

## Radioactivity

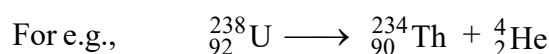
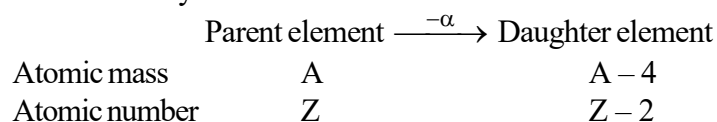
Radioactivity may be defined as a process in which nuclei of certain elements spontaneously disintegrate (transformation into another element by the ejection of  $\alpha$  - or  $\beta$  - particle) at a rate characteristic for each particular active isotope (Becquerel, 1896). All the heavy elements from bismuth (atomic number 83) through uranium and also a few of the lighter elements possess radioactive properties. However, the radioactive property of the different radioactive elements differs widely, e.g. radium atoms have about three million times the activity of uranium atoms. Uranium in the form of potassium uranyl sulphate,  $\text{K}_2\text{UO}_2(\text{SO}_4)_2$  was the first compound found to be radioactive. Radioactive changes are spontaneous. These are not controlled by temperature, pressure or nature of chemical combination.

### Radioactive disintegration

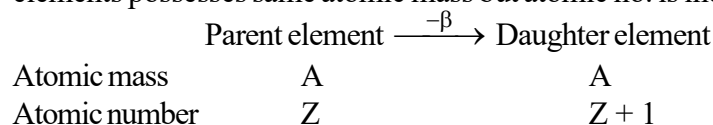
The atomic nuclei of radioactive elements can disintegrate any moment. During disintegration, atoms of new elements having different physical and chemical properties are formed, called daughter elements.

Disintegration occurs by the following processes :

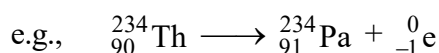
(i)  $\alpha$ -particle emission : When an  $\alpha$ -particle ( ${}^4_2\text{He}$ ) is emitted from the nucleus of parent element, the new element formed called daughter element, possess atomic mass less by 4 unit & atomic number less by 2 units.



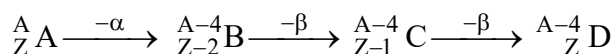
(ii)  $\beta$ -particle emission - When  $\beta$ -particle is emitted from parent element thus formed daughter elements possesses same atomic mass but atomic no. is increased by 1 unit.



- \* Elements having same mass number called isobars. (A - same, Z- different)  
 $\therefore$  daughter element formed by the  $\beta$ -particle emission is an isobar of parent element.



If in a radioactive transformation  $\alpha$  &  $\beta$  both are emitted then atomic mass & atomic number changes accordingly & produces an isotope of the parent element.



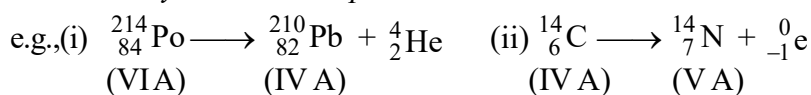
(A & D are isotopes)

- \* Elements having same no. of protons called isotopes. e.g.,  ${}^{12}_6\text{C}$ ,  ${}^{14}_6\text{C}$  and  ${}^{16}_8\text{O}$ ,  ${}^{17}_8\text{O}$  etc.  
 (A - different, Z- same)
- \* Elements having same no. of neutrons are called isotones. e.g.,  ${}^{14}_6\text{C}$ ,  ${}^{16}_8\text{O}$  &  ${}^{19}_9\text{F}$ ,  ${}^{18}_8\text{O}$  etc.  
 (A - different, Z- different)
- \* Elements having same value of (A - 2Z) are called isodiaphers. e.g.,  ${}^{19}_9\text{F}$ ,  ${}^{39}_{19}\text{K}$   
 (A - different, Z- different, A - 2Z -same)
- \* Elements having same number of electrons are called isoelectronic. e.g.,  $\text{SO}_4^{2-}$ ,  $\text{PO}_4^{3-}$
- \* Compounds having same number of atoms as well as same number of electrons are called isosters.

- (i) Atoms of all radioactive elements undergo spontaneous disintegration and form new radioactive elements. The disintegration is accompanied by the emission of  $\alpha$ ,  $\beta$ , or  $\gamma$ -rays.
- (ii) The disintegration is at random, i.e. every atom has equal chance for disintegration at any time.
- (iii) The number of atoms that disintegrate per second is directly proportional to the number of remaining unchanged radioactive atoms present at any time. The disintegration is independent of all physical and chemical conditions like temperature, pressure chemical combination etc.

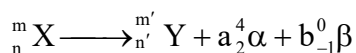
*The two laws of radioactive disintegration can be summed up as below:*

1. **Group displacement law :** The result of  $\alpha$ - and  $\beta$ - particle changes can be summed up in the form of group displacement law. *“In an  $\alpha$ -particle change the resulting element has an atomic weight less by four units and atomic number less by two units and it falls in a group of the periodic table two columns to the left of the original element, and in a  $\beta$ -particle change the resulting element has same atomic weight but its atomic number is increased by one than its parent and hence it lies one column to right”*.



2. **Law of radioactive decay :** According to the law of radioactive decay, *the quantity of a radioelement which disappears in unit time (rate of disintegration) is directly proportional to the amount present.*

Consider the following general reaction.



Then,  $m = m' + 4a + 0b$  (ii)  $n = n' + 2a - b$

Solve for a and b

Where a is the number of  ${}^4_2\text{He}$  emitted and b is the number of  ${}^0_{-1}\beta$  emitted

1. Rate of decay (activity, A) is the number of atoms undergoing decay to unit time; it is represented by  $-\frac{dN_t}{dt}$ .

2. Rate of decay of a nuclide is directly proportional to the number of atoms of that nuclide present at that moment, hence.

$$\frac{dN_t}{dt} \propto N \quad \text{or} \quad \frac{dN_t}{dt} = \lambda N_b$$

(the negative sign shows that the number of radioactive atoms,  $N_t$ , decreases as time  $t$  increases)

3. Rate of decay of nuclide is independent of temperature, so its energy of activation is zero.
4. Since the rate of decay is directly proportional to the amount of the radioactive nuclide present and as the number of undecomposed atoms decreases with increase in time, the rate of decay also decreases with the increase in time.

Various forms of equation for radioactive decay are

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

$$\log N_0 - \log N_t = 2.303\lambda t$$

$$\log \frac{N_0}{N_t} = \frac{\lambda t}{2.303}$$

$$\lambda = \frac{2.303}{t} \log \frac{N_0}{N_t} \quad \dots\dots (I)$$

Note that the equation (I) is similar to that of first order reaction, hence we can say that radioactive disintegration are examples of first order reactions.

Where  $N_0$  = Initial number of atoms of the given nuclide, i.e. at time 0

$N_t$  = No. of atoms of that nuclide present after t

$\lambda$  = Decay constant

However, unlike first order rate constant (K), the decay constant ( $\lambda$ ) is independent of temperature.

**Decay constant :** The ratio between the number of atoms disintegrating in unit time to the total number of atoms present at that time is called the decay constant of that nuclide.

**Characteristics of decay constant ( $\lambda$ )**

1. It is characteristic of a nuclide (not of an element)
2. Its units are  $\text{time}^{-1}$
3. Its value is always less than one

**Half-life Period ( $T_{1/2}$  or  $t_{1/2}$ ) :** Rutherford in 1904 introduced a constant known as half-life period of the radio-element for evaluating its radioactivity or for comparing its radioactivity with the activities of other radio-elements. The half-life period of a radio-element is defined as the time required by a given amount of the element of decay to one-half of its initial value.

$$\text{Mathematically, } T_{1/2} = \frac{0.693}{\lambda}$$

**Average Life Period (T) :** Since total decay period of any element is infinity, it is meaningless to use the term total decay period (total life period) for radio elements. Thus the term average life is used which is determined by the following relation.

$$\text{Average life (T)} = \frac{\text{Sum of lives of the nuclei}}{\text{Total number of nuclei}}$$

Relation between average life and half-life. Average life (T) of an element is the inverse of its

decay constant i.e.,  $T = \frac{1}{\lambda}$

Substituting the value of  $\lambda$  in the above equation,  $T = \frac{T_{1/2}}{0.693} = 1.44T_{1/2}$

Thus, Average life (T) =  $1.44 \times \text{Half-life } (T_{1/2}) = \sqrt{2} \times T_{1/2}$

Thus the average life period of a radioisotope is approximately under-root two times of its half life period.

**Specific activity :** It is the measure of radioactivity of a radioactive substance. It is defined as 'the number of radioactive nuclei which decay per second per gram of radioactive isotope'. Mathematically, if 'm' is the mass of radioactive isotope, then

$$\text{Specific activity} = \frac{\text{Rate of decay}}{m} = \frac{\lambda N}{m} = \lambda \times \frac{\text{Avogadro number}}{\text{Atomic mass in g}}$$

Where N is the number of radioactive nuclei, which undergoes disintegration.

## 2. Radioactivity :

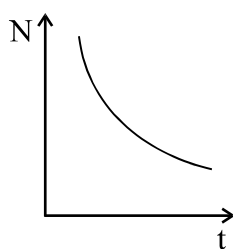
- (a) The phenomenon of spontaneous disintegration of nuclei of unstable atoms is defined as radioactivity.
- (b) Generally it is exhibited by atoms with  $A > 192$  and  $Z > 82$
- (c) It was discovered by Henry Becquerel
- (d) Lead isotope is the stable end product of any natural radioactive series
- (e) Radio activity is a nuclear process and not an atomic process
- (f) Radioactivity is not associated with the electron configuration of the atom.

## 3. Rutherford-Soddy Theory :

- (a) If  $N$  is the number of radioactive nuclei present in a sample at a given instant of time, then the rate of decay at that instant is proportional to  $N$  i.e.,

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

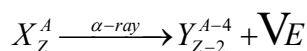
- (b) If  $N_0$  is the number of radioactive nuclei at time  $t = 0$ , then the number of radioactive nuclei at a later time  $t$  is given by,  $N = N_0 e^{-\lambda t}$



- (c) The nuclei of unstable atoms decay spontaneously emitting  $\alpha$ ,  $\beta$  particles and  $\gamma$  rays
- (d) Radioactivity remains unaffected due to the physical and chemical changes of the material.
- (e) Radioactivity obeys the law of probability i.e it is uncertain that when a particular atom will decay.

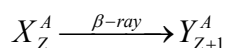
## 4. Soddy-Fajan's Laws :

- (a) During an  $\alpha$ -decay, mass number decreases by 4 units and atomic number by 2 units.



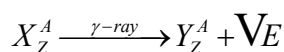
Daughter nucleus will occupy two positions before that of parent nucleus, in periodic table.

- (b) During  $\beta$ -decay mass number of the atom will not change and atomic number increases by 1 unit



Daughter nucleus will occupy one position on the right of that of parent nucleus in periodic table

- (c) During  $\gamma$ -decay, the mass number and atomic number of the nucleus remain unchanged



4.

- (a) Emission of  $\alpha$ -particle means loss of two protons and two neutrons
- (b) Emission of  $\beta$ -particle means loss of an electron.
- (c) Emission of a  $\gamma$ -ray means no change in charge and mass, but only energy changes

### 5. Activity (A) :

- (a) The number of atoms of any material decaying per second is defined as the activity of that material.
- (b) Its value depends on the quantity and nature of that material.
- (c) Units of activity –  
fundamental unit – disintegrations per second i.e., Bq  
 $1 \text{ Bq} = 1 \text{ disintegration/s}$
- (d) Practical units: curie and rutherford.  
 $1 \text{ curie} = 3.7 \times 10^{10} \text{ disintegration/second}$   
 $1 \text{ Rutherford} = 10^6 \text{ disintegrations/second}$ .
- (e) Formulae of activity

$$(i) A = -\frac{dN}{dt} \quad (ii) A = \lambda N \quad (iii) A_0 = \lambda N_0 \quad (iv) A = A_0 e^{-\lambda t} \quad (v) A = \frac{0.693 N_A m}{WT}$$

where  $A_0$  = maximum initial activity;  $A$  = activity after time  $t$ ,  $\lambda$  = decay constant,

$N_A$  = Avogadro number,

$m$  = mass of material,

$W$  = atomic weight of material,

$T$  = half life of material

### 6. Decay Constant ( $\lambda$ ) :

- (a) Decay constant is equal to the reciprocal of that time in which the activity of the material reduces to  $\frac{1}{e}$  or 37 % of its initial activity.

$$(b) \lambda = \frac{-\frac{dN}{dt}}{N} = \frac{\text{No. of atoms decaying per second (Rate of disintegration)}}{\text{No. of atoms remaining after decay}}$$

i.e. The rate of disintegration per atom is defined as decay constant

- (c) Decay constant does not depend on temperature, pressure and volume. It depends on the nature of material.
- (d) Its unit per second.

$$(e) \text{ Decay constant } \left( \lambda = \frac{-\frac{dN}{dt}}{N} \right) \text{ represents the probability of decay per second.}$$

$$(f) \lambda = \frac{2.303}{t} \log_{10} \frac{N_0}{N} = \frac{2.303}{t} \log_{10} \frac{A_0}{A} = \frac{2.303}{t} \log_{10} \frac{M_0}{M}$$

- (g) Its value is equal to the negative of the slope of  $N$ - $t$  curve.
- (h) The decay constant of stable element is zero.

### 7. Half-life ( $T_{1/2}$ ) :

- (a) The time, in which the number of atoms ( $N$ ) reduces to half of its initial value ( $N_0$ ), is defined as the half-life of the element (i.e. half of the atoms decay).  $t = T_{1/2}$ ,  $N = \frac{N_0}{2}$
- (b) The time in which the activity reduces to half of its initial value is defined as half life.

$$\text{At } t = T_{\frac{1}{2}}, \quad A = \frac{A_0}{2}$$

- (c) Its unit is second  
(d) Formulae of half life

$$(i) \quad T_{\frac{1}{2}} = \frac{0.693}{\lambda} = \frac{\log_e 2}{\lambda}$$

$$(ii) \quad T_{\frac{1}{2}} = \frac{\log_e 2}{\log_{10} \left( \frac{N_0}{N} \right)} = \frac{\log_e 2}{\log_{10} \left( \frac{A_0}{A} \right)} = \frac{\log_e 2}{\log_{10} \left( \frac{M_0}{M} \right)}$$

$$(iii) \quad T_{\frac{1}{2}} = \frac{t}{n} \text{ where } n = \text{No. of half lives}$$

$$(iv) \quad \text{Time of disintegration } t = \frac{T \log_{10} \left( \frac{N_0}{N} \right)}{\log_{10} 2} = \frac{T \log_{10} \left( \frac{N_0}{N} \right)}{0.3010}$$

### 8. Mean life ( $\tau$ ) :

- (a) The time, for which a radioactive material remains active, is defined as mean life of that material :

$$(b) \quad \tau = \frac{\text{Sum of lives of all atoms}}{\text{total number of atoms present}} = \frac{\int t |dN|}{N_0}$$

- (c) The average time taken in decaying by the atoms of an element is defined as its mean life  $\tau$ .

$$(d) \quad \tau = 1/\lambda$$

- (e) Its units are second, minute, hour day, month, year etc.

- (f) Mean life does not depend on the mass of material. It depends on the nature of the material.

- (g) The magnitude of slope of decay curve is equal to the mean life.

- (h) Relation between the mean life and half-life.

$$(i) \quad \tau = \frac{T_{\frac{1}{2}}}{0.693}$$

$$(ii) \quad \tau = 1.44 T_{\frac{1}{2}}$$

$$(iii) \quad \tau > T_{\frac{1}{2}}$$

- (iv) The time, in which the number of radioactive atoms decays to  $1/e$  or 37% of its initial value, is defined as the mean life of that material.

### 9. Important Formulae Related to Law of Disintegration ( $\tau$ ) :

$$(a) \quad N = N_0 e^{-\lambda t}$$

$$(b) \quad A = A_0 e^{-\lambda t}$$

$$(c) \quad M = M_0 e^{-\lambda t}$$

$$(d) \quad \lambda = \frac{2.3027 \log_{10} \left( \frac{N_0}{N} \right)}{t}$$

$$(e) \quad \lambda = \frac{2.3027 \log_{10} \left( \frac{A_0}{A} \right)}{t}$$

$$(f) \quad \lambda = \frac{2.3027 \log_{10} \left( \frac{M_0}{M} \right)}{t}$$

$$(g) \quad \lambda = \lambda_{\alpha} + \lambda_{\beta}$$

$$(h) \quad \tau = \frac{\tau_\alpha \tau_\beta}{\tau_\alpha + \tau_\beta} \text{ (When two particles decay simultaneously)}$$

$$(i) \quad N = \frac{N_0}{2^n} = \frac{N_0}{2^{\left(\frac{T}{T_{1/2}}\right)}}$$

$$(j) \quad A = \frac{A_0}{2^{\left(\frac{T}{T_{1/2}}\right)}}$$

$$(k) \quad M = \frac{M_0}{2^{\left(\frac{T}{T_{1/2}}\right)}}$$

### 10. Useful Hints :

$$(i) \quad \text{Percentage decreases in activity} = \left[1 - \frac{A}{A_0}\right] \times 100$$

$$(ii) \quad \text{Number of atoms remaining after } n \text{ half lives } N = \frac{N_0}{2^n}$$

$$(iii) \quad \text{Number of atoms decayed after time } t = N_0 - N = N_0 \left[1 - \frac{1}{2^n}\right]$$

$$(iv) \quad \text{The fraction of radioactive material at time } T = \left[1 - \frac{N}{N_0}\right] = \left[1 - \frac{1}{2^{\frac{T}{T_{1/2}}}}\right]$$

$$(v) \quad \text{Percentage of radioactive material decayed at time } T = \left[1 - \frac{N}{N_0}\right] \times 100 = \left[1 - \frac{1}{2^{\frac{T}{T_{1/2}}}}\right] \times 100$$

$$(vi) \quad \text{Percentage of radioactive material decayed in } n \text{ half lives} = \frac{N}{N_0} \times 100 = \frac{1}{2^{\frac{T}{T_{1/2}}}} \times 100$$

$$(vii) \quad \text{Fraction of radioactive material decayed in } n \text{ half lives} = 1 - \frac{N}{N_0} = \left[1 - \frac{1}{2^n}\right]$$

$$(viii) \quad \text{Percentage of radioactive material decayed in } n \text{ half lives } \left[1 - \frac{N}{N_0}\right] \times 100 = \left[1 - \frac{1}{2^n}\right] \times 100$$

$$(ix) \quad \text{Percentage of radioactive material remaining after } n \text{ half-lives. } \frac{N}{N_0} \times 100 = \frac{1}{2^n} \times 100$$

$$(x) \quad \text{When decay process is too slow then } N = N_0 - N_0 \lambda t \text{ or } N = -(N_0 \lambda)t + N_0$$

$$(xi) \quad N\text{-}t \text{ graph is a straight line with -ve slope, for slow decay process.}$$

## 11. Characteristics of $\alpha$ , $\beta$ , and $\gamma$ rays

S.No	Property	$\alpha$ -Particles	$\beta$ -Particles	$\gamma$ -rays
1.	Nature and value of charge	Positive and double of the charge of the proton	Negative and equal to the charge of electron $1.6 \times 10^{-19} \text{ C}$	Uncharged (Neutral)
2.	Nature of particle	Doubly ionized helium atom (2 protons and 2 neutrons)	Electron (or) positron	Electromagnetic waves
3.	Mass	Four times the mass of the proton $(4 \times 1.67 \times 10^{-27} \text{ kg})$	Equal to the mass of electron $9.1 \times 10^{-31} \text{ kg}$	Mass less
4.	Specific charge $\frac{q}{m}$	$\frac{3.2 \times 10^{-19}}{4 \times 1.67 \times 10^{-27}} = 4.79 \times 10^7$	$1.7 \times 10^{11} \text{ Ckg}^{-1}$	Uncharged and mass less
5.	Explained by	Tunnel effect	Neutrino hypothesis	Transitions of nuclei into the ground energy level after $\alpha$ and $\beta$ decay
6.	Effect of electric and magnetic fields	Deflected by electric and magnetic fields	Deflected by electric and magnetic fields	Unaffected
7.	Penetrating power	1	100	10000
8.	Ionizing power	100000	100	1
9.	Velocity	Less than the velocity of light $(1.4 \times 10^7 \text{ m/s to } 2.2 \times 10^7 \text{ ms}^{-1})$	Approximately equal to the velocity of light	$3 \times 10^8 \text{ m/s}$
10.	Mutual interaction with matter	Produce heat	Produce heat	Produce the phenomenon of Photoelectric effect, Compton

## 12. $\alpha$ -emission

### (a) Characteristics of $\alpha$ -decay :

- (i) The spectrum of  $\alpha$  -particles is a discrete line spectrum.
- (ii) Spectrum of  $\alpha$  -particles has fine structure i.e. every spectral line consists of a number of fine lines.
- (iii) The  $\alpha$  -emitting nuclei have discrete energy levels i.e energy levels in nuclei are analogous to discrete energy levels in atoms..
- (iv)  $\alpha$  -decay is explained on the basis of tunnel effect.
- (v) Geiger-Muller law -  $\log_e \lambda = A + B \log_e R$  For radioactive series B is same whereas A is different

**(b) Range of  $\alpha$ -particles :**

- (i) The maximum distance traversed by  $\alpha$ -particles in air before being finally stopped is defined as the range of  $\alpha$ -particles.
- (ii) The maximum distance traversed by  $\alpha$ -particles before being finally absorbed after ionizing gas molecules, is defined as the range of  $\alpha$ -particles.
- (iii) The range of  $\alpha$ -particles in air is from 2.6cm to 8.6cm.
- (iv) Relations between the range of  $\alpha$ -particles and their energy

$$(I) \quad R = 0.318E^{3/2}$$

$$(II) \quad \log R = \log 0.318 + \frac{3}{2} \log E$$

**(c) Size of the nucleus decreases by  $\alpha$  emission****13. Characteristics of  $\beta$ -decay :**

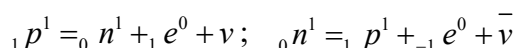
- (i) The energy spectrum of  $\beta$ -particles is continuous i.e.  $\beta$ -particles of all energies upto a certain maximum are emitted
- (ii) The number of such  $\beta$ -particles is maximum whose energy is equal to the maximum probable energy i.e. at  $E = E_{mp}$ ,  $N_B = \text{maximum}$ .
- (iii) There is a characteristic maximum value of energy in the spectrum of  $\beta$ -particles which is known as the end point energy ( $E_0$ )
- (iv) In  $\beta$ -decay process, a neutron is converted into proton or proton is converted into neutron.



- (v) The energy of  $\beta$ -particles emitted by the same radioactive material may be same or different.
- (vi) The number of  $\beta$ -particles with energy  $E = E_0$  (end point energy) is zero.

**14. Neutrino Hypothesis :**

- (a) According to Pauli, whenever neutron is converted into proton or proton into neutron then this process is accompanied with the emission of a new particle to which he named as neutrino.

**(b) Properties of neutrino :**

- (i) The charge on neutrino is zero
- (ii) The rest mass of neutrino is zero
- (iii) Its spin angular momentum is  $\pm \frac{h}{2}$
- (iv) Its speed is equal to that of light.
- (v) It has finite magnetic moment but the magnitude is very small
- (vi) Its antiparticle is anti-neutrino.
- (vii) The linear momentum vector  $\vec{p}$  and spin vector  $\vec{S}$  are mutually in opposite directions.
- (viii) Its energy is equal to  $(E_{end} - E_\beta)$ .
- (ix) It does not interact with matter.
- (x) Neutrino was discovered by Pauli and its experimental verification is done by Reines and Cowan.

### 15. (a) Characteristics of $\gamma$ -decay

- (i) The spectrum of  $\gamma$  -rays is a discrete line spectrum.
- (ii) Whenever  $\alpha$  or  $\beta$  - particles is emitted by a nucleus then the daughter nucleus is left in the excited state. It suddenly makes transition in the ground state thereby emitting  $\gamma$  -rays.
- (iii) Knowledge about nuclear energy levels is obtained by  $\gamma$  -spectrum.
- (iv)  $\gamma$  -rays interact with matter as a consequence of which the phenomena of photoelectric effect, Compton effect and pair production happen. (At low energy photoelectric effect and at high energy pair-production are effective).

### 15. (b) Intensity of $\gamma$ -rays in materials

- (i) When  $\gamma$  -rays penetrate matter, then their intensity (a) decreases exponentially with depth (x) inside the matter. The intensity of  $\gamma$  -rays at depth x inside the matter is given by  $I = I_0 e^{-\mu x}$ .
- (ii) The thickness of matter, at which the intensity of  $\gamma$  -rays (I) reduces to half its initial maximum value ( $I_0$ ), is known as its half-value thickness.  $\left( X_{1/2} = \frac{.693}{\mu} \right)$
- (iii) The reciprocal of the distance inside matter, at which the intensity (I) reduces to  $\frac{1}{e}$  or 37 % of its maximum value ( $I_0$ ), is defined as the coefficient of absorption ( $\mu$ ) of that material.
- (iv) Coefficient of absorption
  - (I)  $\mu = -\frac{dI/I}{dx}$
  - (II)  $\mu$  depends on the wavelength of  $\gamma$  -rays ( $\mu \propto \lambda^3$ ) and the nature of absorbing material

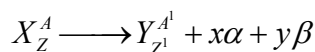
### 16. Radioactive Series :

If parent element is unstable then it will dissociate into daughter element & if this daughter element is still unstable, then it will again dissociate into a new daughter element & process continuous till the formation of a stable element. Series of element obtained from parent element to the finally stable non-radioactive element is known as radioactive disintegration series.

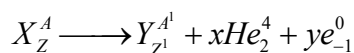
( $4n + 1$ ) is artificial series &  $4n$ , ( $4n + 2$ ), ( $4n + 3$ ) are natural series.

S.No	Series	Name of the series	Initial element	Final element	Nature of series	No of $\alpha$ & $\beta$  Particles emitted
1.	$4n+2$	Uranium series	${}_{92}\text{U}^{238}$	${}_{82}\text{Pb}^{206}$	Natural	$8\alpha, 6\beta$
2.	$4n+3$	Actinium series	${}_{92}\text{U}^{235}$	${}_{82}\text{Pb}^{207}$	Natural	$7\alpha, 4\beta$
3.	$4n$	Thorium series	${}_{90}\text{Th}^{232}$	${}_{82}\text{Pb}^{208}$	Natural	$6\alpha, 4\beta$
4.	$4n+1$	Neptunium series	${}_{93}\text{Np}^{237}$	${}_{83}\text{Bi}^{209}$	Artificial	$7\alpha, 4\beta$

## 17. To Calculate no of $\alpha$ -particles and $\beta$ -Particles emitted

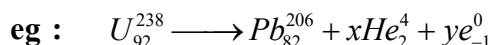


x: no of  $\alpha$ -particles emitted    y: no of  $\beta$ -particles emitted



$$A = A^1 + 4x \qquad x = \frac{A - A^1}{4}$$

$$Z = Z^1 + 2x - y \qquad y = Z^1 - Z + 2x \qquad y = \left( \frac{A - A^1}{2} \right) - (Z - Z^1)$$



$$x = \frac{A - A^1}{4} = \frac{238 - 206}{4} = 8\alpha - \text{particles}$$

$$y = \left( \frac{A - A^1}{2} \right) - (Z - Z^1) = \left( \frac{238 - 206}{2} \right) - (92 - 82) = 16 - 10 = 6\beta - \text{particles}$$

### Units of radioactivity :

The unit of radioactivity is curie (Ci). It is the quantity of any radioactivity substance which has decay rate of  $3.7 \times 10^{10}$  disintegrations per second.

1 millicurie (mCi) =  $3.7 \times 10^7$  disintegrations per sec.

1 microcurie ( $\mu$ Ci) =  $3.7 \times 10^4$  disintegrations per sec.

There is another unit called rutherford (Rd) which is defined as the amount of a radioactive substance which undergoes  $10^6$  disintegrations per second.

1 milli rutherford =  $10^3$  disintegration per sec.

1 micro rutherford = 1 disintegration per sec.

The SI unit radioactivity is proposed as Becquerel which refers to one dps.

1 curie =  $3.7 \times 10^4$  Rutherford

1 curie = 3.7 GBq

Here, G stands for  $10^9$ , i.e., giga.

## 18. Isotopes , Isobars and Isotones :

S.No	Isotopes	Isobars	Isotones
1.	The atoms of the same elements whose charge number (Z) is same but mass number is different are known as isotopes.	The atoms with mass number same and charge number different are known as isobars.	The atoms with same neutron number but A and Z are different are known as isotones
2.	Chemical properties are same	Chemical properties are different	Chemical properties are different
3.	Number of electrons is same	Number of electrons is different	Number of electrons is different
4.	Occupy same place in periodic table	Occupy different places in periodic table	Occupy different places in periodic table.
5.	Example ${}_8O^{16}$ , ${}_8O^{17}$ , ${}_8O^{18}$ ${}_1H^1$ , ${}_1H^2$ , ${}_1H^3$ ${}_{10}Ne^{20}$ , ${}_{10}Ne^{21}$ , ${}_{10}Ne^{22}$	${}_1H^3$ and ${}_2He^3$ ${}_6C^{14}$ and ${}_7N^{14}$ ${}_8O^{17}$ and ${}_9F^{17}$	${}_3Li^7$ and ${}_4Be^8$ ${}_1H^2$ and ${}_2He^3$ ${}_1H^3$ and ${}_2He^4$

## 19. Radioactive Isotopes :

The isotopes of elements which spontaneously decay by emitting radioactive radiations are defined as radioactive isotopes.

They are two types .

- (a) Natural radioactive isotopes                      (b) Artificial radioactive isotopes

(a) **Natural radioactive isotopes :** Those radioactive isotopes which exist naturally are known as natural radioactive isotopes. e.g.  $Th^{232}$ ,  $Pu^{240}$  etc.

(b) **Artificial radioactive isotopes :** Those isotopes, which are prepared artificially by bombarding fundamental particles like  $\alpha, \beta, \gamma, p, n$  etc, no matter, are known as artificial isotopes.

## 20. Uses of Radioactive Isotopes :

(a) **In Medicine :**

- (i) For testing blood chromium-51
- (ii) For testing blood circulation-Sodium-24
- (iii) For detecting brain tumor-Radio mercury-203
- (iv) For detecting fault in thyroid gland-Ratio iodine-131
- (v) For cancer-Cobalt-60
- (vi) For blood-Gold-189
- (vii) For skin diseases-Phosphorous-31

(b) **In Archaeology :**

- (i) For determining age of archaeological sample (Carbon dating) -  $C^{14}$
- (ii) For determining age of meteorites -  $K^{40}$
- (iii) For determining age of earth-Land isotopes

(c) **In Agriculture :**

- (i) For protecting potato crop from earthworm – Cobalt-60
- (ii) For artificial rains  $AgI$
- (iii) As fertilizers-Phosphorous-32

(d) **As tracers :**

Very small quantity of radio isotopes present in a mixture is known as tracer . Tracer technique is used for studying biochemical reactions in trees and animals.

(e) **In industries :**

- (i) For detecting leakage in oil or water pipe lines.
- (ii) For testing machine parts

(f) **In research :**

- (i) In the study of carbon-nitrogen cycle.
- (ii) For determining the age of planets

## Daily Practice Problem Sheet 1

1. The following data represent for the decomposition of  $\text{NH}_4\text{NO}_2$  in aqueous solution

Time in minute	10	15	20	25	$\infty$
Volume of $\text{N}_2$ (in mL)	6.25	9.0	11.40	13.65	33.05

- (a) Show that reaction is of I order. (b) Calculate velocity constant.

2. Derive the O. R. for decomposition of  $\text{H}_2\text{O}_2$  from the following data

Time in minute	10	15	20	25	$\infty$
Vol. of $\text{O}_2$ given by $\text{H}_2\text{O}_2$	6.30	8.95	11.40	13.5	35.75

3. Decomposition of diazobenzene chloride was followed at constant temperature by measuring volume of  $\text{N}_2$  evolved at definite intervals of time. Calculate O. R. and rate constant

Time in minute	0	2.0	5.5	7.0	$\infty$
Volume of $\text{N}_2$ in mL	0	10	25	35	163

4. The decomposition of  $\text{N}_2\text{O}_5$  in chloroform was followed by measuring the volume of  $\text{O}_2$  gas evolved;  $2\text{N}_2\text{O}_5 \longrightarrow 2\text{N}_2\text{O}_4 + \text{O}_2$  (g). The maximum volume of  $\text{O}_2$  gas obtainable was  $100\text{cm}^3$ . In 500 minutes,  $90\text{cm}^3$  of  $\text{O}_2$  were evolved. Calculate the first order rate constant of the reaction.

5. The specific rate constant of the decomposition of  $\text{N}_2\text{O}_5$  is  $0.008\text{ min}^{-1}$ . The volume of  $\text{O}_2$  collected after 20 minute is 16 mL. Find the volume that would be collected at the end of reaction.  $\text{NO}_2$  formed is dissolved in  $\text{CCl}_4$ .

6. Derive order of reaction, for the decomposition of  $\text{H}_2\text{O}_2$  from the following data .

Time in minute	0.	10	20	30
Volume of $\text{KMnO}_4$ needed for $\text{H}_2\text{O}_2$	25	16	10.5	7.09

7. The kinetics of hydrolysis of methyl acetate in excess dilute  $\text{HCl}$  at  $25^\circ\text{C}$  were followed by withdrawing 2 mL of the reaction mixture at intervals of (t), adding 50 mL water and titrating with baryta water. Determine the velocity constant of hydrolysis.

t (in minute)	0	75	119	259	$\infty$
Titre value (in mL)	19.24	24.20	26.60	32.23	42.03

8. The acid catalysed hydrolysis of an organic compound A at  $30^\circ\text{C}$  has half life of 100 minute when carried out in a buffer solution of  $\text{pH} = 5$  and 10 minute when carried out at  $\text{pH} = 4$ . Both the times the half life are independent of the initial concentration of A. If the rate of reaction is given by :  $\text{rate} = k[\text{A}]^m [\text{H}^+]^n$ , what are the values of m and n and also calculate the rate of reaction ?

9. In the inversion of cane sugar in presence of an acid, the following polarimeter readings are obtained

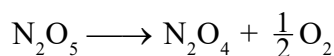
Time in minute	0	30	90	230	$\infty$
Rotation in degree	+46.75	+41.0	+30.75	+12.75	-18.75

Calculate rate constant.

10. The inversion of cane sugar proceeds with constant half life of 500 minutes at  $\text{pH} = 5$  for any

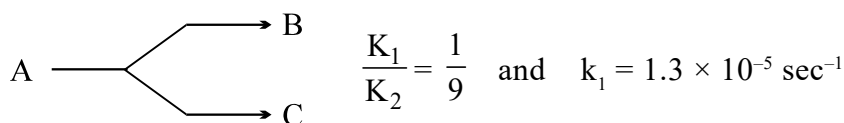
concentration of sugar. However, if pH = 6, the half life changes to 50 minutes. Derive the rate law for inversion of cane sugar.

11. A solution of  $\text{N}_2\text{O}_5$  in  $\text{CCl}_4$  at  $45^\circ\text{C}$  produces 5.02 mL of  $\text{O}_2$  in 1198 sec and 9.58 mL  $\text{O}_2$  after a long time. Calculate rate constant assuming I order for the reaction.



## Daily Practice Problem Sheet 2

1. An organic compound A decomposes following two parallel first order mechanisms :

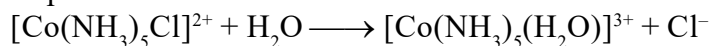


Calculate the concentration ratio of C to A, if an experiment is allowed to start with only A for one hour.

2. Trans-1,2-dideuterocyclopropane (A) undergoes a first order decomposition. The observed rate const. at certain temp., measured in terms of disappearance of 'A' was  $1.52 \times 10^{-4} \text{ sec}^{-1}$ . Analysis of products showed that the reaction followed two parallel paths, one leading to dideuteropropane. (B) and the other to cis-1,2-dideuterocyclopropane (C). (B) was found to constitute 11.2 % of the reaction product, independently of extent of reaction. What is the order of reaction for each path and what is the value of the rate constant for the formation of each of the products?
3. Bicyclohexane was found to undergo two parallel first order rearrangements. At 730 K, the first order rate constant for the formation of cyclohexane was measured as  $1.26 \times 10^{-4} \text{ s}^{-1}$ , and for the formation of methyl cyclopentene the rate constant was  $3.8 \times 10^{-5} \text{ s}^{-1}$ . What is the percentage distribution of the rearrangement products?
4. For the reaction ,  

$$[\text{Cr}(\text{H}_2\text{O})_4\text{Cl}_2]^+(\text{aq}) \xrightarrow{K_1} [\text{Cr}(\text{H}_2\text{O})_5\text{Cl}]^{2+}(\text{aq}) \xrightarrow{K_2} [\text{Cr}(\text{H}_2\text{O})_6]^{3+}(\text{aq})$$
 $k_1 = 1.78 \times 10^{-3} \text{ s}^{-1}$  and  $k_2 = 5.8 \times 10^{-5} \text{ s}^{-1}$  for the initial concentration of  $[\text{Cr}(\text{H}_2\text{O})_4\text{Cl}_2]^+$  is 0.0174 mol/litre at  $0^\circ\text{C}$ . Calculate the value of  $t$  at which the conc. of  $[\text{Cr}(\text{H}_2\text{O})_5\text{Cl}]^{2+}$  is maximum.
5. Two first order reactions proceed at  $25^\circ\text{C}$  at the same rate. The temperature coefficient of the rate of the first reaction is 2 and that of second reaction is 3. Find the ratio of the rates of these reactions at  $75^\circ\text{C}$ .
6. The half life of a substance in a first-order reaction is 100 minutes at 323.2 and 15 min at 353.2 K. Calculate the temperature coefficient of the rate constant of this reaction.
7. The activation energy for the reaction,  $\text{O}_3(\text{g}) + \text{NO}(\text{g}) \longrightarrow \text{NO}_2(\text{g}) + \text{O}_2(\text{g})$  is 9.6 kJ/mole. Prepare an activation energy plot if  $\Delta H^\circ$  for this reaction is  $-200 \text{ kJ/mole}$ . What is the energy of activation for the reverse reaction?
8. Which reaction will have the greater temperature dependence for the rate constant-one with a small value of energy of activation (E) or one with a large value of E?
9. For a chemical reaction the energy of activation is  $85 \text{ J mol}^{-1}$ . If the frequency factor is,  $4.0 \times 10^9 \text{ L mol}^{-1} \text{ s}^{-1}$ , what is the rate constant at 400 K?

10. For the displacement reaction



the rate constant is given by,  $\ln [k/(\text{min}^{-1})] = -\frac{11067}{T} + 31.33$ .

Evaluate  $k$ ,  $E$  and  $A$  for the chemical reaction at  $25^\circ\text{C}$ .

11. For the reaction,  $2\text{N}_2\text{O}_5 \longrightarrow 4\text{NO}_2 + \text{O}_2$

the rate constant is given by,  $\ln [k(\text{sec}^{-1})] = -\frac{10500}{T} + 33$ .

Evaluate  $k$ ,  $E$  and  $A$  for the chemical reaction at  $27^\circ\text{C}$ .

12. For a first order reaction, the rate constant is given by,  $\ln [k(\text{sec}^{-1})] = -\frac{11400}{T} + 34.7$

Evaluate  $k$ ,  $E$  and  $A$  for the chemical reaction at  $27^\circ\text{C}$ .

13. The time required for 20 % completion of a first order reaction at  $27^\circ\text{C}$  is 1.5 times that required for its 30 % completion at  $37^\circ\text{C}$ . If the pre exponential factor for the reaction is  $3 \times 10^9 \text{ sec}^{-1}$ , calculate the time required for 40 % completion at  $47^\circ\text{C}$  and also the energy of activation.

14. The rate constant of a reaction increases by 7 % when its temperature is raised from 300 K to 301 K while its equilibrium constant increases by 3 %. Calculate the activation energy of the forward and reverse reactions.

15. A bottle of milk stored at 300 K sours in 36 hours. When stored in a refrigerator at 275 K it sours in 360 hrs. Calculate the energy of activation of the reaction involved in the souring process.

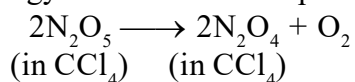
16. Calculate the ratio of the catalysed and uncatalysed rate constant at  $20^\circ\text{C}$  if the energy of activation of a catalysed reaction is  $20 \text{ kJ mol}^{-1}$  and for the uncatalysed reaction is  $75 \text{ kJ mol}^{-1}$ .

17. A second order reaction where  $a = b$  is 20 % completed in 500 seconds. How long will the reaction take to be 60 % complete.

18. Two reactions of same order have equal pre-exponential factors but their activation energies differs by  $41.9 \text{ J/mole}$ . Calculate the ratios between rate constants of these reactions at 600 K.

19. Rate constant of a reaction changes by 2 % by  $0.1^\circ\text{C}$  rise in temperature at  $25^\circ\text{C}$ . The standard heat of reaction is  $121.6 \text{ kJ mol}^{-1}$ . Calculate  $E_a$  of reverse reaction.

20. The energy of activation and specific rate constant for a first-order reaction at  $25^\circ\text{C}$



are  $100 \text{ kJ/mole}$  and  $3.46 \times 10^{-5} \text{ s}^{-1}$  respectively. Determine the temperature at which the half-life of the reaction is 2 hours.

21. In Arrhenius' equation for a certain reaction, the value of  $A$  and  $E$  (activation energy) are  $4 \times 10^{13} \text{ s}^{-1}$  and  $98.6 \text{ kJ mol}^{-1}$  respectively. If the reaction is of first order, at what temperature will its half-life period be ten minutes?

22. Two reactions proceed at  $25^\circ\text{C}$  at the same rate. The temperature coefficient of the rate of the first reaction is 2 and that of the second is 2.5. Find the ratio of the rates of these reactions at  $95^\circ\text{C}$ .

23. What is the energy of activation of a reaction if its rate doubles when the temperature is raised from 290 K to 300 K ?
24. For the reaction  $A + B \longrightarrow C + D$ ;  $\Delta H = +20$  kJ/mole, the activation energy of the forward reaction is 85 kJ/mole. Calculate the activation energy of the reverse reaction.
25. What is the value of the rate constant, predicted by the Arrhenius's equation if  $T \longrightarrow \infty$  ? Is this value physically reasonable ?
26. The activation energy of a certain uncatalysed reaction at 300 K is 76 kJ mol<sup>-1</sup>. The activation energy is lowered by 19 kJ mol<sup>-1</sup> by the use of catalyst. By what factor, the rate of catalysed reaction is increased ?
27. Given that  $K (\text{sec}^{-1}) = 5 \times 10^{14} e^{-124080/RT}$  where activation energy is expressed in joule. Calculate the temperature at which reaction has  $t_{1/2}$  equal to 25 minute. Assume I order reaction.
28. For the reaction  $A \longrightarrow \text{products}$ , the time for half change is 5000 second at 300K and 1000 second at 310 K. If the reaction obeys first order kinetic, calculate energy of activation .
29. Two reactions of same order have equal exponential factors but their activation energy differ by 24.9 kJ mol<sup>-1</sup>. Calculate the ratio between the rate constant of these reactions at 27°C  
[  $R = 8.314 \text{ JK}^{-1} \text{ mol}^{-1}$  ]
30. The energy of activation of a I order reaction is 104.5 kJ mol<sup>-1</sup> and pre-exponential factor A in Arrhenius equation is  $5 \times 10^{13} \text{ sec}^{-1}$ . At what temperature will the reaction have half life of 1 minute ?

## Daily Practice Problem Sheet 3

- Q.1 Calculate the number of neutrons in the remaining atom after emission of an alpha particle from  $^{238}_{92}\text{U}$  atom.
- Q.2 Radioactive disintegration of  $^{226}_{88}\text{Ra}$  takes place in the following manner into RaC.
- $$\text{Ra} \xrightarrow{-\alpha} \text{Rn} \xrightarrow{-\alpha} \text{RaA} \xrightarrow{-\alpha} \text{RaB} \xrightarrow{-\beta} \text{RaC}$$
- Determine mass number and atomic number of RaC.
- Q.3 A radioactive element A disintegrates in the following manner
- $$\text{A} \xrightarrow{-\alpha} \text{B} \xrightarrow{-\beta} \text{C} \xrightarrow{-\beta} \text{D}$$
- (i) Which one of the elements A, B, C, D are isotopes ?  
(ii) Which one of the elements A, B, C, D are isobars ?
- Q.4 Write the particles emitted from each nucleides in the following reactions :
- (a)  $^{231}_{90}\text{Th} \xrightarrow{\text{(i)}} ^{231}_{91}\text{Pa} \xrightarrow{\text{(ii)}} ^{227}_{89}\text{Ac}$       (b)  $^{217}_{85}\text{At} \xrightarrow{\text{(i)}} ^{213}_{83}\text{Bi} \xrightarrow{\text{(ii)}} ^{209}_{81}\text{Tl}$
- Q.5 An atom has atomic mass 232 and atomic number 90. During the course of disintegration, it emits  $2\beta$ -particles and few  $\alpha$ -particles. The resultant atom has atomic mass 212 and atomic number 82. How many  $\alpha$ -particles are emitted during this process.
- Q.6 In the sequence of the following nuclear reaction
- $$^{238}_{98}\text{X} \xrightarrow{-\alpha} \text{Y} \xrightarrow{-\beta} \text{Z} \xrightarrow{-\beta} \text{L} \xrightarrow{n\alpha} ^{218}_{90}\text{M}$$
- what is the value of n  
(A) 3                                      (B) 4                                      (C) 5                                      (D) 6
- Q.7 The isotope  $^{235}_{92}\text{U}$  decays in a number of steps to an isotope of  $^{207}_{82}\text{Pb}$ . The groups of particles

emitted in this process will be

- (A)  $4\alpha, 7\beta$  (B)  $6\alpha, 4\beta$  (C)  $7\alpha, 4\beta$  (D)  $10\alpha, 8\beta$

- Q.8** The  ${}^{238}_{92}\text{U}$  disintegrates to give 4  $\alpha$ - and 6  $\beta$ - particles. The atomic number of the end product is  
(A) 92 (B) 96 (C) 84 (D) 90

- Q.9** Following are the atoms having the number of neutrons and protons as given below :

Atoms	Protons	Neutron
A	8	8
B	8	9
C	8	10
D	7	8
E	7	9

Select incorrect conclusion(s) :

- (A) A, B and C, D are isotopes (B) A and D are isotones  
(C) A and E are isobars (D) A and B are isodiaphers

- Q.10** An alkaline earth element is radioactive. It and its daughter elements decay by emitting there  $\alpha$ -particles in sucession. The daughter element formed wil belong to group -  
(A) 8 (B) 16 (C) 14 (D) 12

- Q.11**  ${}^{210}_{84}\text{Po} \longrightarrow {}^{206}_{82}\text{Pb} + {}^4_2\text{He}$

In above reaction, predict the position of Po in the periodic table when lead belongs to IVB group :

- (A) IIA (B) VI B (C) IV B (D) V B

- Q.12** Radioactive substance of 1 curie is the amount that can produce ..... disintegrations per second.

- Q.13** The last member of  $4n + 1$  series is an isotope of .....

- Q.14** The  $4n$  series starts from Th-232 and ends at

- (A) Pb-208 (B) Bi-209 (C) Pb-206 (D) Pb-207

- Q.15** Select the wrong statement

- (A) Nuclear isomers contain the same number of protons and neutrons  
(B) The decay constant is independent of the amount of the substance taken  
(C) One curie =  $3.7 \times 10^{10}$  dis/minute  
(D) Actinium series starts with  $\text{U}^{238}$

- Q.16** The correct starting material and product of different disintegration series are :

- (A)  ${}^{232}\text{Th}, {}^{208}\text{Pb}$  (B)  ${}^{235}\text{U}, {}^{206}\text{Pb}$  (C)  ${}^{238}\text{U}, {}^{207}\text{Pb}$  (D)  ${}^{237}\text{Np}, {}^{209}\text{Bi}$

- Q.17** Which of the following is/are correct

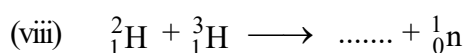
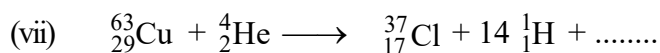
- (A) 1 curie =  $3.7 \times 10^{10}$  d/s (B) 1 rutherford =  $10^6$  d/s  
(C) 1 becquerel = 1 d/s (D) 1 fermi =  $10^3$  d/s

- Q.18** To which radioactive families do the following nucleides belong ?

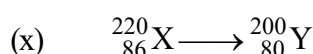
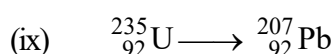
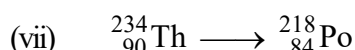
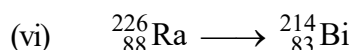
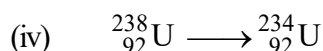
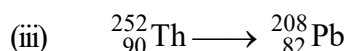
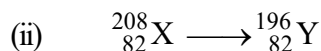
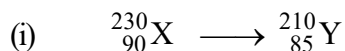
${}^{222}\text{Rn}, {}^{228}\text{Ra}, {}^{207}\text{Pb}, {}^{209}\text{Bi}, {}^{233}\text{Pa}$ .

- Q.19** Balance the following nuclear reactions.

- (i)  ${}^9_4\text{Be} + {}^4_2\text{He} \longrightarrow \dots\dots + {}^1_0\text{n}$  (ii)  ${}^6_3\text{Li} + \dots\dots \longrightarrow {}^7_3\text{Li} + {}^1_1\text{H}$   
(iii)  ${}^9_4\text{Be} + \dots\dots \longrightarrow {}^8_4\text{Be} + {}^1_0\text{n}$   
(iv)  ${}^{235}_{92}\text{U} + {}^1_0\text{n} \longrightarrow {}^{141}_{56}\text{Ba} + \dots\dots + 3 {}^1_0\text{n}$   
(v)  ${}^{31}_{15}\text{P} + {}^1_1\text{H} \longrightarrow {}^{31}_{16}\text{S} + \dots\dots$  (vi)  ${}^{75}_{33}\text{As} + {}^2_1\text{H} \longrightarrow \dots\dots + {}^1_1\text{H}$



**Q.20** Calculate  $\alpha$  and  $\beta$  particles emitted during the process.



## Daily Practice Problem Sheet 4

- The triad of nuclei that represents isotopes is:  
 (A)  ${}_6\text{C}^{14}$ ,  ${}_7\text{N}^{14}$ ,  ${}_9\text{F}^{19}$  (B)  ${}_6\text{C}^{12}$ ,  ${}_7\text{N}^{14}$ ,  ${}_9\text{F}^{19}$   
 (C)  ${}_6\text{C}^{14}$ ,  ${}_6\text{C}^{13}$ ,  ${}_6\text{C}^{12}$  (D)  ${}_6\text{C}^{14}$ ,  ${}_7\text{N}^{14}$ ,  ${}_9\text{F}^{17}$
- The triad of nuclei that represents isotones is:  
 (A)  ${}_6\text{C}^{12}$ ,  ${}_7\text{N}^{14}$ ,  ${}_9\text{F}^{19}$  (B)  ${}_6\text{C}^{14}$ ,  ${}_7\text{N}^{15}$ ,  ${}_9\text{F}^{17}$   
 (C)  ${}_6\text{C}^{14}$ ,  ${}_7\text{N}^{14}$ ,  ${}_9\text{F}^{17}$  (D)  ${}_6\text{C}^{14}$ ,  ${}_7\text{N}^{14}$ ,  ${}_9\text{F}^{19}$
- The rate of radioactive disintegration..... with time:  
 (A) Increases (B) Decreases (C) Is constant (D) May increase
- When a radioactive element emits an electron the daughter element formed will have:  
 (A) Mass number one unit less (B) Atomic number one unit less  
 (C) Mass number one unit more (D) Atomic number one unit more
- Decrease in atomic no. is observed during:  
 (A) Alpha emission (B) Electron capture  
 (C) Positron emission (D) all
- Successive emission of an  $\alpha$ -particle and two  $\beta$ -particles by an atom of an element results in the formation of its:  
 (A) Isodiapher (B) Isomorph (C) Isotope (D) Isotherm
- If  $N_0$  is the initial number of nuclei, number of nuclei remaining undecayed at the end of  $n$ th half life is:  
 (A)  $2^{-n} N_0$  (B)  $2^n N_0$  (C)  $n^{-2} N_0$  (D)  $n^2 N_0$
- Which one of the following nuclear reaction is correct:  
 (A)  ${}_6\text{C}^{13} + {}_1\text{H}^1 \longrightarrow {}_7\text{N}^{13} + \beta^- + \gamma$  (B)  ${}_{11}\text{Na}^{23} + {}_1\text{H}^1 \longrightarrow {}_{10}\text{Ne}^{20} + {}_2\text{He}^4$   
 (C)  ${}_{13}\text{Al}^{23} + {}_0\text{n}^1 \longrightarrow {}_{11}\text{Na}^{23} + {}_{-1}\text{e}^0$  (D)  ${}_{12}\text{Mg}^{24} + {}_2\text{He}^4 \longrightarrow {}_{13}\text{Al}^{27} + {}_0\text{n}^1$
- The activity of a radionuclide ( $\text{X}^{100}$ ) is 6.023 curie. If the disintegration constant is  $3.7 \times 10^4 \text{ sec}^{-1}$ , the mass of radionuclide is:

- (A)  $10^{-14}$  g                      (B)  $10^{-6}$  g                      (C)  $10^{-15}$  g                      (D)  $10^{-3}$  g
10. The half life of  $I^{131}$  is 8 day. Given a sample of  $I^{131}$  at  $t = 0$ , we can assert that:  
(A) No nucleus will decay at  $t = 4$  day  
(B) No nucleus will decay before  $t = 8$  day  
(C) All nucleus will decay before  $t = 16$  day  
(D) A given nucleus may decay at any time after  $t = 0$
11. If 5g of a radioactive substance has  $t_{1/2} = 14$  hr., 2 g of the same substance will have a  $t_{1/2}$  equal to:  
(A) 56 hr                      (B) 3.5 hr                      (C) 14 hr                      (D) 28 hr
12. The half life of a radioactive isotope is 2.5 hour. The mass of it that remains undecayed after 10 hour is (If the initial mass of the isotope was 16 g):  
(A) 32 g                      (B) 16 g                      (C) 4 g                      (D) 1 g
13. The number of  $\alpha$ -and  $\beta$ -particles emitted during the transformation of  ${}_{90}^{232}\text{Th}$  to  ${}_{82}^{208}\text{Pb}$  is respectively:  
(A) 2, 2                      (B) 4, 2                      (C) 6, 4                      (D) 8, 6
14. If 75% quantity of a radioactive isotope disintegrates in 2 hour, its half life would be:  
(A) 1 hour                      (B) 45 minute                      (C) 30 minute                      (D) 15 minute
15. A certain radioactive isotope has a half life of 50 day. Fraction of the material left behind after 100 day will be:  
(A) 50%                      (B) 75%                      (C) 12.5%                      (D) 25%
16. The half life period of a radioactive elements is 140 day. After 560 day, 1 g of the element will reduce to:  
(A) 0.5 g                      (B) 0.25 g                      (C)  $1/8$  g                      (D)  $1/16$  g
17. 75% of a first order reaction was completed in 32 minute. When will be 50% of the reaction complete.  
(A) 24 minute                      (B) 16 minute                      (C) 8 minute                      (D) 4 minute
18. The half life of a radioactive isotope is 1.5 hour. The mass of it that decayed after 6 hour is (the initial mass of the isotope is 32 g):  
(A) 32 g                      (B) 16 g                      (C) 30 g                      (D) 2 g
19. Half life period of a substance is 1600 minute. What fraction of the substance will remain after 6400 minute:  
(A)  $1/16$                       (B)  $1/4$                       (C)  $1/8$                       (D)  $1/2$
20. The half life period of a radioactive nuclide is 3 hour. In 9 hour its activity will be reduced by  
(A)  $1/9$                       (B)  $7/8$                       (C)  $1/27$                       (D)  $1/6$
21. A radioactive isotope having a half life of 3 day was received after 12 day. It was found that there were 3 g of the isotope in the container. The initial weight of the isotope when packed was:  
(A) 12 g                      (B) 24 g                      (C) 36 g                      (D) 48 g
22. A sample of rock from moon contains equal number of atoms of uranium and lead ( $t_{1/2}$  for U =  $4.5 \times 10^9$  year). The age of the rock would be:  
(A)  $4.5 \times 10^9$  year                      (B)  $9 \times 10^9$  year                      (C)  $13.5 \times 10^9$  year                      (D)  $2.25 \times 10^9$  year
23. Two radioactive elements X and Y have half lives of 50 and 100 minute respectively. Initial sample of both the elements have same no. of atoms. The ratio of the remaining number of atoms of X and

Y after 200 minute is:

- (A) 2 (B) 1/2 (C) 4 (D) 1/4

24. The time in which activity of an element is reduced to 90% of its original value is, (given  $t_{1/2} = 1.4 \times 10^{10}$  yr):  
(A)  $1.128 \times 10^9$  yr (B)  $2.128 \times 10^9$  yr (C)  $3.128 \times 10^9$  yr (D) None
25. The number of  $\alpha$ - and  $\beta$ - particles emitted in the nuclear reaction  ${}_{90}^{228}\text{Th} \longrightarrow {}_{83}^{212}\text{Bi}$  are:  
(A)  $4\alpha$  and  $1\beta$  (B)  $3\alpha$  and  $7\beta$  (C)  $8\alpha$  and  $1\beta$  (D)  $4\alpha$  and  $7\beta$
26. Two radioisotopes P and Q of atomic weight 10 and 20 respectively are mixed in equal amount by weight. After 20 day, their weight ratio is found to be 1 : 4. Isotope P has a half life of 10 day. The half life of isotope Q is:  
(A) Zero (B) 5 day (C) 20 day (D) infinite
27. The radioactivity due to the  $\text{C}^{14}$  isotope ( $t_{1/2} = 6000$  year) of a sample of wood from an ancient tomb was found to be nearly half that of fresh wood; the tomb is, therefore, about:  
(A) 3000 year old (B) 6000 year old (C) 9000 year old (D) 12000 year old
28. The activity of a radioactive sample drops to 1/64th of its original value in 2hr. The decay constant for the sample is:  
(A)  $5.775 \times 10^{-4} \text{ sec.}^{-1}$  (B)  $5.775 \times 10^4 \text{ sec.}^{-1}$   
(C)  $5.775 \times 10^2 \text{ sec.}^{-1}$  (D) None
29. A radioactive element has a half life of  $4.5 \times 10^9$  year. If 80 g of this was taken, the time taken for it to decay to 40 g will be:  
(A)  $2.25 \times 10^9$  year (B)  $4.50 \times 10^9$  year (C)  $6.75 \times 10^9$  year (D)  $8.75 \times 10^9$  year
30. A certain nuclide has a half life period of 30 minute. If a sample containing 6000 atoms is allowed to decay for 90 minute, how many atoms will remain:  
(A) 200 atoms (B) 450 atoms (C) 750 atoms (D) 150 atoms
31. A substance is kept for 2 hour and three fourth disintegrates during this period. The half life of the substance is:  
(A) 2 hour (B) 1 hour (C) 30 minute (D) 4 hour
32. The binding energy of an element is 64 MeV. If BE/nucleon is 6.4, the number of nucleons are:  
(A) 10 (B) 64 (C) 16 (D) 6
33. The half life of  ${}_{92}\text{U}^{238}$  against  $\alpha$ -decay is  $4.5 \times 10^9$  year. The time taken in year for the decay of 15/16 part of this isotope is:  
(A)  $9.0 \times 10^9$  (B)  $1.8 \times 10^{10}$  (C)  $4.5 \times 10^9$  (D)  $2.7 \times 10^{10}$
34. A radioactive isotope has a half life of 10 day. If today there are 125g of it left, what was its original weight 40 day earlier:  
(A) 600 g (B) 1000 g (C) 1250 g (D) 2000 g
35. Radium has atomic weight 226 and half life of 1600 year. The number of disintegration produced per sec. from 1 g are:  
(A)  $4.8 \times 10^{10}$  (B)  $3.7 \times 10^{10}$  (C)  $9.2 \times 10^6$  (D)  $3.7 \times 10^8$
36. If the amount of radioactive substance is increased three times, the number of atoms disintegrated per unit time would:

- (A) Be double      (B) Be triple      (C) Remain one third      (D) Not change
37. The half life of a radioactive element is 35 year. If there are  $4 \times 10^6$  nuclei at the start, then after how many year they will be left  $0.5 \times 10^6$ .  
 (A) 35      (B) 70      (C) 105      (D) 140
38. Wooden article and freshly cut tree show activity  $7.6$  and  $15.2 \text{ min}^{-1} \text{ g}^{-1}$  of carbon ( $t_{1/2} = 5760$  year) respectively. The age of the article is:  
 (A) 5760 year    (B)  $5760 \times \frac{15.2}{7.6}$  year    (C)  $5760 \times \frac{7.6}{15.2}$  year    (D)  $5760 \times (15.2 - 7.6)$  year
39. For a radioactive substance with half life period 500 year, the time for complete decay of 100 milligram of it would be:  
 (A) 1000 year      (B)  $100 \times 500$  year      (C) 500 year      (D) Infinite time
40. The decay constant of a radioactive element is defined as the reciprocal of the time interval after which the number of atoms of the radioactive element falls to nearly:  
 (A) 50% of its original number      (B) 36.8% of its original number  
 (C) 63.2% of its original number      (D) 75% of its original number
41. The radioactive decay rate of a radioactive element is found to be  $10^3$  dps at a certain time. If the half life of element is 1 sec, the decay rate after 1 sec. is..... and after 3 sec. is.....  
 (A) 500, 125      (B) 125, 500      (C)  $10^3$ ,  $10^3$       (D) 100, 10
42. The counting rate observed from a radioactive source at  $t = 0$  seconds was 1600 counts/sec and at  $t = 8$  sec it was 100 counts/sec. The counting rate observed as count per sec at  $t = 6$  sec will be:  
 (A) 400      (B) 300      (C) 200      (D) 150
43. A freshly prepared radioactive source of half life 2 hr. emits radiations of intensity which is 64 times the permissible safe level. The minimum time after which it would be possible to work safely with this source is:  
 (A) 6 hr      (B) 12 hr      (C) 24 hr      (D) 128 hr
44. One mole of A present in a closed vessel undergoes decay as  ${}_Z\text{A}^m \longrightarrow {}_{Z-4}\text{B}^{m-8} + 2 {}_2\text{He}^4$ . The volume of He collected at NTP after 20 days is ( $t_{1/2} = 10$  day):  
 (A) 11.2 litre      (B) 22.4 litre      (C) 33.6 litre      (D) 67.2 litre
45. The number of  $\beta$ -particle emitted during the change  ${}_a\text{X}^c \longrightarrow {}_d\text{Y}^b$  is:  
 (A)  $\frac{a-b}{4}$       (B)  $d + \left[ \frac{a-b}{2} \right] + c$       (C)  $d + \left[ \frac{c-b}{2} \right] - a$       (D)  $d + \left[ \frac{a-b}{2} \right] - c$

### Daily Practice Problems Sheet 1

1.  $k = 2.0 \times 10^{-2} \text{ min}^{-1}$
3. I,  $3.2 \times 10^{-2} \text{ min}^{-1}$
5. 108.23 ml
8.  $k = 3.27 \times 10^{-3} \text{ min}^{-1}$
9.  $k = 3.12 \times 10^{-3} \text{ min}^{-1}$
10.  $r = k [\text{sugar}]^1 [\text{H}^+]^0$
11.  $6.2 \times 10^{-4} \text{ sec}^{-1}$

### Daily Practice Problems Sheet 2

1. 0.537
2.  $K_b = 1.7 \times 10^{-5} \text{ sec}^{-1}$   $K_c = 1.35 \times 10^{-4}$  (order = 1 for each path)
3. methyl cyclopentene = 23%, cyclohexane = 77%
4. 1990 sec.
5. 7.5937
6. 1.88
7.  $E_a = 209.6 \text{ kJ}$
8. Large value of E
9.  $k = 3.19 \times 10^{-2} \text{ L mol}^{-1} \text{ s}^{-1}$
10.  $k = 5.10 \times 10^{-5} \text{ s}^{-1}$ ;  $E = 92.011 \text{ kJ/mol}$ ;  $A = 6.73 \times 10^{11} \text{ s}^{-1}$
11.  $k = 10^{-2} \text{ s}^{-1}$ ;  $E = 87.297 \text{ kJ/mol}$ ;  $A = 2.2 \times 10^{14} \text{ s}^{-1}$
12.  $k = 5 \times 10^{-4} \text{ s}^{-1}$ ;  $E = 94.78 \text{ kJ/mol}$ ;  $A = 10^{15} \text{ s}^{-1}$
13.  $t = 19 \text{ sec}$ ,  $E_a = 67.6 \text{ kJ mol}^{-1}$
14.  $E_a^f = 50.80 \text{ kJ/mol}$ ;  $E_a^b = 27.61 \text{ kJ/mol}$
15. 63.18 kJ/mol
16.  $6.4 \times 10^9$
17. 3000 seconds
18. 0.002
19. 24.7 kJ/mol
20.  $T = 310 \text{ K}$
21. Ans. 311.2
22. 4.768
23.  $\approx 12 \text{ kcal}$
25.  $k = A$ , but it is not reasonable since  $E_a$  can not be zero
26. 2033.8
27.  $86.1^\circ \text{C}$
28.  $124.46 \text{ mol}^{-1}$
29.  $2.1645 \times 10^4$
30. 349.04 K

### Daily Practice Problems Sheet 3

1. 144
2. 214, 83
3. (i) AD (ii) BCD
4. (a) i- $\beta$  ii- $\alpha$ , (b) i- $\alpha$ , ii- $\alpha$
5. 5
6. B
7. C
8. D
9. A, D
10. C
11. B
12.  $3.7 \times 10^{10}$
13. Bi
14. A
15. C, D
16. A, D
17. A, B, C
18.  $4n+2, 4n, 4n+3, 4n+1, 4n+1$
19. (i)  $^{12}_6\text{C}$  (ii)  $^1_1\text{H}$  (iii)  $\gamma$  (iv)  $^{92}_{36}\text{Kr}$  (v)  $^1_0\text{n}$   
(vi)  $^{76}_{33}\text{As}$  (vii)  $^{16}_0\text{n}$  (viii)  $^4_2\text{He}$
20. (i)  $5\alpha, 5\beta$  (ii)  $3\alpha, 6\beta$  (iii)  $11\alpha, 14\beta$  (iv)  $\alpha, 2\beta$  (v)  $2\alpha$   
(vi)  $3\alpha, \beta$  (vii)  $4\alpha, 2\beta$  (viii)  $7\alpha, 4\beta$  (ix)  $7\alpha, 14\beta$  (x)  $5\alpha, 4\beta$

### Daily Practice Problems Sheet 4

1. C
2. C
3. B
4. D
5. D
6. A
7. A
8. B
9. C
10. D
11. C
12. D
13. C
14. A
15. D
16. D
17. B
18. C
19. A
20. B
21. D
22. A
23. D
24. D
25. A
26. D
27. B
28. A
29. B
30. C
31. B
32. A
33. B
34. D
35. B
36. D
37. D
38. A
39. D
40. B
41. A
42. C
43. B
44. C
45. C