioactive substance is being produced at a constant rate of 10 nuclei/s. The decay constant of the substance is 1/2 sec^{-1}. After what time the number of radioactive nuclei will become 10. Initially there are no nuclei present. Assume decay law holds for the sample.

1) 2.45 sec 2) log (2) sec 3) 1.386 sec 4) $\frac{1}{\ln(2)}$ sec

14. 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) 3.9×10^9 per sec. 2) 3.9×10^{12}per sec. 3) 3.9×10^3per sec. 4) 3.9×10^6 per sec.

15. The half-life of a radioisotope is 10 hours. Find the total number of disintegrations in the tenth hour measured from a time when the activity was 1 Ci.

1) 6.9×10^{23} 2) 2.8×10^9 3) 6.9×10^{19} 4) 6.9×10^{13}

16. The selling rate of a radioactive isotopes decided by its activity. What will be the second-hand rate of a one month old ${}^{31}P(t_{1/2} = 14.3\text{ days})$ source if it was originally purchased for 800 rupees ?
    1) 687 rupee 2) 487 rupee 3) 187 rupee 4) 287 rupee

17. The fraction f_1 of a radioactive sample decays in one mean life and a fraction f_2 decays in one half life then:
    1) $f_1 > f_2$ 2) $f_1 < f_2$ 3) $f_1 = f_2$
    4) May be (1), (2) or (3) depending on the value of mean life and half life.

18. 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) 3.9×10^9 per sec. 2) 3.9×10^{12} per sec. 3) 3.9×10^3 per sec. 4) 3.9×10^6 per sec.

Numerical Value Type Questions

19. Starting with a sample of pure Cu^{66}, 7/8 of it decays into Zn in 15 min. The corresponding half life in min.

20. A sample of radioactive element has a mass of 10 g at an instant t = 0. The mass (gm) of the element in the sample after 2-mean lives is :

LEVEL-II (ADVANCED)

Straight Objective Type Questions

1. Three radioactive substances have their activity in the ratio 1: 3 : 5. The substance are heated to double its temperature. Then the activity will be:
   a) 5 : 3 : 1 b) 3 : 1 : 5 c) 3 : 5 : 1 d) 1 : 3 : 5

2. A radioactive nucleus can decay by two different processes. The half-life for the first process is t_1 and that for the second process is t_2. The effective half-life to of the nucleus is given by
   a) $\frac{1}{t} = \frac{1}{t_1^2} + \frac{1}{t_2^2}$ b) $\frac{1}{t} = \frac{1}{t_1} + \frac{1}{t_2}$ c) $\frac{1}{t^2} = \frac{1}{t_1} + \frac{1}{t_2}$ d) $\frac{1}{t} = \frac{t_1 t_2}{(t_1 + t_2)^2}$

3. 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 and Y have the same decay rate initially. b) X and 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.

4. The activity of a sample of radioactive substance is A_1 at time t_1 and A_2 at the t_2 $(t_2 > t_1)$. If its mean life is τ, then correct relation is :
   a) $A_1 = A_2 \propto (t_2 - t_1)$ b) $A_1 t_1 = A_2 t_2$ c) $A_2 = A_1 e^{-(t_1/t_2)\tau}$ d) $A_2 = A_1 e^{-\left(\frac{t_2 - t_1}{\tau}\right)}$

5. The activity of a radioactive sample is A_1 at time t_1 and A_2 at time t_2. If the mean life of the sample is τ, then the number of nuclei decayed in time $(t_2 - t_1)$ is proportional to :
   a) $A_1\tau_1 - A_2\tau_2$ b) $\frac{A_1 - A_2}{\tau}$ c) $(A_1 - A_2)(\tau_2 - \tau_1)$ d) $(A_1 - A_2)\tau$

6. 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 their present activities are A_1 and A_2 respectively, then their age difference equals to :
   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) $T\ln\left|\frac{A_2}{2A_1}\right|$

7. A sample of radioactive material has a mass m, decay constant λ and molecular weight M. If Avogadro constant N_A then initial activity of the sample is:

a) λM b) $\frac{\lambda m}{M}$ c) $\frac{\lambda m N_A}{M}$ d) $N_A e^{kt}$

8. In above question the activity of the substance after t sec is :

a) $\left(\frac{mN_A}{M}\right)e^{-\lambda t}$ b) $\left(\frac{mN_A\lambda}{M}\right)e^{-\lambda t}$ c) $\left(\frac{mN_A}{M\lambda}\right)e^{-\lambda t}$ d) $\frac{m}{\lambda}\left(1-e^{-\lambda t}\right)$

9. A radioactive nuclide is produced at the constant rate of n per second (say, by bombarding a target with neutrons). If N_0 is number of nuclei at t = 0, then expected number N of nuclei in existence after *t* seconds is given by :

a) $N = N_0 e^{-\lambda t}$ b) $N = \frac{n}{\lambda} + N_0 e^{-\lambda t}$ c) $N = \frac{n}{\lambda} + \left(N_0 - \frac{n}{\lambda}\right)e^{-\lambda t}$ d) $N = \frac{n}{\lambda} + \left(N_0 + \frac{n}{\lambda}\right)e^{-\lambda t}$

10. 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) $\frac{N_y}{N_x - N_y} = \frac{\lambda_x}{\lambda_x - \lambda_y}$ c) $\lambda_y N_y = \lambda_x N_x$ d) $\lambda_x N_x = \lambda_x N_y$

11. Consider the reaction, ${}_1^2H + {}_1^2H \to {}_2^3He + {}_0^1n$, $m\left({}_1^2H\right) = 2.014082u$, $m\left({}_2^3He\right) = 3.016029u$,

$m\left({}_0^1n\right) = 1.008665u$. Then, mark the correct option

a) Threshold energy of 3.23 MeV is required to initiate the reaction

b) Reaction occurs when total KE of reactants exceeds 3.23 MeV

c) Reaction occurs such that final total KE is 3.23 MeV lesser than total initial KE

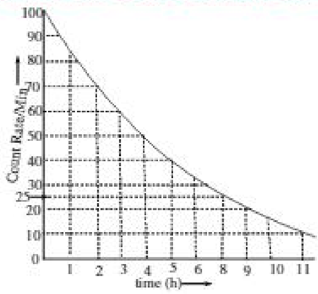
d) No, threshold energy is required for the reaction

12. At time t = 0, N_1 nuclei of decay constant λ_1 & N_2 nuclei of decay constant λ_2 are mixed. The decay constant of the mixture is :

a) $N_1 N_2 e^{-(\lambda_1 + \lambda_2)t}$ b) $+\left(\frac{N_1}{N_2}\right)e^{-(\lambda_1 - \lambda_2)t}$

c) $+\frac{(N_1\lambda_1 e^{-\lambda_1 t} + N_2\lambda_2 e^{-\lambda_2 t})}{(N_1 e^{-\lambda_1 t} + N_2 e^{-\lambda_2 t})}$ d) $+ N_1\lambda_1\ N_2\lambda_2\ e^{-(\lambda_1 + \lambda_2)t}$

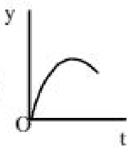
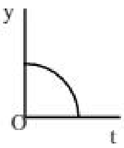
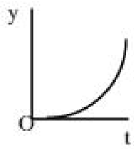
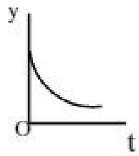
13. The count rate for 10g of a radioactive material was measured at different times and plotted as shown in figure. The half-life of the material and the total count in the first half-life period, respectively are



a) 5 h and 350 approximately b) 4 h and 18000 approximately

c) 2 h and 12000 approximately d) 10 h and 500 approximately

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

a) 
b) 
c) 
d) 

15. A charged capacitor of capacitance C is discharged through a resistance R. A radioactive sample decays with an average-life τ. The value of R for which the ratio of the electrostatic field energy stored in the capacitor to the activity of the radioactive sample remains constant in time is given by.

a) τ/C b) $2\tau/C$ c) $3\tau/C$ d) $4\tau/C$

16. In the reaction, ${}_0^1n + {}_{12}^{24}Mg \rightarrow {}_{11}^{23}Na + {}_1^2H$,

$m({}_{12}^{24}Mg) = 23.985042$, $m({}_{11}^{23}Na) = 23.985042$ the bombarding neutrons have 16 MeV of kinetic energy. Then,

a) 6.55 MeV of extra energy is required for the reaction to occur
b) 6.55 MeV of energy is released in the reaction
c) reaction cannot occur
d) 16 MeV of energy is released in the reaction

17. Radon-220 will eventually decay to Bismuth-212 as ${}_{86}Rn^{220} \longrightarrow {}_{84}Po^{216} + {}_2He^4$; half life = 55 s,

${}_{84}Po^{216} \longrightarrow {}_{82}Pb^{212} + {}_2He^4$; half life = 0.016 s; ${}_{82}Pb^{212} \longrightarrow {}_{83}Bi^{212} + {}_{-1}e^0$; half life = 10.6h,

If a certain mass of Radon-220 is allowed to decay in a certain - container, after 10 minutes the elements with the greatest mass will be:

a) radon b) polonium c) lead d) bismuth

More than One correct answer Type Questions

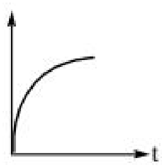
18. When a nucleus with atomic number Z and mass number A undergoes a radioactive decay process:

a) both Z and A will decrease, if the process is α decay
b) Z will decrease but A will not change, if the process is β^+ decay
c) Z will decrease but A will not change, if the process is β^- decay
d) Z and A will remain unchanged, if the process is γ decay.

19. The half-life of ${}^{131}I$ is 8 days. Given a sample of ${}^{131}I$ at time t = 0 we state that

a) no nucleus will decay before t = 4 days b) no nucleus will decay before t = 8 days
c) no nucleus will decay before t = 16 days d) a given nucleus may decay at any time after t = 0.

20. For the graph shown in figure, which of the following statements is/are possible?



a) y-axis shows a number of nuclei of a radioactive element which is produced at a constant rate
b) y-axis represents the number of nuclei decayed in a ratio nuclide
c) y-axis represents the activity of a radio nuclide
d) None of the above

21. Samples of two radioactive nuclides A and B are taken. λ_A and λ_B are the disintegration constants of A and B respectively. In which of the following cases, the two sample can simultaneously have the same decay rate at any time?

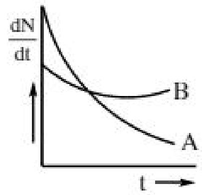
a) initial rate of decay of A is twice the initial rate of decay of B and $\lambda_A = \lambda_B$

b) initial rate of decay of A is twice the initial rate of decay of B and $\lambda_A > \lambda_B$

c) Initial rate of decay of B is twice the initial rate of decay of A and $\lambda_A > \lambda_B$

d) Initial rate of decay of B is same as the rate of decay of A at t = 2h and $\lambda_B < \lambda_A$

22. The variation of decay rate of two radioactive samples. A and B with time is shown in figure.



a) Decay constant of A is greater than that of B, hence, A always decays faster than B

b) Decay constant of B is greater than that of A but its decay rate is always smaller than that of A

c) Decays constant of A is greater than that of B but it does not always decay faster than B

d) Decay constant of B is smaller than that of A but still its decay rate becomes equal to that of A at a later instant

Linked Comprehension Type Questions

Passage-I :

Suppose that you have come across a piece of wood that is supposed to be of great antiquity. The piece has a mass of 40 g and shows an activity of 280 disintegrations per minute. The living plant shows a ^{14}C activity of 12 disintegrations per minute per gram. The half-life of ^{14}C is 5730 years.

23. The wood was a part of a tree that was cut down approximately

a) 7000 years ago b) 8503 years ago c) 6000 years ago d) 4450 years ago

24. The activity of the piece of wood if it were 10,000 years old would be

a) 200 disintegrations/min b) 143 disintegrations/min

c) 250 disintegrations/min d) 280 disintegrations/minv

Passage-II :

The atomic mass of $^{11}_{6}C$ is approximately 11.0g and therefore 11.0g of $^{11}_{6}C$ contains Avogadro's number (6.023×10^{23}) of nuclei. A radiactive sample contains 3.50 μg of pure $^{11}_{6}C$, which has a half-life of 20.4 min.

25. The activity of the sample (in dps) initially is

a) 1.09×10^{14} b) 3.4×10^{16} c) 1.92×10^{17} d) 1.92×10^{15}

26. The activity of the sample (in decays/s) after 8.00 h is

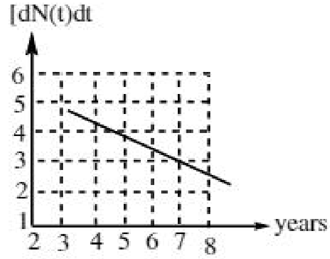
a) 8.59×10^{3} b) 8.59×10^{4} c) 8.59×10^{6} d) 8.59×10^{7}

27. The number of radioactive nuclei remaining after 8.00h is:

a) 1.58×10^{10} b) 1.58×10^{7} c) 1.58×10^{6} d) 8.59×10^{6}

Integer Type Questions

28. To determine the half–life a radioactive element a student plots a graph of *ln* /dN(t)/dt [Versus t]. Here dN(t)/dt is the rate of radioactive decay at time t. If the number of radioactive nuclei of this element decreases by a factor of P after 4.16 years, the value of P is



29. As a health physicist, you are being consulted about a spill in a radiochemistry lab. The isotope spilled was 500μCi of ^{131}Ba, which has a half-life of 12 days. The integer part of result mass (in kg) of ^{131}Ba spilled was

EXERCISE-III

(Nuclear Fission & Fusion)

LEVEL-I (MAIN)

Straight Objective Type Questions

1. Fission of nuclei is possible because the binding energy per nucleon in them
   1) increases with mass number at high mass numbers
   2) decreases with mass number at high mass numbers
   3) increases with mass number at low mass numbers
   4) decreases with mass number at low mass numbers

2. In a nuclear fission:
   i) in elements of high atomic mass number, energy is released.
   ii) linear momentum and total energy are conserved but not angular momentum.
   iii) linear momentum, angular momentum and total energy are conserved.
   iv) the probability of neutron being absorbed by a fissionable nucleus, increases when the neutrons are slowed down

   1) (i), (ii) and (iii) are correct 2) (i), (iii) and (iv) are correct
   3) (ii), (iii) and (iv) are correct 4) (ii) and (iv) are correct

3. Assuming the energy released per fission of U^{235} is 200 MeV, the energy released in the fission of 1kg of U^{235} is
   1) 0.91×10^{11}J 2) 0.91×10^{13}J 3) 8.19×10^{11}J 4) 8.19×10^{13}J

4. In each fission of U^{235}, 200 MeV of energy is released. If a reactor produces 100MW power the rate of fission in it will be
   1) 3.125×10^{18} per min 2) 3.125×10^{17} per sec 3) 3.125×10^{17} per min 4) 3.125×10^{18} per sec

5. If 50% of energy released during fission would be converted into electrical energy, then the number of fissions in a second in a nuclear reactor of 6.4MW output is (Energy per fission is 200MeV)
   1) 4×10^{15} 2) 4×10^{16} 3) 4×10^{17} 4) 4×10^{18}

6. Choose the correct statement:
   1) Nuclei of small mass numbers are more prone toward nuclear fission as well as fusion
   2) Nuclei of large mass numbers are more prone toward nuclear fission as well as fusion
   3) Nuclei of small and large mass numbers are respectively more prone toward nuclear fusion and fission
   4) Nuclei of large and small mass numbers are respectively more prone toward nuclear fusion and fission

7. In the nuclear reaction, ${}_1H^2 + {}_1H^2 \rightarrow {}_2He^3 + {}_0n^1$. If the mass of the deuterium atom = 2.014741 amu, mass of ${}_2He^3$ atom = 3.016977 amu and mass of neutron = 1.008987 amu, then the Q value of the reaction is nearly:

1) 0.00352MeV	2) 3.27 MeV
3) 0.82 MeV	4) 2.45 MeV

Numerical Value Type Questions

8. The power obtained in a reactor using U^{235} disintegration is 1000kW. The mass decay(μg) of U^{235} per hours is:

9. ${}^{238}_{92}U$ is an unstable nuclide and so it spontaneously decays to Pb-206 through series of x (where x is not known) α – decays and 6β – decays. Atomic number of Pb from this information is

LEVEL-II (ADVANCED)

Straight Objective Type Questions

1. Consider the following nuclear reaction ${}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{94}_{38}Sr + {}^{140}_{54}Xe + 2\left({}^{1}_{0}n\right)$. The fission fragments are however not stable. They undergo successive β – decays until ${}^{94}_{38}Sr$ becomes ${}^{94}_{90}Zr$ and ${}^{140}_{54}Xe$ becomes ${}^{140}_{55}Ce$. Which of the statement(s) are relevant to the above process.
   I) All the energy released is available as kinetic energy of the fission products.
   II) All conservation laws can be valid in the subsequent reactions.
   III) The entire energy released is not available to Zr and Ce as kinetic energy.

a) I and II are correct	b) only III is correct
c) only I is correct	d) Both II and III are correct

2. Observe the following statements regarding nuclear fission and arrange them as a sequence of events which lead to nuclear fission phenomenon.
   I) Formation of a compound (excited) nucleus.
   II) Capture of a thermal neutron by ${}^{235}U$.
   III) The slope of nucleus splits into two fragments emitting several neutrons.
   IV) The shape of nucleus is distorted as a result of violet oscillations. The coulombic forces tend to increase the disturtions

a) II, III, I, IV	b) II, I, III, IV
c) II, I, IV,III	d) II, IV, I, III

3. Binding energy for nuclei P,Q and R are $E_P E_Q$ and E_R respectively. In the fusion processes
   $3P \rightarrow Q + \text{Energy}(E_1)$ $2Q \rightarrow R + \text{Energy}(E_2)$
   then, total energy released in the fusion process
   $6P \rightarrow R + \text{Energy}(E_3)$ is

a) $E_1 + E_2$	b) $E_1 - E_2$	c) $E_1 - 2E_2$	d) $2E_1 + E_2$

4. Consider the following reaction ${}^{238}_{92}U \rightarrow {}^{237}_{92}U + {}^{1}_{0}n + Q$; $m\left({}^{238}_{92}U\right) = 238.05081u$; $m\left({}^{237}_{92}U\right) = 237.0487u$; m(n) = 1.00867u. Which of the following statements is correct
a) The above reaction is possible as neutron is produced
b) The above reaction is impossible, as the reaction is endoergic
c) The above reaction is impossible even if energy is supplied to ${}^{238}_{92}U$
d) all the above

5. The element ${}^{218}_{92}Cm$ has a mean life of 10^{13} seconds. Its primary made of decay are spontaneous fission and $\alpha-$decay the former with a probability of 8% and the latter with a probability of 92%. Each fission releases 200meV of energy
$m\left({}^{248}_{96}Cm\right)$=248.0722u ; $m\left({}^{244}_{94}Pu\right)$ = 244.094100 u; $m\left({}^{4}_{2}He\right)$ = 4.002603u, (1u = 931 MeV/c^2).
The power output of the fission is ______ MeV/second
a) 10^8 b) 8×10^7 c) 16×10^7 d) 10^6

6. A nuclear explosion is designed deliver 1MW of heat energy. How many fission events must be required to a gain this power level (you can assume amount of energy released per fission even is 200MeV)
a) 6.25×10^{10}/sec b) 3.125×10^{16}/sec c) 8.2×10^{16} /sec d) 3.125×10^{10}/sec

7. In a nuclear fission reaction slow neutrons bombard the heavy parent nucleus in release of fragments. These slow neutrons are also known as thermal neutrons as
a) the slow neutrons have sufficient temp. to heat and melt the fission material into smaller fragments
b) the thermal neutrons should have more temp. then that of fission material to induce fragmentation
c) the thermal neutrons are in thermal equilibrium with the atoms of the fission material
d) the thermal energy is very high for these neutrons

8. A star had 10^{40} deuterons. It produces energy via the process: ${}_1H^2 + {}_1H^2 \rightarrow {}_1H^3 + p$ and ${}_1H^2 + {}_1H^3 \rightarrow {}_2He^4 + {}_0n^1$. If the average power radiated by the star is 10^{16} W, the deuteron supply of the star is exhausted in a time of the order of (The masses of nuclei are as follows: $M(H)^2$ = 2.014 amu; M(p) = 1.007 amu; M(n) = 1.008 amu and M(He^4) = 4.001 amu)
a) 10^6 second b) 10^8 second
c) 10^{12} second d) 10^{16} second

9. In the nuclear fusion reaction: ${}_1H^2 + {}_1H^3 \rightarrow {}_2He^4 + n$ given that the repulsive potential energy between the two nuclei is $\sim7.7\times10^{-14}$J, the temperature at which the gases must be heated to initiate the reaction is nearly [Boltzmann's constant K = 1.38×10^{-23} J/K]:
a) 10^9 K b) 10^7 K c) 10^5 K d) 10^3 K

10. The binding energies of the atoms of elements A and B are E_a and E_b respectively. There atoms of the elements B fuse to give one atom of element A. This process is accompanied by release of energy e. Then E_a , E_b and e are related to each other as:
a) $E_a + e = 3E_b$ b) $E_a = 3E_b$ c) $E_a - e = 3E_b$ d) $E_a + 3E_b + e = 0$

11. A nuclear reaction generates at 50% by fission of ${}^{235}_{92}U$ into two equal fragments of ${}^{116}_{46}Pd$ with the emission of 2-γ rays of 5.2 MeV each average binding energy per particle of ${}^{235}U$ and ${}^{116}Pd$ is 7.2MeV and 8.2 MeV respectively. Estimate the amount of ${}^{235}U$ consumed to produce 1600 megawatt power
a) 14 gm b) 140.5gm c) 28 gm d) 100gm

12. Under certain circumstances, a nucleus can decay by emitting a particle more massive than on α – particle. Consider the following decay processes.

(I)$^{223}_{88}Ra \rightarrow ^{209}_{22}Pb + ^{14}_{6}C + Q_1$; (II)$^{223}_{88}Ra \rightarrow ^{219}_{86}Rn + ^{4}_{2}He + Q_2$

$m\left(^{223}_{88}a\right) = 223.018504$; $m\left(^{209}_{82}Pb\right) = 208.98107u$; $m\left(^{14}_{6}C\right) = 14.00324u$; $m\left(^{219}_{86}Rn\right) = 219.00948u$;

$m\left(^{4}_{2}He\right) = 4.00260u$. Consider 1u = 931.5MeV. which of the following statements is correct

a) Q_1 and Q_2 are both negative hence the decays are not allowed

b) Q_1 is energetically allowed and Q_2 is not allowed

c) Q_2 is energetically allowed and Q_1 is not allowed

d) Q_1 and Q_2 are both positive hence allowed

More than One correct answer Type Questions

13. Consider one of the fission reactions by thermal neutrons: $^{235}_{92}U + ^{1}_{0}n \rightarrow ^{94}_{38}Sr + ^{140}_{54}Xe + 2^{1}_{0}n$

If $m(^{235}U) = 235.04394$; m_n = 1.008664 ; $m(^{94}Zr)$ = 93.90654 ; $m(^{140}Ce)$ = 139.90554

However, the fission fragments are not stable. They undergo successive β decays, until $^{94}_{38}Sr$ becomes $^{94}_{40}Zr$ and $^{140}_{54}Xe$ becomes $^{140}_{55}Ce$. Which of the following statement(s) is/are correct?

a) $^{94}_{38}Sr \rightarrow ^{94}_{40}Zr + 2(_{-1}e^0) + \bar{\upsilon} + Q$

b) $^{140}_{54}Xe \rightarrow ^{140}_{58}ce + 4(_{-1}e^0) + \upsilon + Q$

c) total energy released in the process in nearly 208 MeV

d) all the energy available is converted into kinetic energy of the fission products Zr and Ce

14. The fission bomb that was dropped on the Japanese city of Hiroshima in 1945 contained approximately 64kg of $^{235}_{92}U$ and released an amount of energy equivalent to the explosion of approximately 15,000 tons of TNT (called '15-keloton bomb')

a) All the 64 kg of $^{235}_{92}U$ undergoes fission

b) only 1% (nearly) out of 60kg undergoes fission

c) the explosion can cause harmful release of energy known as nuclear holocaust

d) The destructive form of release of energy known as atomic bomb explosion gives large amount of energy in a very small interval of time

15. The fission of $^{235}_{92}U$ by thermal neutrons (neutrons that are in thermal equilibrium with the atoms of a substance with energy about 0.03eV is as shown $^{1}_{0}n + ^{235}_{92}U \rightarrow ^{23}_{92}U \rightarrow X + Y$ + neutrons + radiaction the released neutrons if uncontrolled can trigger a chain reaction, which is the principle of a atom bomb. If the mass of the fissionable material and its size must not be less than the critical mass and critical size. Wether or not any mass will sustain a chain reaction at all is determine by multiplication factor (or) reproduction factor (K)

$$\text{Here } K = \frac{\text{number of neutrons in the present generation}}{\text{number of neutrons in the previous generation}}$$

In the above phenomenon of fission event, which of the following statements is/are correct?

a) $^{236}_{92}U^*$ is an intermediate excited state that lasts for nearly 10^{-12} second and comes to ground state by releasing γ – ray photon

b) In the above fission reaction X and Y can be Ba and Kr

c) On an average 2.5 neutrons are released in a fission even

d) When K = 1 the number of neutrons remain same in all generation of fission events and the mass is said to be critical

16. Choose the correct statement from the following

a) Like other light nuclei the $_2He^4$ nuclei also have a low value of the binding energy per nucleon

b) The binding energy per nucleon decreases for nuclei with small as well as large atomic numbers

c) The energy required to remove one neutron from $_3Li^7$ to transform it into the isotope $_3Li^6$ is 5.6 MeV, which is the same as the binding energy per nucleon of $_3Li^6$

d) When two deuterium nuclei fuse together, they give rise to a tritium nucleus accompanied by a release of energy

17. The total binding energy of an $\alpha-$particle ($_2He^4$) is 24.4 MeV, whereas the total binding energy of a deutron ($_1H^2$) is merely 2.2 MeV. When two deutrons are made to combine:

a) an $\alpha-$particle will be obtained

b) an amount of 22.2 MeV energy will be released

c) an amount of 20.0 MeV energy will be released

d) an amount of 2.22 MeV energy will be released

Linked Comprehension Type Questions

Passage-I :

A nuclear reactor generates P = 20 MW powe at an efficiency of η = 60% by nuclear fission of a ratio-nuclide, whose half-life is 2.2 year. (Given each fission releases E = 200 MeV of energy N = 6×10^{23} $\log_e^2 = 0.693$; 1year = 3.15×10^7 sec)

18. The number of fissions per second required to operate the nuclear reactor is

a) $\frac{2p}{\eta E}$ b) $\frac{p}{\eta E}$ c) $\frac{p}{2\eta E}$ d) $\frac{p}{3\eta E}$

19. At any given instant of time 't' if 'n' is the number of nuclei of the radionuclide and λ is the disintegration constant, then the rate of change of nuclei can be represented as

a) $\frac{dn}{dt} = (\lambda n + n_0)$ b) $\frac{dn}{dt} = \lambda n - n_0$ c) $\frac{-dn}{dt} = \lambda n + n_0$ d) $\frac{dn}{dt} \equiv n_0 - \lambda n$

20. Find the time during 10 mole of the radionuclide will be completely consumed

a) $10^8 \log_e(z)$sec b) $10^8 \log_e(4)$sec

c) $10^8 \log_e(1.0576)$sec d) $10^6 \log_e(4)$sec

Passage-II:

Assume that solar energy is due to thermo-nuclear reaction.

I) $\left({}_1^1H\right) \rightarrow \left({}_2^4He\right) + 2\left({}_{-1}^{0}e\right)$ ***and II)*** ${}_1e^0 + {}_{-1}e^0 \rightarrow \gamma - \text{photon}$

Given : Energy reaching the earth is 1400 Wm^{-2} on the surface.

**** Distance between earth and sun is D = 1.5 × 10^8 km***

******* $m\left({}_1^1H\right)$ = ***1.0078 amu **** $m\left({}_2^4He\right)$ = ***4.0028 amu **** $m\left({}_1e^0\right)$ = ***0.005 amu***

**** Radius of sun = 7 × 10^8 m * Density of sun =*** $\frac{50}{7}$ Kgm^{-3}

21. When the four protons combine to form He and positrons in reaction-I and II, the energy released is

a) 28.5 MeV b) 7.125 MeV c) 50 MeV d) 12.25 MeV

22. The rate of burning of hydrogen is _____ kg per second

a) 5.76×10^{11} b) 5.76×10^{14} c) 6.87×10^{14} d) 6.87×10^{11}

23. Calculate the time in which there would be no sun in second

a) 5×10^{5} b) 2.5×10^{15} c) 8×10^{15} d) 2.5×10^{26}

Matrix Matching Type Questions

24. Match Column-I of the nuclear processes with Column-II containing parent nucleus and one of the end products of each process and then select the correct answer using the codes given below the Columns.

Column-I	Column-II
A) Alpha decay	1) ${}^{15}_{8}0 \rightarrow {}^{15}_{7}N + ...$
B) β^{+} decay	2) ${}^{238}_{92}U \rightarrow {}^{234}_{90}Th + ...$
C) Fission	3) ${}^{185}_{83}Bi \rightarrow {}^{184}_{82}Pb + ...$
D) Proton emission	4) ${}^{239}_{94}Pu \rightarrow {}^{140}_{57}La + ...$

25. Match the processes given in Column-I with the changes brought out by them given in Column-II.

Column-I	Column-II
A) Nuclear	p) converts some matter into energy
B) Nuclear fission	q) generally possible for nuclei with low atomic numbers
C) $\beta-$ decay	r) generally possible for nuclei with higher atomic number
D) Exothermic nuclear reaction	s) essentially proceeds by weak nuclear forces

Integer Type Questions

26. In the fusion reaction ${}_{1}H^{2} + {}_{1}H^{2} \longrightarrow {}_{2}He^{3} + {}_{0}n^{1}$ the masses of deuteron, helium and neutron expressed in amu are 2.015u, 3.017u and 1.009u respectively. It 1kg of deuteron undergoes complete fusion, the amount of energy released (in 10^{13}J) is

27. ${}^{2}_{1}H + {}^{2}_{1}H \rightarrow {}^{4}_{2}He$ in a nuclear reactor of 200 MW rating. If the energy from the above reaction is used with a 25% efficiency in the reactor, If number grams of deuterium will be needed per day? The masses of ${}^{2}_{1}H$ and ${}^{4}_{2}He$ are 2.0141u and 4.0026u respectivelyis 30x, then x =

28. Consider so called D-T reaction (deuterium - tritium fusion reaction) which may be the basic reaction of a future thermonuclear fusion reactor ${}^{2}_{1}He + {}^{3}_{1}H \rightarrow {}^{4}_{2}He + {}^{1}_{0}n + Q$. If the amount of heat Q released is nearly (3x)MeV, then x =

KEY SHEET (LECTURE SHEET)

EXERCISE-I

LEVEL-I

1) 3 2) 2 3) 4 4) 2 5) 3 6) 1 7) 3 8) 2
9) 1 10) 3 11) 3 12) 3 13) 4 14) 3

LEVEL-II

1) a 2) c 3) d 4) b 5) d 6) a 7) b 8) d
9) a 10) a 11) c 12) a 13) d 14) a 15) a 16) abcd
17) bc 18) abcd 19) ad 20) bd 21) c 22) b 23) a 24) c
25) c 26) a 27) A-p; B-q,t; C-r,s,D-r,s 28) A-q,t; B-p,r; C-s,D-p,r

EXERCISE-II

LEVEL-I

1) 1 2) a 3) 2 4) 4 5) 3 6) 4 7) 3 8) 4
9) 1 10) 1 11) 1 12) 3 13) 3 14) 3 15) 4 16) 3
17) 1 18) 3 19) 5 20) 1.35

LEVEL-II

1) d 2) b 3) c 4) d 5) d 6) c 7) c 8) d
9) c 10) d 11) d 12) c 13) b 14) d 15) b 16) b
17) c 18) abd 19) ab 20) ab 21) bd 22) cd 23) d 24) b
25) a 26) c 27) b 28) 8 29) 6

EXERCISE-III

LEVEL-I

1) 2 2) 2 3) 4 4) 4 5) 2 6) 3 7) 2 8) 40
9) 80

LEVEL-II

1) d 2) c 3) d 4) b 5) c 6) b 7) c 8) c
9) a 10) a 11) b 12) d 13) ac 14) bcd 15) abc 16) bc
17) ac 18) b 19) b 20) c 21) a 22) b 23) b
24) A-q; B-p; C-s; D-r 25) A-p,q,s,t; B-q; C-s; D-s
26) 9 27) 4 28) 6

PRACTICE SHEET

EXERCISE-I

(Nucleus & properties; Nuclear decays (α, β, γ, K capture))

LEVEL-I (MAIN)

Straight Objective Type Questions

1. Binding energies of ${}_1H^2$, ${}_2He^4$, ${}_{26}Fe^{56}$, and ${}_{92}U^{235}$ nuclei are 2.22MeV,28.4MeV, 492MeV and 1786MeV respectively which one of the following is more stable?
   1) ${}_1H^2$ 2) ${}_2He^4$ 3) ${}_{26}Fe^{56}$ 4) ${}_{92}U^{235}$

2. The BE/A for deutron and an α- particle are X_1 and X_2 respectively. The energy released in the reaction will be ${}_1H^2 + {}_1H^2 \to {}_2He^4$

1) $X_2 - X_1$ 2) $2(X_2 - X_1)$ 3) $4(X_2 - X_1)$ 4) $8(X_2 - X_1)$

3. A nucleus at rest splits into two nuclear parts having radii in the ratio 1:2. Their velocities are in the ratio

1) 8:1 2) 6:1 3) 4:1 4) 2:1

4. A nucleus ruptures into two nuclear parts which have their elocity ratio equal to 2:1. What will be the ratio of their nuclear sizes?

1) $2^{2/3}:1$ 2) $1:2^{1/3}$ 3) $3^{1/2}:1$ 4) $1:3^{1/2}$

5. In the nuclear reaction, ${}_1H^2 + {}_1H^2 \to {}_0n^1 + {}_2He^3$ if the binding energy of deuteron is 2.23 MeV and the Q-value of the reaction is 3.27 MeV then the binding energy of ${}_2He^3$ is

1) 1.19 MeV 2) 7.73 MeV 3) 4.46 MeV 4) 3.27 MeV

6. (ii) Consider the fission of ${}^{235}_{92}U$ by the slow neutrons ${}^{1}_{0}n + {}^{235}_{92}U \to {}^{236}_{92}U^* \to {}^{95}_{42}Mo + {}^{139}_{57}La + 2n$. Calculate the energy released in the process. For the following calculations use following data $m({}^{235}U) = 235.0439$, $m({}^{95}Mo) = 94.9058$, $m({}^{139}La) = 138.9061$

1) 192.5 MeV 2) 26.57 MeV 3)150 MeV 4) 207.16 MeV

7. A positron is a particle with

1) same mass as that of proton and with a positive charge
2) same mass as that of proton but with a negative charge
3) same mass as that of an electron but with no charge
4) same mass as that of an electron but with positive charge

8. Neutron decay in free space is given as follows: ${}_0n^1 \to {}_1H^1 + {}_{-1}e^0 + [\ ]$
Then the particle in the bracket is:

1) neutrino 2) photon 3) antineutrino 4) graviton

9. In the nuclear reaction: ${}_{92}U^{238} \to {}_zTh^A + {}_2He^4$ the values of A and Z are:

1) A = 230, Z = 8 2) A = 234, Z = 90 3) A = 228, Z = 94 4) A = 232, Z = 91

10. A neutrino is :

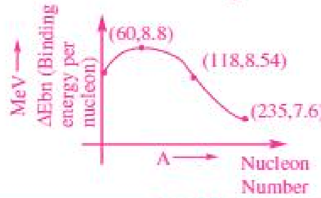
1) chargeless and has no spin 2) chargeless but has spin
3) charged like an electron but has spin 4) uncharged but has mass nearly that of a proton.

11. A proton, $\alpha-$particle and a neutron are projected towards a target nucleus. Which particle is more likely to be absorbed by the nucleus?

1) Proton 2) $\alpha-$particle 3) Neutron
4) All particles are about equally likely to be absorbed.

12. When fission of U^{235} takes place the nucleus splits roughly into two equal parts. Use the given graph to find the energy released. Energy released for each nucleus split of U^{235} is

1) more than 200 MeV
2) less than 200 MeV
3) equals to 200 Mev
4) Data insufficient



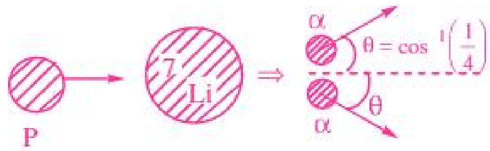
13. A γ – ray photon is emitted:

1) After ionization of an atom
2) After de-excitation of a nucleus
2) Due to conversion of a neutron into a proton in the nucleus
4) Due to conversion of a proton into a neutron in the nucleus

14. A free neutron decays to a proton but a free proton does not decay to a neutron. This is because

1) neutron is a composite particle made of a proton and an electron whereas proton is a fundamental particle
2) neutron is an uncharged particle whereas proton is a charged particle
3) neutron has larger rest mass than the proton
4) weak forces can operate in a neutron but not in a proton.

15. A proton is bombarded over a lithium nucleus. Due to collision two α -particles are produced



If direction of motion of the α -particles with the direction of bombarding proton is at an angle of $\cos^{-1}(1/4)$, then the correct relation between KE of proton (K_p) andKE of α -particles (K_α) is

1) $K_p = 2K_\alpha$ 2) $K_p = \frac{1}{2}K_\alpha$ 3) $2K_p = 3k_\alpha$ 4) $K_p = k_\alpha$

LEVEL-II (ADVANCED)

Straight Objective Type Questions

1. Which of these might be the reason for the fact that neutron penetrates matter more readily as compared to protons?

a) Electrical neutrality of neutrons b) Neutrons are more massive than protons
c) Neutrons are generally move energetic compared to protons
d) Neutrons have more momentum compared to protons for a given kinetic energy

2. The nuclear radius of $_8C^{16}$ is 3×10^{-15} metre. If an atomic mass unit is 1.67×10^{-27} kg, then the nuclear density is approximately:

a) 235×10^{17} gm per cm^3 b) 2.35×10^{17} kg per metre^3
c) 2.35×10^{17} gm per metre^3 d) 235×10^{17} kg per cm^3

3. Beta particles are emitted:

1) when outermost orbital electrons leave the atom.
2) due to conversion of neutrons into protons in the nucleus.
3) due to conversion of protons into neutrons
4) due to reversion of the excited nucleus to the ground state.

4. The binding energies per nucleon are 5.3 MeV, 6.2MeV and 7.4 MeV for the nuclei with mass numbers 3,4 and 5 respectively. If one nucleus of mass number 3 combines with one nucleus of mass number 5 to give two nuclei of mass number 4, then:

a) 0.3 MeV energy is absorbed b) 0.3 MeV energy is released
c) 28.1 MeV energy is absorbed d) 3.3 MeV energy is absorbed

5. The binding energy expressed in MeV is given for the following nuclear reactions:
$_2He^3 + {}_0n^1 \rightarrow {}_2He^4 + 20MeV$; $_2He^4 + {}_0n^1 \rightarrow {}_2He^5 + 0.9$ MeV
Which of the following conclusions is correct
a) $_2He^4$ is less stable than both $_2He^3$ and $_2He^5$
b) $_2He^4$ is less stable than $_2He^3$ but more stable than $_2He^5$
c) $_2He^4$ is less than stable than $_2He^5$ but more stable than $_2He^3$
d) $_2He^4$ is more stabler than both $_2He^3$ and $_2He^5$

6. In an α-decay the kinetic energy of α-particle is 48 MeV and Q-value of the reaction is 50 MeV. The mass number of the mother nucleus is: (Assume that daughter nucleus is in ground state)
a) 96 b) 100 c) 104 d) none of these

7. A nucleus of mass number 220, initially at rest emits an α-particle. If the Q value of the reaction is 5.5 MeV, the energy of the emitted α-particle will be in MeV.
a) 4.8 MeV b) 5.4 MeV c) 6.0 MeV d) 6.8 MeV

8. The rest mass of the deuteron, ${}_1^2H$, is equivalent to an energy of 1876 MeV, the rest mass of a proton is equivalent to 939 MeV and that of a neutron to 940 MeV. A deuteron may disintegrate to a proton and a neutron if it
a) emits a γ- ray photon of energy 2 MeV b) captures a γ- ray photon of energy 2 MeV
c) emits a γ- ray photon of energy 3 MeV d) captures a γ- ray photon of energy 3 MeV

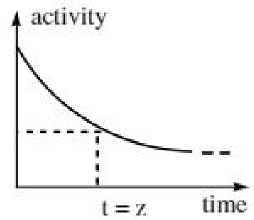
9. ^{228}Th emits an alpha particle and reduces to ^{224}Ra. Calculate the kinetic energy of the alpha particle emitted in the following decay; in MeV. $^{228}Th \rightarrow {}^{224}Ra^* + \alpha$; $^{224}Ra^* \rightarrow {}^{224}Ra + \gamma$ (217 keV). Atomic mass of ^{228}Th is 228.028726 u, that of ^{224}Ra is 224.020196 u and that of ${}_2^4He$ is 4.00260 u.
a) 5300 b) 530 c) 53 d) 5.3

10. When U^{238} nucleus, originally at rest, decay by emitting and alpha particle having a speed *u*. The recoil speed of the residual nucleus is
a) 4u/238 b) –4u/234 c) 4u/234 d) –4u/238

11. A radioactive nucleus (initial mass number A and atomic number Z) emits 3 α–particles and 2 positrons. The ratio of number of neutrons to that of protons in the final nucleus will be:
a) $\frac{A-Z-4}{Z-2}$ b) $\frac{A-Z-8}{Z-2}$ c) $\frac{A-Z-4}{Z-8}$ d) $\frac{A-Z-12}{Z-8}$

12. Which of the following statements is not true? Beta particles:
a) have the same properties as atomic electrons b) originate from atomic nuclei
c) lead to the prediction of neutrino d) can have positive charge

13. The activity of a certain radioactive sample is plotted against time as shown . It the initial slope of the curve is m, then the slope of the curve at p is



a) me b) $\frac{m}{e}$ c) $m-\left(1-\frac{1}{e}\right)$ d) cannot be determines

14. A nucleus with Z=92 emits the following in a sequence: α,α,β^{-1}, β^{-1}, $\alpha,\alpha,\alpha,\alpha,\beta^{-1},\beta^{-1},\alpha,\beta^{+},\beta^{+}$ and α. The Z of the resulting nucleus is:

a) 76 b) 78 c) 82 d) 74

15. Calculate the maximum kinetic energy of the beta particle emitted in the following decay scheme; in MeV. ${}_{7}^{12}N \rightarrow {}_{6}^{12}C^{*} + {}_{+1}e^{0} + \nu$; ${}_{6}^{12}C^{*} \rightarrow {}_{6}^{12}C + \gamma$ (4.43 MeV). The atomic mass of ^{12}N is 12.018613 u.

a) 0.019 b) 1190 c) 12.9 d) 11.9

16. When a nucleus in an atom undergoes a radioactive decay, the electronic energy levels of the atom:

a) do not change for any type of radioactivity

b) change for α and β radioactivity but not for γ-radioactivity

c) change for $\alpha-$radioactivity but not for others

d) change for β-radioactivity but not for others

More than One correct answer Type Questions

17. Choose the incorrect assertion regarding binding energy per nucleon

a) binding energy per nucleon is practically constant for nuclei with mass numbers b/w 30 and 170

b) binding energy per nucleon is maximum for ^{56}Fe (equal to 8.75 meV)

c) binding energy per nucleon for ^{6}Li is lower compared to ^{4}He

d) higher the binding energy per nucleon, more stable is the nucleus

18. Consider the process, ${}_{92}^{232}U \rightarrow {}_{90}^{228}Th + H_{2}^{4}e$ Masses of reactants and products are $m\left({}_{90}^{228}Th\right) = 228.0998u$, $m\left({}_{2}^{4}He\right) = 4.0039u$, $m\left({}_{92}^{232}U\right) = 232.1095u$, Then,

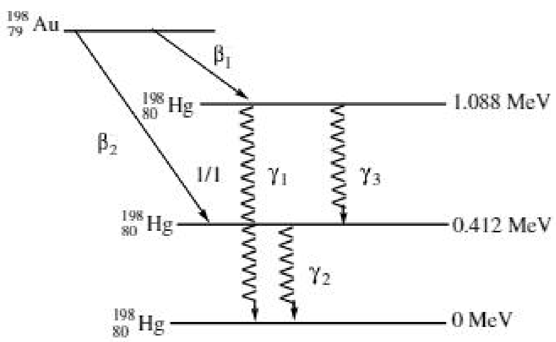
a) process may occur spontaneously

b) kinetic energy of an α - particle emitted is always less than or equal to 5.30 MeV

c) kinetic energy of an α -particle emitted is alwys less than or equal to 5.30 Mev

4) process requires a total of 5.40 MeV of energy to proceed

19. In the diagram shown the γ-decay scheme is shown in sequential process.



You are given that $m(Au^{198}) = 197.968233u$, $m(Hg^{198}) = 197.966760$ u

a) The maximum kinetic energy of β_1 -particle is 0.284 MeV

b) The maximum kinetic energy of β_2 -particle is 0.960 MeV

c) The radiation frequency of γ_1 is 2.6×10^{20} Hz

d) The radiaiton frequency of γ_2 is 0.995×10^{20} Hz

20. When a nucleus with atomic number Z and mass number A undergoes a radioactive decay process:
   a) both Z and A will decrease if the process is α – decay
   b) Z will decrease but A will not change if the process is β^+ –decay
   c) Z will increase but A will not change if the process is β^- –decay
   d) Z and A will remain unchanged if the process is γ – decay

Linked Comprehension Type Questions

Passage-I :

During cosmic ray showers γ – rays of energy ε >1.02 MeV decay to produce e^- and e^+ pair called pair production. Also e^- and e^+ combine to produce γ – rays called Annihilation of matter. Both phenomenon continue simultaneously.

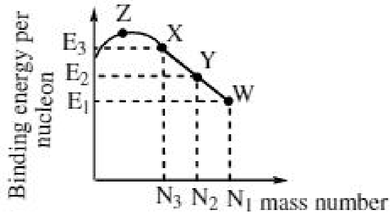
21. In pair production $\gamma \rightarrow e^- + e^+$ then in annihilation of electron and positron the number of γ – ray photons produced is
   a) 1 b) 2 c) 3 d) any number

22. Wavelength of photon emitted is
   a) 1.2 nm b) 2.4 pm c) 1.2 pm d) 2.4 nm

23. Frequency of light photon emitted is about:
   a) 1.24×10^{20} Hz b) 2.5×10^{20} Hz c) 5×10^{20} Hz d) 10^{21} Hz

Passage-II :

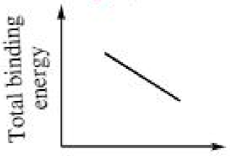
Consider nuclear fission reaction W $\rightarrow$ X+Y. Using graph given, answer the following questions

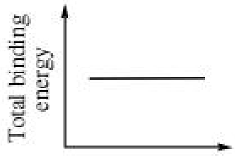


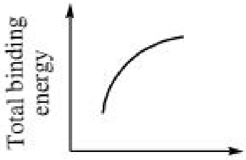
24. What is Q value of reaction
   a) $E_1N_1 - (E_2N_2 + E_3N_3)$ b) $E_2N_2 + E_3N_3 - E_1N_1$ c) $E_2N_2 + (E_1N_1 - E_3N_3)$ d) $E_1N_1 + E_3N_2 - E_2N_2$

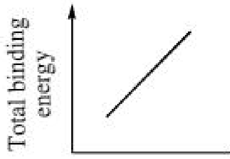
25. If M_W is mass of W, M_X is mass of X and M_Y is mass of Y nucleus, choose correct alternative
   a) $\frac{M_W}{N_1} > \frac{M_Y}{N_2} > \frac{M_X}{N_3}$ b) $\frac{M_W}{N_1} < \frac{M_Y}{N_2} < \frac{M_X}{N_3}$ c) $\frac{M_W}{N_1} < \frac{M_Y}{N_2} > \frac{M_X}{N_3}$ d) $\frac{M_W}{N_1} > \frac{M_Y}{N_2} < \frac{M_X}{N_3}$

26. Which of the following graphs might represent relationship between atomic mass number (i.e., atomic weight) and total binding energy of nucleus. for nuclei heavier than Z?

a) 

b) 

c) 

d) 

Integer Type Questions

27. The nucleus $^{238}_{92}U$ is unstable against $\alpha-$decay with a half-life of about 4.5×10^9 years. Write down the equation of the decay and estimate the kinetic energy of the emitted $\alpha-$particle from the following data

28. The nucleus $^{23}_{10}Ne$ decays by β^- emission. Write down the β^--decay equation and determine the maximum kinetic energy of the electrons emitted from the following data

29. Would it have been possible of rRutherford to have used $\alpha-$particles with a kinetic energy of 1.0 MeV to produce the nuclear reaction $^4_2He+^{14}_7N\rightarrow^{17}_8O+^1_1H$

EXERCISE-II

(Radioactive Laws & Application)

LEVEL-I (MAIN)

Straight Objective Type Questions

1. Activity of a radioactive element is decreased to one-third of original activity R_0 in 9 years. After further 9 years, its activity will be:

1) R_0 2) $\frac{2}{3}R_0$ 3) $\frac{R_0}{9}$ 4) $\frac{R_0}{6}$

2. A radioactive sample at any instant has its disintegration rate 5,000 disintegrations per minute. After 5 minutes the rate is 1250 disintegrations per minute. Then, the decay constant (per minute) is:

1) 0.4 1n 2 2) 0.2 ln 2 3) 0.1 in 2 4) 0.8 1n 2

3. The activity of a radioactive sample is measured as N_0 counts per minute at t = 0 and (N_0/e) counts per minute at t=5 minutes. The half-life (in minutes) at which the activity reduces to half its value is

1) $5\log_e 2$ 2) $\log_e (2/5)$ 3) $\frac{5}{\log_e 2}$ 4) $5\log_{10}5$

4. The half-life of a radioactive isotope X is 20years. It decays to another element Y which is stable . The two elements X and Y were found to be in the ratio 1:7 is a sample of a given rock. The age of the rock is estimated to be:

1) 40 years 2) 60 years 3) 80 years 4) 100 years

5. *n*–alpha particles per second are emitted from N atoms of a radioactive element. The half-life of the radioactive element is:

1) $\frac{n}{N}s$ 2) $\frac{N}{n}s$ 3) $\frac{0.693N}{n}s$ 4) $\frac{0.693n}{N}s$

6. $^{221}_{87}Ra$ is a radioactive substance having half-life of 4 days. Find the probability that a nucleus undergoes decay after two half-lives

1) 1 2) 1/2 3) 3/4 4) 1/4

7. The half-life of At^{215} is 100μs. If a sample contains 215 mg of At^{215}, the activity of the sample initially is:

1) 10^2 Bq 2) 3×10^{10} Bq 3) 4.17×10^{24}Bq 4) 1.16×10^5 Bq

8. Two radioactive materials X_1 and X_2 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 X_1 to that of X_2 will be 1/e after a time:

1) $\frac{1}{10\lambda}$ 2) $\frac{1}{11\lambda}$ 3) $\frac{11}{10\lambda}$ 4) $\frac{1}{9\lambda}$

9. The half-life of a radioactive isotope 'X' is 50 years. It decayed to another element 'Y' which is stable. The two elements 'X' and 'Y' were found to be in ratio of 1:15 in a sample of a given rock. The age of the rock was estimated to be:

1) 100 years 2) 150 years 3) 200 years 4) 250 years

LEVEL-II (ADVANCED)

Straight Objective Type Questions

1. Two radioactive substance A and B have decay constant 5λ and λ respectively. At t = 0, they have the same number of nuclei. The ratio of number of nuclei of A to those of B will be $(1/e)^2$ after a time interval:

a) 4λ b) 2λ c) $1/2\lambda$ d) $1/4\lambda$

2. Half-lives of two radioactive substances A and B are respectively 20 minutes and 40 minutes. Initially the samples of A and B have equal numbers of nuclei. After 80 minutes, the ratio of remaining numbers of A and B nuclei is:

a) 1:4 b) 4:1 c) 1:16 d) 1:1

3. In a radioactive material, the activity at time t_1 is R_1 and at a later time t_2, it is R_2. If the decay constant of the material is λ, then

a) $R_1 = R_2$ b) $R_1 = R_2 e^{-\lambda(t_1 - t_2)}$ c) $R_1 = R_2 e^{-\lambda(t_1 + t_2)}$ d) $R_1 = R_2 e^{(t_1/t_2)}$

4. The threshold energy of the bombarding particle for a nuclear reaction is equal to (Take, m_b = mass of bombarding particle, m_{pr}= Total of products and Q = mass energy of reaction)

a) $\frac{Q.m_b}{m_{pr}}$ b) $-\frac{Q.m_b}{m_{pr}}$ c) $\frac{-Q.m_{pr}}{m_{pr} - m_b}$ f) $\frac{Q.m_{pr}}{m_{pr} - m_b}$

5. In CO_2, obtained from atmospheric air, small fraction of 1.3×10^{-12} is the radioactive isotope ${}^{14}_{6}C(\lambda = 3.83 \times 10^{-12})$. If 200g of carbon fragment is found in an animal's bone in an archaeological site shows an activity of 16 decays in 1 second, then the age of bone will be (Take, in(25/8) $\simeq$ 1.1)

a) about 9.5 Yr b) about 95 Yr

c) about 950 Yr d) about 9500Yr

6. A sample of radioactive material decays simultaneously by two processes A and B with half lives $\frac{1}{2}$ and $\frac{1}{4}$ hour respectively. For first half hour it decays with the process A, next one hour with the process B and for further half an hour with both A and B. If originally there were N_0 nuclei, find the number of nuclei after 2hr of such decay

a) $\frac{N_0}{(2)^8}$ b) $\frac{N_0}{(2)^4}$ c) $\frac{N_0}{(2)^4}$ d) $\frac{N_0}{(2)^5}$

7. Only $\frac{1}{8}$th of total initial number of active radioactive nuclei of a sample is left after 6 days. Then in 10 days fraction that decays is

a) $\frac{15}{16}$ b) $\frac{31}{32}$ c) $\frac{77}{80}$ d) $\frac{71}{80}$

8. Let two radioactive materials A and B have decay constants 10λ and λ respectively. Initially their samples have same number of atoms. The ratio of number of nuclei of A to that of B after a time $(\lambda/9)$ seconds will be

a) 1 : 10 b) 10 : 1 c) e d) e^{-1}

9. Mean lives of a radioactive substance are 1620 Yr and 405 Yr for α-emission and β emission respectively. If a sample of this substance decays by emitting both α and β emissions simultaneously, then time in which $\frac{3}{4}$th of sample will decay is (Take, $\log_e 2=0.693$)

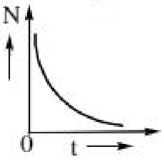
a) 1653 Yr b) 324 Yr c) 449 Yr d) 1468 Yr

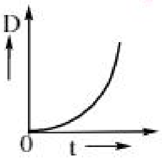
10. Analysis of potassium and argon atoms in a moon rock sample by a mass spectrometer shows that the ratio of the number of stable Ar^{40} atoms present to the number of radioactive K^{40} atoms is 7:1. Assume that all the argon atoms were produced by the decay of potassium atoms wit a half life of 1.25×10^9 year. How old is the rock?

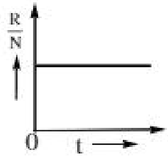
a) 1.25×10^9 year b) 3.75×10^9 year c) 8.75×10^9 year d) 1.00×10^{10} year

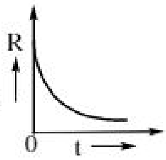
More than One correct answer Type Questions

11. A large population of radioactive nucleus starts disintegrating at t = 0. At time t, if N = number of parent nuclei present, D = the number of daughter nuclei present and R = rate at which the daughter nuclei are produced, then the correct representation will be:

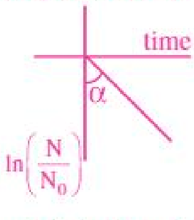
a) 

b) 

c) 

d) 

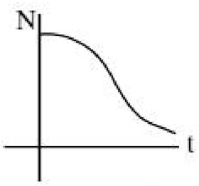
12. A plot of relative fraction of radioactive nuclei $\frac{N}{N^0}$ left undecayed versus time on a semi-logarithmic scale, If $T_{1/2}$ and τ be the half-life and average life period of the radioactive substance as shown, then BDtα = ...

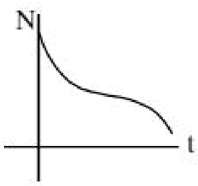


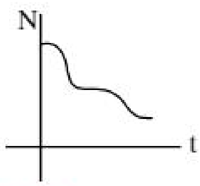
a) α b) $\frac{1}{\tau}$

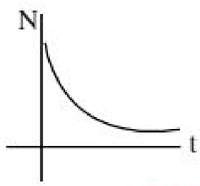
c) $T_{1/2}$ d) $\frac{1}{T_{1/2}}$

13. A radioactive sample consists of two radioactive materials A and B. The half-lives of A and B are 4 days and 8 days respectively. IF the total number of radioactive nuclei (N) be plotted against time (t), then which of the following best represents the qualitative variation ?

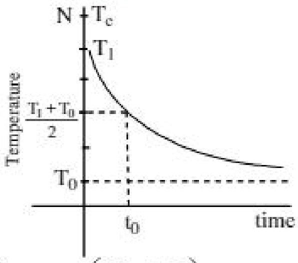
a) 

b) 

c) 

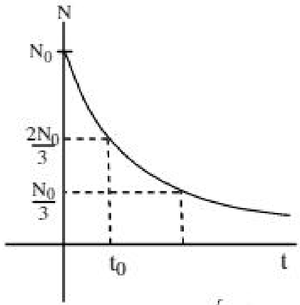
d) 

14. The figure shows the plot of temperature of a liquid (being continuously stirred) place in a slightly cold surrounding. A certain radioactive material with a half life $T_{1/2}$ decays. It is observed that the temperature difference between the liquid and surrounding bears a constant ratio with the number of undecayed radioactive nuclei. The rate of cooling at time $t = t_0$ is



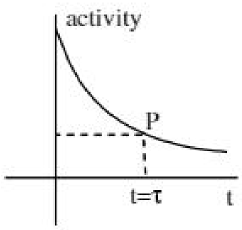
a) $\left(\frac{T_1 - T_0}{T_{1/2}}\right)\ln\left(\frac{1}{\sqrt{2}}\right)$ b) $\left(\frac{T_1 - T_0}{T_{1/2}}\right)\ln 2$ c) $\left(\frac{T_1 + T_0}{T_{1/2}}\right)\ln\left(\frac{1}{\sqrt{2}}\right)$ d) $\left(\frac{T_1 + T_0}{T_{1/2}}\right)\ln 2$

15. The figure shows the number of radioactive atoms left undecayed with time. The time corresponding to $N = \frac{N_0}{3}$ is



a) $3T_0$ b) $t \propto (l\,n\,2)$ c) $t_0\left\{\frac{l\,n(3)}{l\,n(3/2)}\right\}$ d) $4t_0$

16. The activity of a certain radioactive (nuclei) sample is plotted against time as shown



If the initial slope of the curve is "m', then the slope of the curve at point 'P' is

a) me b) $\frac{m}{e}$ c) $\frac{me}{e-1}$ d) 2me

Linked Comprehension Type Questions

Passage-I :

4×10^{23} tritium atoms are contained in a vessel. The half-life of decay of tritium nuclei is 12.3 years.

17. Find the initial activity of the sample
a) $7 \times 10^{14} s^{-1}$ b) $7 \times 10^{18} s^{-1}$ c) $7 \times 10^{24} s^{-1}$ d) $7 \times 10^{4} s^{-1}$

18. Find the number of decays in the next 10 years
a) 1.715×10^{23} b) 2.5×10^{7} c) 2.5×10^{14} d) 3.9×10^{14}

19. Find the number of decays in the 6.15 years from the begining
a) 1.2×10^{14} b) 1.2×10^{18} c) 1.2×10^{23} d) 1.2×10^{30}

Passage-II :

Geologists know about the age of rocks by the method called carbon dating. This is based on the phenomenon that cosmic rays in the atmosphere create C-14 from N-14. The ratio of C-14 to C-12 in the living organism is fixed because of exchange of C-14 to C-12 with time due to radioactive decay. When plants die it no longer absorbs C-14 from atmosphere while C-12 increases thus ratio of C-14 to C-12 decreases. This helps to determine the age of rocks etc which are caused due to damage of living organism during natural calamities:

20. A wooden box contains a human skeleton in iron chains during digging of a rock. The age of rock can be found by observing C-14 to C-12 ratio in:

a) wooden box
b) human skeleton
c) box and skeleton
d) everything like box, skeleton chains etc

21. Which of the following is correct reaction for carbon dating

a) $n + {}^{14}N \rightarrow {}^{14}C + p$ b) $p + {}^{14}N \rightarrow {}^{14}C + n$ c) ${}^{14}N \rightarrow {}^{14}C + e^{+} + v$ d) ${}^{16}O \rightarrow {}^{14}C + 2p$

22. Radioactivity of C-14 is preferred for carbon dating and not of C-11 though it is also radioactive. This is because

a) C-14 is present in atmosphere in abundance
b) C-14 has large life time as compared to C-11
c) C-14 has small life time as compared to C-11
d) C-11 cannot change to C-12 but C-14 can change to C-12 to maintain a fixed ratio

Matrix Matching Type Questions

23. Consider 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-partical and five β-particles. At time t = 0, no.of nuclei of A are $4N_0$ and that of B are N_0. In the conversion of A into C half life A is 1 minute and that B in conversion of B into C is 2 minute. Initially number of nuclei of C are zero then Match the following columns.

Column-I	Column-II
a) The difference between atomic number of A and that of B is	p) 6
b) The difference between mass number of A and that of B is	q) 4
c) If at an instant number of nuclei of A are equal to number of nuclei of B then at the instant the ratio between no.of nuclei of C and no.of nuclei of B is	r) 18
d) The time t at which rate of disintegrations of A are equal to that of B in minute is	s) 2
	t) 0.25

Integer Type Questions

24. A container is filled with a radioactive substance for which the half - life is 2 days. A week later, when the container is opened, it contains 5 grams of the substance. The mass of substance in grams initially placed in the container is $x \times 11.312$. Then the value of x is

25. 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.The decay constant of the sample is___x 10^{-4} s^{-1}

26. At a certain time, a radioactive sample contains 2×10^{20} atoms and its disintegration rate is 3×10^{10} atoms/sec. When 2×10^{15} atoms are left to decay, its disintegration rate will be ____$\times10^{5}$ atoms/sec

EXERCISE-III

(Nuclear Fission & Fusion)

LEVEL-I (MAIN)

Straight Objective Type Questions

1. The neutrons produced in the chain reaction of U^{235} are in:
   1) arithmetic progression 2) harmonic progression
   3) geometric progression 4) none of these
2. Percentage of mass converted into energy is:
   1) more is fission reaction 2) more is fusion reaction
   3) equal in both reaction 4) 100% in fusion reaction
3. Energy released in the fission of a single ${}_{92}U^{235}$ nucleus is 200MeV. The fission rate of ${}_{92}U^{235}$ fuelled reactor operating at a power level of 5 watt is
   1) 1.56×10^{14}/sec 2) 1.56×10^{11}/sec 3) 1.56×10^{20}/sec 4) 1.56×10^{-17}sec
4. For the fission of heavy nucleus, neutron is more effective than the proton of $\alpha-$particle because
   1) neutron is heavier than $\alpha-$particle 2) neutron is lighter than $\alpha-$particle
   3) neutron is uncharged 4) neutron moves with a small velocity
5. The energy released in a typical nuclear fission reaction is:
   1) 200 MeV 2) 120 MeV 3) 80 MeV 4) 15 MeV
6. The energy of neutrons in thermal equilibrium at room temperature is approximately
   1) 5 eV 2) 1 eV 3) 0.1 eV 4) 0.04 eV
7. The binding energy of a deuteron is 2.2 MeV and that of ${}_2^4He$ is 28 MeV. If two deuterons are fused to form one ${}_2^4He$, then the energy released is:
   1) 30.2 MeV 2) 25.8 MeV 3) 23.6 MeV 4) 19.2 MeV
8. Two lithium nuclei in a lithium vapour at room temperature do not combine to form a carbon nucleus because:
   1) carbon nucleus is an unstable particle 2) it is not energetically favorable
   3) nuclei do not come closer due to coulomb repulsion
   4) lithium nucleus is more tightly bound than a carbon nucleus
9. The binding energy per nucleon in a deuterium and helium nuclei are 1.1 MeV and 7 MeV, respectively. When two deuterium nuclei fuse to form a helium nucleus, the energy released in the fusion is:
   1) 23.6 MeV 2) 2.2 MeV 3) 28.0 MeV 4) 30.2 MeV
10. If a star can converts all the He nuclei completely into oxygen nuclei the energy released per oxygen nucleus is: [Mass of He nucleus is 4.0026 amu and mass of oxygen nucleus is 15.9994 amu]
    1) 7.6 MeV 2) 56.12 MeV 3) 10.24 MeV 4) 23.9 MeV

LEVEL-II (ADVANCED)

Straight Objective Type Questions

1. Complete the reaction: $n+_{92}U^{235}\rightarrow _{56}Ba^{144}+....+3n$
   a) $_{36}Kr^{89}$ b) $_{36}Kr^{90}$ c) $_{36}Kr^{91}$ d) $_{36}Kr^{92}$

2. If mass of $U^{235}=235.12142$amu, mass of U^{236} = 236.12305 amu and mass of neutron = 1.008665 amu, then the energy required to remove one neutron from the nucleus U^{236} is nearly about:
   a) 75 MeV b) 65 MeV c) 1 eV d) zero

3. Heavy stable nuclei have more neutrons than protons. This is because of he fact that:
   a) neutrons are heavier than protons
   b) electrostatic forces between protons are repulsive
   c) neutrons decay into protons through beta decay
   d) nuclear forces between neutrons are weaker than that between protons

4. Masses of two isobars $_{29}Cu^{64}$ and $_{30}Zn^{64}$ are 63.9298 amu and 63.9292 amu respectively. It can be concluded from these data that
   a) both the isobars are stable
   b) Zn^{64} is radioactive. decaying to Cu^{64} through β-decay
   c) Cu^{64} is radioactive, decaying to Zn^{64} through γ-decay
   d) Cu^{64} is radioactive, decays to Zn^{64} through β–decay

5. If a deuteron is bombarded on $^{18}_{6}O$ nucleus, then an $\alpha-$particle is emitted. The product nucleus is:
   a) $^{13}_{7}N$ b) $^{10}_{5}B$ c) $^{9}_{4}Be$ d) $^{14}_{7}N$

6. If the binding energy per nucleon in $_3Li^7$ and $_2He^4$ nuclei are 5.60 MeV and 7.06 MeV respectively, then in the reaction: $p+_3Li^7\rightarrow 2_2He^4$, energy of proton must be:
   a) 39.2 MeV b) 28.24 MeV c) 17.28 MeV d) 1.46 MeV

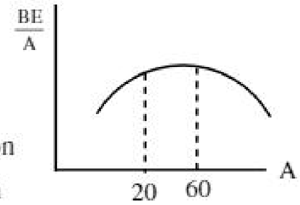
7. In the nuclear reaction, $_1H^2+_1H^2\rightarrow _0n^1+_2He^3$ if the binding energy of deuteron is 2.23 MeV and the Q-value of the reaction is 3.27 MeV then the binding energy of $_2He^3$ is:
   a) 1.19 MeV b) 7.73 MeV c) 4.46 MeV d) 3.27 MeV

8. In the nuclear reaction, $_1H^2+_1H^2\rightarrow _2He^3+_0n^1$. If the mass of the deuterium atom = 2014741 amu, mass of $_2He^3$ atom = 3.016977 amu and mass of neutron = 1.008987 amu, then the Q value of the reaction is nearly:
   a) 0.00352 MeV b) 3.27 MeV c) 0.82 MeV d) 2.45 MeV

More than One correct answer Type Questions

9. The phenomenon of nuclear fission can be carried out both in a controlled and in an uncontrolled way. Out of the following the correct statements *vis-a-vis* these phenomena are:
   a) The fission energy released per reaction is much more than conventional nuclear reactions and one of the products of the reaction is that very particle which initiates the reaction
   b) It is the 'surface to volume' ratio of the sample of nuclear fuel used which determines whether or not the reaction would sustain itself as a 'chain reaction'
   c) The 'control rods' in a nuclear reactor must be made of a material that absorbs neutrons effectively
   d) The energy released per fission as well as energy released per unit mass of the fuel in nuclear fission are both greater than the corresponding quantities for nuclear fusion

10. For nuclei with A > 100:
   a) the binding energy of the nucleus decreases on an average as A increases
   b) the binding energy per nucleon decreases on an average as A increases
   c) if the nucleus breaks into two roughly equal parts, energy is released
   d) if two nuclei fuse to form a bigger nucleus, energy is released
11. Which of the following statements are correct?
   a) Nuclei with small mass number and atomic number are more likely to undergo fusion than fission
   b) Nuclei having a small binding energy per nucleon are more likely to undergo fusion than fission
   c) Nuclei having large binding energy per nucleon are more likely to undergo fusion than fission
   d) Nuclei with large atomic number are more likely to undergo fusion than fission
12. When two light nuclei (A<20) X and Y combine to form more tightly bound bigger nucleus Z, the process is nuclear fusion $x+y \to z$. In the figure shown is BE/A versus 'A' curve (All terms have their usual meaning)



   a) In this situation BE > ($BE_X + BE_Y$)
   b) In this situation BE_Z < ($BE_X + BE_y$)
   c) Q is +ve, hence BE is +ve and energy is released in the fusion
   d) Q is –ve, hence BE is +ve an energy is released in the fusion
13. In the above $\frac{BE}{A}$ versus A curve, process of nuclear fusion
   a) X and Y fuse to give z, z shifts more towards the stable region of BE curve
   b) X and Y fuse to give z, z shifts more away from the stable region of BE curve
   c) X and Y fuse to give z, z shifts more towards the stable region i.e., towards right side in the BE curve
   d) The collision between the two nuclei X and Y nuclei is perfectively inelastic
14. Consider two deutrons ($q = 1.6\times10^{-19}$C) undergo fusion (distance $d \approx 10^{-14}$ m) in a nuclear fusion reaction. Which of the following is/are correct?
   a) The potential energy (u) of the two deutron system is 0.14 MeV
   b) The potential energy (u) of the two deutron system is 2.3×10^{-14} J
   c) The Coulombs potential energy (u) per deutron is 0.07 MeV and to overcome the potential barier, $U_{thermal} > \frac{U}{2}$
   d) The minimum temperature required to fuse the deutrons is 5.3×10^{8} K (ignorins funnel effect)
15. Main source of energy in the sun by nuclear fusion of highly energetic (thermal) protons. Known as proton cycle
   Step-1: ${}^1H + {}^1H \to {}^2H + e^+ + \upsilon$; Step-2: $e^+ + e^- \to 2r$; Step-3 : ${}^2H + {}^1H \to {}^3He + \upsilon$
   Step-4: ${}^3He + {}^3He \to {}^4He + {}^1H + {}^1H \Rightarrow 4\left({}^1_1H\right) \to {}^4_2He + K(r) + \upsilon$
   Which of the following statement(s) is/are correct? (All notations have standard meanings)
   a) In the above process K = 6
   b) In the above process K = 3
   c) In the above process positron and electron get annihilated quickly (true electrons with is the sun) to produce flashes of light
   d) two isotopes of helium (${}^3He$) combine to form a tightly bound helium nucleus

Linked Comprehension Type Questions

Passage:

From study of elastic collision we understand that if two colliding particles have equal masses they interchange their velocities and energy transfer is maximum if they have equal masses and one is at rest w.r.t. other. This principle can be easily used in nuclear reactor to select a moderator. If $m_1 = m_2 = m$ and m_2 at rest then m_1 will stop after colliding with m_2 and m_2 will move with velocity of m_1. In case of nuclear reactor we used a moderator such that neutrons can be slowed down. With above reference answer the following questions

16. Hydrogen is th best material to slow down neutrons but can not be used as moderator. This is because

a) hydrogen is a gas

b) hydrogen has no protons

c) nucleus of hydrogen as proton will attract neutron due to strong nuclear interation

d) atomic hydrogen is not possible in labortory

17. Which is not correct?

a) Neutron can change to proton by emitting π^- inside nucleus $n \to p + \pi^-$

b) Proton can change to neutron by emitting π^+ inside nucleus $n \to p + \pi^+$

c) Neutron can change to proton by emitting π^- outside nucleus $n \to p + \pi^-$

d) Proton can change to neutron by emitting π^+ outside nucleus $p \to n + \pi^+$

18. Which is correct statement

a) Soft water can be used as moderator

b) Heavy water is used as moderator

c) Hard water is used as moderator

d) Hard water or Heavy water can be used as moderator

Matrix Matching Type Questions

19. Nucleus consists of neutrons and protons, neutrons and protons inside the nucleus interact with each other. They interchange into each other. The forces between them are charge independent, short range, mutual non conservative, strongly attractive. But many particles are emitted like α, β, γ rays and other high energy particles as mesons, leptons, baryons etc. Can you match the classification of particles in Column-I with their characters in Coloumn-II.

Column-I	Column-II
A) Chargeless integral spin particle	p) Pion
B) Chargeless half spin particle	q) Photon
C) β- particle	r) Neutrino
D) Exchange particle	s) Positron

20. The most important use of studying nuclear fission and fusion process was to harness nuclear energy for useful purpose of humanity. Nuclear reactor is the machine designed to harness nuclear energy to electricity. The basic principle involved is fission of uranium to krypton and barium by slow moving neutrons as in following ${}_0n^1 + {}^{235}_{92}U \rightarrow {}^{96}_{32}Kr + {}^{141}_{56}Ba + 3{}_0n^1 + Q(200MeV)$ reaction:

But the difficulty is that one neutron striking with ${}^{235}_{92}U$ produces three (2.6 on an average) neutrons which can cause further fission. The neutron intensity available for further fission is controlled by measuring reproduction factor K defined as the average number of neutrons from each fission the causes further fission. Maximum value of $K = 2.6$. For optimum operation of nuclear reactor, the value of K is mentioned in Column-I for various stages in Column-II match the correct columns:

Column-I	Column-II
A) $K \approx 1$	p) Uncontrolled chain reaction
B) $K<1$	q) Critical
C) $K \geq 1$	r) Sub critical
D) $K \approx 25$	s) Super critical

KEY SHEET (PRACTICE SHEET)

EXERCISE-I

LEVEL-I

1) 3	2) 3	3) 1	4) 2	5) 2	6) 4	7) 4	8) 3
9) 2	10) 2	11) 3	12) 1	13) 2	14) 3	15) 4	

LEVEL-II

1) a	2) b	3) b	4) d	5) d	6) b	7) b	8) d
9) d	10) c	11) c	12) c	13) b	14) b	15) c	16) b
17) abc	18) ac	19) abcd	20) abcd	21) b	22) b	23) a	24) b
25) a	26) c	27) 4	28) 4	29) 0			

EXERCISE-II

LEVEL-I

1) 3	2) 1	3) 1	4) 2	5) 3	6) 3	7) 3	8) 4
9) 3							

LEVEL-II

1) c	2) a	3) b	4) c	5) d	6) a	7) b	8) d
9) c	10) b	11) a	12) b	13) b	14) a	15) c	16) b
17) a	18) a	19) c	20) c	21) a	22) b		
23) A-q; B-q; C -r; D-p			24) 5	25) 3	26) 3		

EXERCISE-III

LEVEL-I

1) 3	2) 2	3) 2	4) 3	5) 1	6) 4	7) 3	8) 3
9) 1	10) 3						

LEVEL-II

1) a	2) b	3) b	4) d	5) d	6) c	7) b	8) b
9) abc	10) bc	11) ab	12) acd	13) acd	14) abcd	15) acd	16) a
17) a	18) b	19) A-q; B-r; C-s; D-p			20) A-q; B-r; C-s; D-p		

ADDITIONAL PRACTICE EXERCISE

LEVEL-I (MAIN)

Straight Objective Type Questions

1. Half lives of two isotopes X and Y of a material are known to be 2×10^9 years and 4×10^9 years respectively. If a planet forms with equal number of these isotopes, estimate the current age of the planet, given that currently the material has 20% of X and 80% of Y by number

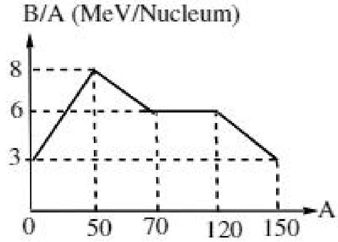
   1) 2×10^9 years 2) 4×10^9 years

   3) 6×10^9 years 4) 8×10^9 years

2. A particular nucleus in a large population of identical radioactive nuclei did survive 5 half lives of that isotope. Then the probability that this surviving nucleus will service the next half life is

   1) $\frac{1}{32}$ 2) $\frac{1}{5}$ 3) $\frac{1}{2}$ 4) $\frac{1}{10}$

3. Assume that the nuclear binding energy per nucleon (B/A) versus mass number (A) is drawn and is as shown in the figure. Consider a nucleus of A = 110. Fission of the nucleus results into 2 fragments. Then which of the following sets could be possibly the mass numbers of the resulting nuclei



   A) 55 and 55 B) 70 and 40

   C) 100 and 10 D) 90 and 20

   1) A, B are possible 2) B,C are possible 3) A,B,C,D are possible 4) A only is possible

LEVEL-II

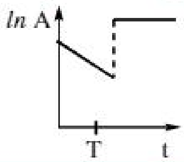
LECTURE SHEET (ADVANCED)

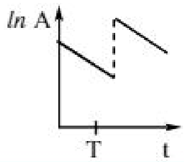
Straight Objective Type Questions

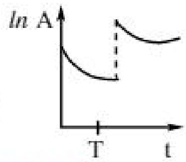
1. Nucleus A decays to B with decay constant λ_1 and B decays to C with decay constants λ_2. Initially at t = 0, number of nuclei of A and B are $2N_0$ and N_0 respectively. At some instant $t = t_0$, number of nuclei of B stop changing. Find t_0 if at this instant number of nuclei of B is $\frac{3N_0}{2}$

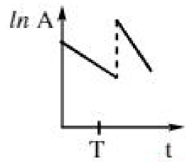
   a) $\frac{1}{\lambda_1} ln\left[\frac{4\lambda_1}{3\lambda_2}\right]$ b) $\frac{1}{\lambda_2} ln\left[\frac{4\lambda_1}{3\lambda_2}\right]$ c) $(\lambda_1+\lambda_2) ln\left[\frac{4\lambda_1}{3\lambda_2}\right]$ d) $\frac{1}{\lambda_1} ln\left[\frac{4\lambda_1}{3\lambda_2}\right]$

2. At time t = 0, some radioactive gas is injected into a sealed vessel. At time T, some more of the same gas is injected into the same vessel. The graph representing the variation of the logarithm of the activity A of the gas with time t is

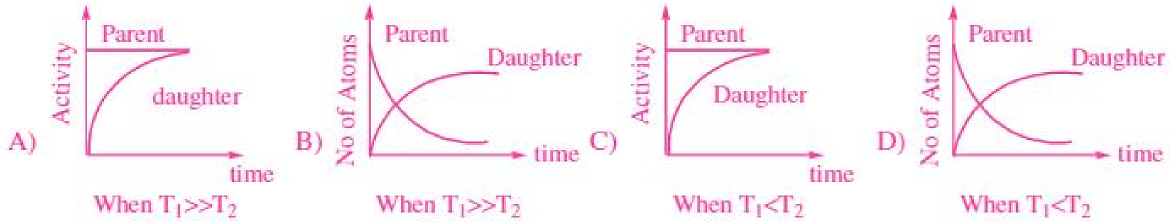
   a) 

   b) 

   c) 

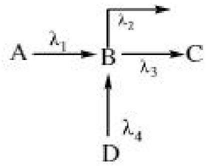
   d) 

3. A nucleus 'A' decays into 'b' with half life 'T_1' and 'B' decays into 'C' with half life 'T_2'. Graphs are drawn between number of atoms/activity versus time which are as shown, then



a) BC are correct b) ABC are correct c) AD are correct d) BCD are correct

4. In radioactive chain reaction shown, initially at t = 0, only No molecules of 'A' are present. At some time t = t, number of molecules of A, B, C, D and E are N_1, N_2, N_3, N_4 and N_5 respectively. Then the activity of 'B' at this time is



a) $\lambda_1 N_1 + \lambda_4 N_4 - \lambda_5 N_2 - \lambda_3 N_2$

b) $(\lambda_3 + \lambda_5) N_2$

c) $\lambda_1 N_1 + \lambda_4 N_4 - \lambda_5 N_5 - \lambda_3 N_3$

d) $(\lambda_1 + \lambda_4 - \lambda_3 - \lambda_5) N_2$

5. A radio nuclide A_1 with decay constant λ_1 transform into radio nuclide A_2 with decay constant λ_2. Assuming that at the initial moment the preparation contained only radio nuclide A_1, then the time interval after which the activity of radio nuclide A_2 reaches its maximum value is

a) $\dfrac{\ln(\lambda_2/\lambda_1)}{\lambda_2 - \lambda_1}$ b) $\dfrac{\ln(\lambda_2/\lambda_1)}{\lambda_2 \lambda_1}$ c) $\ln(\lambda_2 - \lambda_1)$ d) $e^{-(\lambda_1 - \lambda_2)}$

6. A radioactive nucleus undergoes a series of decay according to the scheme.
$A \xrightarrow{\alpha} A_1 \xrightarrow{\beta} A_2 \xrightarrow{\alpha} A_3 \xrightarrow{\gamma} A_4$. If the mass number and atomic number aer 180 and 72 respectively, the mass number (x) and atomic number (y) of A_4 are

a) x= 172; y = 72 b) x = 174; y = 69 c) x = 174; y = 69 d) x = 172; y = 69

7. A rock is 1.5×10^9 year old. The rock contains ^{238}U which disigntegrates to form ^{206}U. Assuming that there is no ^{206}Pb in the rock initially (at t =0) and its is the only stable product formed in the decay. Consider $(T_{1/2})_U = 4.5\times10^9$ years and $2^{1/3} = 2^{1/3} = 1.259$. The ratio of the number of nuclei of ^{238}U and ^{206}Pb in the rock is nearly _____ (round off to the nearest integer)

a) 1 b) 2 c) 4 d) 5

More than One correct answer Type Questions

8. $^{40}_{19}K$ converts to $^{40}_{18}Ar$ by positive β decay as well as electron capture. Let Q values for the β decay and electron capture be Q_1 and Q_2 respectively in the above reaction

a) $Q_1 = Q_2$ b) $Q_1 < Q_2$

c) neutrino emitted in positive β decay is monoenergetic

d) neutrino emitted increases by a factor $\dfrac{27}{8}$

Linked Comprehension Type Questions

Passage-I :

If two deuterium nuclei get close enough to each other, the attraction of the strong nuclear force will fuse them to make an isotope of helium. This process releases a huge amount of energy. The range of nuclear force is 10^{-15} m. This is the principle behind the nuclear fusion reactor. The deuterium nuclei moves to fast that, it is not possible to contain them by physical walls. Therefore they are confined magnetically (Assume coulomb law to hold even at 10^{-18} m)

9. Two deuterium nuclei having same speed undergo a head on collision. Which of the following is closest to the minimum value of v (in km/sec) for which fusion occurs

a) 1000 b) 5000 c) 10000 d) 50000

10. Which of the following strength of magnetic field will make deuterium nuclei moving at minimum possible speed in pervious question, to be confined in a circle of diameter 2.5m

a) 122mT b) 160Mt c) 139mT d) 212mT

Passage-II :

Nuclei of radioactive element 'X' are being produced at a constant rate 'K' and this element decays to a stable nucleus 'Y' with decay constant 'λ' with half lite "t_0". At time t = 0, there are "N_0" number of nucle of the element 'X' then

11. The number N_x of nuclei of 'X' at time $t = t_0$ is

a) $\dfrac{K+\lambda N_0}{2\lambda}$ b) $2(\lambda N_0 - K)\dfrac{1}{\lambda}$ c) $\left(\lambda N_0 + \dfrac{K}{2}\right)\dfrac{1}{\lambda}$ d) $\dfrac{\lambda N_0 - K}{2\lambda}$

12. The number N_Y of nuclei 'Y' at time $t = t_0$ is

a) $K\dfrac{\ln 2}{\lambda} + \dfrac{3}{2}\left(\dfrac{K-\lambda N_0}{\lambda}\right)$ b) $K\dfrac{\ln 2}{\lambda} + \dfrac{1}{2}\left(\dfrac{K-\lambda N_0}{\lambda}\right)$ c) $K\dfrac{\ln 2}{\lambda} - \dfrac{1}{2}\left(\dfrac{K-\lambda N_0}{\lambda}\right)$ d) $K\dfrac{\ln 2}{\lambda} - 2\left(\dfrac{K-\lambda N_0}{\lambda}\right)$

Matrix Matching Type Questions

13. m_e = mass of electron ; m = mass of nucleus ; M = mass of atom

Column-I (radio active decays)	Column-II (Q value of the reactions)
A) ${}_ZX^A \to {}_{Z+1}Y^A \to e^{-1} + \overline{\eta}$	p) $m_x - m_y$
B) ${}_ZX^A \to {}_{Z-1}Y^A \to e^{+1} + \eta$	q) $M_x - M_y$
C) ${}_ZX^A \to \overline{e} \to {}_{Z-1}Y^A + \eta$	r) $m_x - m_y - m_e$
	s) $m_x - m_y + m_e$
Ans : A–qr, B–rt, C–qs	t) $m_x - m_y - 2m_e$

Integer Type Questions

14. For a radioactive material, is activity A and rate of change of its activity R are defined as $A = \dfrac{dN}{dt}$ and $R = \dfrac{dA}{dt}$. Two radioactive sources P (mean life τ) and Q (mean life 2τ) have the same activity at t = 0. Their rates of change of activities at $t = 2\tau$ are R_p and R_0 respectively. If $\dfrac{R_p}{R_0} = \dfrac{n}{e}$, then the value of n is

15. A radioactive material consists nuclides of 3 isotope which decay by α – emision, β – emission and deuteron emission respectively. Their half lives are T_1 = 400 sec, T_2 = 800 sec and T_3 = 1600 sec respectively. At t = 0, probability of getting α, β a and deuteron from radio nuclide are equal. If the probability of α emission at t = 1600 seconds is n/13, then find the value of 'n' is ___

16. A radioactive substance 'A' is being generated at a constant rate C(100×10^6 atoms/sec) it disintegrates at a rate of λ(37 dps) to form B. Initially there are no A and B atoms. If the number of atoms of B after one mean life of A is 1×10^x atoms, then find the value of x

17. In a sample of rock, the ratio of number of ^{206}Pb to ^{238}U nuclei is found to be 0.5. The age of the rock is $(18/n) \times 10^9 \dfrac{ln\left(\frac{3}{2}\right)}{ln\,2}$ year. (Assume that all the Pb nuclides in he rock was produced due to the decay of Uranium nuclides and $T_{1/2}(^{238}U) = 4.5 \times 10^9$ year). Find n.

PRACTICE SHEET (ADVANCED)

Straight Objective Type Questions

1. A radioactive element 'A' decays into another element 'B' with decay constant 4λ, which them decays into a third element 'C' (decay constant = 9λ). If all the atoms in the begining consisted of type 'A' only then the ratio of number of atoms of A to that of type 'B' is maximum (i.e N_A/N_B) when the number of atoms of 'B' is maximum (N_B is maximum)

   a) $\dfrac{3}{2}$ b) $\dfrac{9}{4}$ c) $\dfrac{1}{1}$ d) $\dfrac{\ln 3}{\ln 2}$

2. Some amount of radioactive substance (half life 10days) is spread inside room and consequently the level of radiation becomes 50 times the permissible level for normal occupancy of the room. The number of days after which the room will be ready for safe occupation is (50+x) where x = ____ (Nearly round off to the nearest integer)

   a) 6 b) 7 c) 4 d) 5

3. The mean lives of a radioactive subtance are 1620 and 405 years for α-emission and β-emission simultaneously, the time after which three fourth of sample will decay is nearly $\dfrac{x}{2}\times(10)^2$ year, where x = _____ [take $\log_{10}^{4} = 0.6031$]

   a) 449.94 years b) 323 years c) 350 years d) 329.68 years

4. In the chemical analysis of a rock, the mass ratio of two radioactive isotopes (A and B) is 100:1 and the ratio of their atomic weights is 1.02:1. If $\tau_A = 4\times10^9$ year & $\tau_B = 2\times10^9$ year and the two isotopes are in equal proportion at formation, the age of the rock is nearly $n\times(10)^{10}$ year where n = _____ (take $\log_{10}\left(\dfrac{100}{1.02}\right) = 1.9914$)

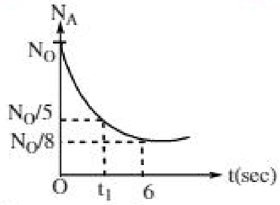
   a) 2 b) 8 c) 10 d) 20

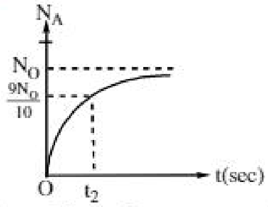
More than One correct answer Type Questions

5. Let M_1 and M_2 be the masses of the nuclei $_1H^2$ and $_2H^4$ respectively. Also let m_p and m_n be the masses of proton and neutron respectively

   a) $m_p + m_n < M_1$ b) $2[m_p + m_n] > M_2$ c) $M_2 = 2M_1$ d) $M_2 < 2M_1$

6. In a decay process A decays to B, $A \rightarrow B$. Two graphs of number of nuclei of A and B versus time is given then





a) $t_2 - t_1 = 4sec$ b) $t_2 - t_1 = 2sec$ c) $t_1 = 2\log_2 5$ sec d) $t_2 = \log_2 100sec$

7. At given instant, there are 25% undecayed nuclei in a sample. After 10 second the number of nuclei reduces to 12.5%

a) The mean life of the nuclei 0.0693 second

b) The mean life of the nuclei is 14.43 second

c) The time internal in undecayed which the number of nuclei further reduce to 16.25% is 40 second

d) The time interval in which the number of undecayed nuclei further reduce to 6.25% is 30 second

8. A nuclear explosion is designed to deliver 1MW of heat energy. The explosion is designed with a nuclear fuel ^{235}U to run the reactor to ...... This power level if 200 MeV of energy is released for each fission event, then

a) Energy per fission is joule is 3.2×10^{-11}

b) The number of fission events that must be required in a second to attain this power level is 3.125×10^{16}

c) The total number of fusion events required in one year to maintain at this power level is 9.85×10^{3}

d) The total mass of uranium fuel needed in one year to maintain the reactor at that power output level is 384.5 gm

9. The element curium $^{218}_{96}C_m$ has a mean life of 10^{13} second. Its primary decay modes are spontaneous fission and α – decay, the former with a probability of 8% and the latter with a probability of 92%. Each fission releases 200MeV energy. The masses involved in the α – decay are as follows

$^{248}_{98}Cm$ = 248.07220 amu ; $^{244}_{94}Pu$ = 244.064100 amu; $^{4}_{2}He$ = 4.002603 amu ; 1 amu = $931 MeV/c^2$

a) The activity of fission $R = 10^7$

b) The actual rate of fission is 8×10^5 sec

c) The rate of decay of α – particle is 92×10^5/sec

d) The power output due to α – decay is 4.725×10^7 MeV/sec and the total power output is 33.16 μw

Linked Comprehension Type Questions

Passage-I:

A radionuclide with half life T is produced in a reactor at a constant rate P nuclei per second. During each decay, energy E_0 is releaxsed. If production of radionuclide is started at t = 0

10. The number of nuclei in the radionuclide at time '*t*' is

a) $N = \dfrac{PT}{\log_e 2}\left[1 - e^{-\left(\frac{\log_e 2}{t}\right)t}\right]$

b) $N = \dfrac{PT}{\log_e 2}\left[1 - e^{-\left(\frac{\log_e 4}{t}\right)t}\right]$

c) $N = \dfrac{PT}{\log_e 4}\left[1 - e^{-\left(\frac{\log_e 2}{T}\right)t}\right]$

d) $N = \dfrac{PT}{\log_e 2}\left[1 + e^{-\left(\frac{\log_e 2}{T}\right)t}\right]$

11. The rate of release of energy as a function of time is

a) $PE_0\left(1-e^{-\left(\frac{\log_e 4}{T}\right)t}\right)$ b) $PE_0\left(1-e^{-\left(\frac{\log_e 2}{T}\right)t}\right)$ c) $PE_0\left(1+e^{-\left(\frac{\log_e 4}{T}\right)t}\right)$ d) $PE_0\left(1+e^{-\left(\frac{\log_e 2}{T}\right)t}\right)$

Passage-II:

A nuclear at rest undergoes a decay emitting and $\alpha-$particle of de-Broglie wavelength $\lambda=5.76\times10^{-15}$ meter. The mass of the daughter nucleus is 223.610 amu and that of the $\alpha-$particle is 4.002 a.m.u. $\left(\mathbf{1amu=931.470\frac{MeV}{C^2}}\right)$

12. Momentum of the $\alpha-$particle is nearly

a) 1.15×10^{-19} kgm-s^{-1} b) 1.15×10^{-20} kg-ms^{-1} c) 11.5×10^{-25} kg-ms^{-1} d) 3.30×10^{-19} kg-m-s^{-1}

13. Mass of the parent nucleus is

a) 227.605 amu b) 227.605 kg c) 227.605 mg d) 2.27 kg

14. The total kinetic energy of the system in the final state is (m_d = mass of daughter nucleus) m_α = mass of $\alpha-$particle

a) $\frac{P_\alpha^2(m_\alpha+m_d)}{2m_\alpha m_d}$; ($P_d$ = linear momentum of α -particle)

b) $\frac{P_d{}^2(m_\alpha+m_d)}{2m_\alpha m_d}$; ($P_d$: linear momentum of daughter nucleus)

c) 10^{-12}J d) 6.625MeV

Matrix Matching Type Questions

15. **Column-I** | **Column-II**

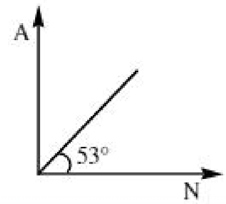
Column-I	Column-II
A) Alpha decay	p) ${}_8^{15}O\rightarrow{}_7^{15}N+....$
B) β^+ decay	q) ${}_{92}^{238}U\rightarrow{}_{90}^{234}Th+....$
C) Fission	r) ${}_{83}^{185}Bi\rightarrow{}_{82}^{184}Pb+{}_1^1H$
D) Proton emission	s) ${}_{94}^{239}Pu\rightarrow{}_{57}^{140}La+......$

Integer Type Questions

16. The present day abundances (in moles) of the isotopes U^{238} and U^{235} are in the ratio of 128 : 1. They have half lives of 4.5×10^9 years and 7×10^8 years respectively. If age of earth in $\frac{49X}{76}\times10^7$ years, then calculate X (Assume equal moles of each isotope existed at the time of formation of the earth)

17. A sample of radioactive nuclide A^{150} is having half life 2 hours and produce B^{146} after emitting α particle. Initially in sample only A was present having mass 50 gm. After four hours difference in mass of sample (A + B) is x gm then value of X is.

18. A nuclide can decay simultaneously by two different process A graph is plotted between activity (A) and number of nuclei (N) left at any time t as shown is figure. If the decay constant in one of the process is $\frac{1}{3}S^{-1}$ then find the other decay constant. (take tan 37^0 = $\frac{3}{4}$)



KEY SHEET (ADDITIONAL PRACTICE EXERCISE)

LEVEL-I (MAIN)

1) **4** 2) **3** 3) **1**

LEVEL-II

LECTURE SHEET (ADVANCED)

1) **a** 2) **b** 3) **c** 4) **b** 5) **a** 6) **d** 7) **c** 8) **d** 9) **c** 10) **c**

11) **a** 12) **c** 13) **A-qr, B-rt, C-qs** 14) **2** 15) **1** 16) **6** 17) **4**

PRACTICE SHEET (ADVANCED)

1) **b** 2) **d** 3) **a** 4) **a** 5) **b** 6) **b** 7) **b** 8) **abcd** 9) **abcd** 10) **a**

11) **b** 12) **a** 13) **a** 14) **abc** 15) **A-q; B-p; C-s; D-r** 16) **9** 17) **1** 18) **1**