PHYSICS - IMPORTANT FORMULAE & VALUES

UNIT- 1

Force	$F = m \times a$	Momentum of a couple	$M = F \times S$
Linear Momentum	$p = m \times v$	Change in momentum	$\Delta p = m(v-u)$
Torque	$\tau = F \times d$	Impulse	$J = F \times t = \Delta p$
Gravitational Force	$F = \frac{Gm_1m_2}{r^2}$	Acceleration due to gravity	$g = \frac{GM}{R^2}$
Weight	$W = m \times g$	Kinetic Energy	$E_k = \frac{1}{2}mv^2 = \frac{p^2}{2m}$

Important Values: Acceleration due to gravity on Earth: 9.8 ms^{-2} & on Moon: 1.625 ms^{-2}
Radius of Earth (R) = 6400km ; Gravitational constant(G) = 6.674×10^{-11} $Nm^2\,kg^{-2}$
Mass of Earth (M) = 5.972×10^{24}kg

UNIT- 2

Velocity of light	$c = \nu\lambda$	Snell's law	$\frac{\sin i}{\sin r} = \frac{\mu_2}{\mu_1}$	Rayleigh's law	$S \alpha \frac{1}{\lambda^4}$
Magnification	$\frac{v}{u} = \frac{h'}{h}$	Power	$P = \frac{1}{f}$	Lens Formula	$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$

Focal length of corrective lens for Myopia : $f = \frac{xy}{x-y}$ (concave lens)& Hypermetropia : $f = \frac{dD}{d-D}$ (convex lens)

UNIT- 3

Linear expansion	$\frac{\Delta L}{L_0} = \alpha_L \Delta T$	Boyle's law	$P \alpha \frac{1}{V}$	**Important Values:**
Cubical expansion	$\frac{\Delta V}{V_0} = \alpha_V \Delta T$	Charles's law	$V \alpha T$	$N_A = 6.023 \times 10^{23}$ /mol ;
Superficial expansion	$\frac{\Delta A}{A_0} = \alpha_A \Delta T$	Avogadro's law	$V \alpha n$	$k_B = 1.38 \times 10^{-23}$ JK^{-1}
		Ideal gas equation	$PV = RT$	$R = 8.31$ J $mol^{-1}K^{-1}$

UNIT- 4

Current	$I = \frac{Q}{T}$	Resistance	$R = \frac{V}{I}$	Resistivity	$\rho = \frac{RA}{L}$
Ohm's law	$V = IR$ / $I = \frac{V}{R}$ / $R = \frac{V}{I}$	Conductance	$G = \frac{1}{R}$	Conductivity	$\sigma = \frac{1}{\rho}$

Resistors in Series $R_s = R_1 + R_2 + R_3 + \ldots\ldots$ (for equal resistance $R_s = nR$)
Resistors in Parallel $\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots\ldots$ (for equal resistance $R_P = \frac{R}{n}$)

Potential difference(V)	$\frac{\text{Work done (W)}}{\text{Charge (Q)}}$	Electric Power	$P = \frac{\text{Work}}{\text{Time}} = VI = \frac{V^2}{R}$
Electrical energy	$E = P \times t$	Joule's law of heating	$H = I^2Rt$

UNIT- 5

Wave velocity	$V = \frac{\lambda}{T} = n\lambda$	Velocity of sound in air is 340 ms^{-1}	Hearing range 20 to 20,000 Hz
Effect of density	$V \alpha \sqrt{\frac{1}{d}}$	Speed of Echo $\frac{2d}{t}$	Minimum distance to hear echo is 17.2 m
Effect of Temperature	$V \alpha \sqrt{T}$; $V_T = (V_0 + 0.61T)ms^{-1}$	Doppler Frequency	$n' = \left(\frac{V+V_L}{V-V_S}\right)n$

UNIT- 6

Permitted range of radiation 100 mR per week (or) 20 milli Sievert per year = Safe limit
100 R →leukemia (or) cancer & 600 R → death

1. LAWS OF MOTION

1. Two bodies have a mass ratio of 3:4. The force applied on the bigger mass produces an acceleration of 12 m s^{-2}. What could be the acceleration of the other body, if the same force acts on it.

Given : $m_1 : m_2 = 3:4$; $F_1 = F_2$ Let m_2 be bigger, then $a_2 = 12\ \mathrm{ms}^{-2}$

Solution :

$$F_1 = F_2$$
$$m_1 a_1 = m_2 a_2 \quad (\because F = ma)$$
$$a_1 = \frac{m_2}{m_1}\, a_2 = \frac{4}{3} \times 12 = 16\ \mathrm{ms}^{-2}$$

$\therefore$ Acceleration, a_1 is $\mathbf{16\ ms^{-2}}$

2. A ball of mass 1 kg moving with a speed of 10 m s^{-1} rebounds after a perfect elastic collision with the floor. Calculate the change in linear momentum of the ball.

Given : m = 1 kg, u = 10 m s^{-1},

Solution : It is perfect elastic collision, ball rebounds with same speed but in opposite direction

$\therefore v = -10$ m s^{-1}

$$\Delta p = mv - mu = 1 \times (-10) - 1 \times (10)$$
$$= -10 - 10 = -20\ \mathrm{kg\ m\ s^{-1}}$$

$\therefore$ Change in Linear momentum is $\boldsymbol{20 kgms^{-1}}$

3. A mechanic unscrew a nut by applying a force of 140 N with a spanner of length 40 cm. What should be the length of the spanner if a force of 40 N is applied to unscrew the same nut?

Given : $F_1 = 140\ N,\ d_1 = 40\ cm$;

$F_2 = 40\ N,\ \ d_2 = ?$

Solution : Moment of couple is same,

$$F_1 d_1 = F_2 d_2$$
$$d_2 = \frac{F_1 d_1}{F_2} = \frac{40 \times 140}{40} = 140\ cm$$

$\therefore$ Length should be 140 cm / 1.4 m.

4. The ratio of masses of two planets is 2:3 and the ratio of their radii is 4:7. Find the ratio of their accelerations due to gravity.

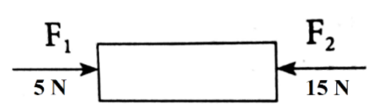
Given : $\mathrm{m_1 : m_2} = 2 : 3$; $\mathrm{R_1 : R_2} = 4 : 7$; $\mathrm{g_1 : g_2}$ = ?

Solution : $g_1 = \frac{GM_1}{R_1^2}$ ---- (1) $\quad g_2 = \frac{GM_2}{R_2^2}$ ------ (2)

Eqn (1) ÷ (2) $\Rightarrow$
$$\frac{\mathrm{g_1}}{\mathrm{g_2}} = \frac{\frac{\mathrm{GM_1}}{\mathrm{R_1^2}}}{\frac{\mathrm{GM_2}}{\mathrm{R_2^2}}} = \frac{\cancel{\mathrm{G}}\mathrm{M_1}}{\mathrm{R_1^2}} \times \frac{\mathrm{R_2^2}}{\cancel{\mathrm{G}}\mathrm{M_2}} = \frac{\mathrm{M_1}}{\mathrm{M_2}} \times \frac{\mathrm{R_2^2}}{\mathrm{R_1^2}}$$
$$\frac{\mathrm{g_1}}{\mathrm{g_2}} = \frac{2}{3} \times \frac{7^2}{4^2} = \frac{2}{3} \times \frac{49}{16} = \frac{49}{24}$$

$\therefore$ $\mathrm{g_1 : g_2}$ = 49 : 24

5. If a 5 N and a 15 N forces are acting opposite to one another. Find the resultant force and the direction of action of the resultant force.



Given , $F_1 = 5N$ $\quad F_2 = 15\ N$

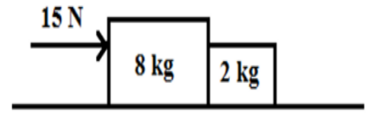
$$F_{net} = F_2 - F_1 = 15 - 5 = 10\ N.$$

$\therefore$ Magnitude is 10 N and direction is along 15 N force.

6. Two blocks of masses 8 kg and 2 kg respectively lie on a smooth horizontal surface in contact with one other. They are pushed by a horizontally applied force of 15 N. Calculate the force exerted on the 2 kg mass.

Given **:** $m_1 = 8$ kg , $m_2 = 2$ kg, Force, F = 15 N

Solution :



$$F = ma = (m_1 + m_2)\,a$$

$$a = \frac{F}{m_1+m_2} = \frac{15}{8+2} = \frac{15}{10} = 1.5\ ms^{-2}$$

Force on 2 kg mass, $m = 2$ kg, $a = 1.5\ ms^{-2}$

$$F = ma = 2\times 1.5 = 3N$$

∴ Force on 2kg mass is **F = 3N**

7. A heavy truck and bike are moving with the same kinetic energy. If the mass of the truck is four times that of the bike, then calculate the ratio of their momenta. (Ratio of momenta = 2 : 1)

Given **:** Let, Mass of bike $= m_B$; Mass of truck $= m_T$; $\frac{m_T}{m_B} = 4$

Solution : Kinetic Energy $= \frac{1}{2} mv^2$

K.E of truck = K.E of bike

$$\cancel{\tfrac{1}{2}}\, m_T v_T^2 = \cancel{\tfrac{1}{2}}\, m_B v_B^2$$

$$\left(\frac{v_B}{v_T}\right)^2 = \frac{m_T}{m_B} = 4$$

$$\frac{v_B}{v_T} = 2 \Rightarrow \frac{v_T}{v_B} = \frac{1}{2}$$

Ratio of their momentum is, $\frac{p_T}{p_B} = \frac{m_T\,V_T}{m_B\,V_B} = 4 \times \frac{1}{2} = 2$

∴ **Ratio of their momentum is 2 : 1.**

Example Problems

1. Calculate the velocity of moving body of mass 5 kg whose linear momentum is 2.5 kg m s^{-1}.

Given **:** Mass = 5 kg ; Linear momentum = 2.5 kg m s^{-1} **[TB-12]**

Solution **:** Velocity = linear momentum / mass ⇒ V= $\frac{2.5}{5}$ = 0.5 m s^{-1}

∴ ***Velocity of moving body is 0.5 ms^{-1}***.

2. A door is pushed, at a point whose distance from the hinges is 90 cm, with a force of 40N. Calculate the moment of the force about the hinges. [TB-12]

Given **:** F=40 N ; d=90 cm = 0.9 m

Solution **:** The moment of a force M = F × d ⇒ M = 40 × 0.9 = **36 Nm**

3. At what height from the centre of the Earth, the acceleration due to gravity will be 1/4th of its value as at the Earth. [TB-12] [PTA-6]

Given **:** Height from the centre of the earth, $R' = R + h$

Acceleration due to gravity at that height, $g' = \frac{g}{4}$

Solution: $g = \frac{GM}{R^2}$, $g' = \frac{GM}{R'^2}$ ⇒ $\frac{g}{g'} = \left(\frac{R'}{R}\right)^2$

$$\frac{g}{g/4} = \left(\frac{R+h}{R}\right)^2 = \left(1 + \frac{h}{R}\right)^2$$

$$4 = \left(1 + \frac{h}{R}\right)^2 \text{ (take square root on both sides)}$$

$$2 = 1 + \frac{h}{R} \Rightarrow h = R$$

$$R' = R + R = 2R$$

∴ From the centre of the Earth, the object is placed at twice the radius of the earth.

Additional Questions

8. A lift is moving downwards with an acceleration of $1.8\ \text{m s}^{-2}$. What is apparent weight realised by a man of mass 50 kg? [PTA-1]

Given : $a = 1.8\ \text{m s}^{-2}$ $m = 50$ kg

Solution: Apparent weight, R = m(g–a)

$= 50\ (9.8 - 1.8)$

$R = 50 \times 8$

∴ Apparent weight is **400 N**

9. A force of 5 N applied on a body produces and acceleration 5 cm s^{-2}. Calculate the mass of the body. [PTA-5]

Given : F = 5 N, $a = 5\ \text{cms}^{-2} = 0.05\ \text{ms}^{-2}$

Solution : F = ma

$$m = \frac{F}{a} = \frac{5}{0.05}$$

m = 100 kg

∴ Mass = 100kg

10. A weight of a man is 686 N on the surface of the earth. Calculate the weight of the same person on moon. ('g' value of a moon is $1.625\ \text{m s}^{-2}$) [PTA-2]

Given : $W_e = mg_e = 686$ N; $g_m = 1.625\ \text{m s}^{-2}$

Solution : $m = \frac{W_e}{g_e} = \frac{686}{9.8} = 70$ kg

$W_m = mg_m = 70 \times 1.625$

$W_m = 113.75$ N

∴ Weight on moon is 113.75 N

11. Calculate the velocity of moving body of mass 5 kg whose linear momentum is 2 kg m s^{-1}. [MDL-19]

Given : m = 5 kg ; p = 2 kg m s^{-1}

Solution : p = mv

$$v = \frac{p}{m} = \frac{2}{5} = 0.4\ \text{m s}^{-1}$$

∴ Velocity = 0.4 m s^{-1}.

2. OPTICS

1. An object is placed at a distance 20 cm from a convex lens of focal length 10 cm. Find the image distance and nature of the image.

Given : f = 10 cm, u = − 20 cm, v = ?

Solution : $\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \implies \frac{1}{v} = \frac{1}{f} + \frac{1}{u} = \frac{1}{10} + \frac{1}{-20}$

$$= \frac{2-1}{20} = \frac{1}{20}$$

v = 20 cm

<u>Image distance</u> is 20 cm.

<u>Nature of image</u> is Real and inverted image.

> ***<u>Sign for f, u & v</u>***
>
> *For Concave lens,*
>
> **f, u, v** → – (All are negative.)
>
> *For Convex lens,*
>
> **f** → + **u** → –
>
> **v** → + (-ve only if object is between F&O)

2. An object of height 3 cm is placed at 10 cm from a concave lens of focal length 15 cm. Find the size of the image.

Given : f = −15 cm, u = − 10 cm, h = 3 cm, h' = ?

Solution : $\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \Rightarrow \frac{1}{v} = \frac{1}{f} + \frac{1}{u} = \frac{1}{-15} + \frac{1}{-10} = \frac{-2-3}{30}$

$$\frac{1}{v} = -\frac{5}{30} = -\frac{1}{6}$$

$$v = -6\ \text{cm}$$

$$\text{Magnification } m = \frac{v}{u} = \frac{-6}{-10} = 0.6$$

$$\text{Magnification } m = \frac{h'}{h} = \frac{h'}{3} = 0.6$$

$$h' = 0.6 \times 3 = 1.8\ \text{cm}$$

∴ Height of the image h' is 1.8 cm.

Example Problems

3. Light rays travel from vacuum into a glass whose refractive index is 1.5. If the angle of incidence is 30^0. Calculate the angle of refraction inside the glass. [TB-28]

Given **:** $\mu_1 = 1,\ \mu_2 = 1.5 \quad i = 30^0$

Solution : Snell's law, $\frac{\sin i}{\sin r} = \frac{\mu_2}{\mu_1}$

$$\frac{\mu_1}{\mu_2} \times \sin i = \sin r$$

$$\sin r = \frac{1}{1.5} \times \sin 30^0$$

$$\sin r = \frac{1}{1.5} \times \frac{1}{2} = \frac{1}{3} = 0.333$$

$$r = \sin^{-1}(0.333)$$

$$\Longrightarrow r = 19.45^0$$

4. A beam of light passing through a diverging lens of focal length 0.3 m appear to be focused at a distance 0.2 m behind the lens. Find the position of the object. [TB – 28] [SEP – 2020]

Given **:** The given lens is concave lens.

f = −0.3 m, v = −0.2 m

Solution **:** $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$

$$\frac{1}{u} = \frac{1}{v} - \frac{1}{f}$$

$$= \frac{1}{-0.2} - \frac{1}{-0.3}$$

$$\frac{1}{u} = \frac{-0.3+0.2}{0.06} = \frac{-0.1}{0.06} = -\frac{10}{6}$$

$$u = -\frac{6}{10} = -0.6 \text{ m}$$

∴ The object is placed in a distance of **0.6 m** at **2 F**.

5. A person with myopia can see objects placed at a distance of 4 m. If he wants to see objects at a distance of 20 m. What should be the focal length and Power of the concave lens he must wear? [TB-28] [MAY, AUG – 2022]

Given **:** $x = 4$ m, $y = 20$ m

Solution : Focal length of the required lens is

$$f = \frac{xy}{x-y} = \frac{4\times20}{4-20} = \frac{80}{-16} = -5 \text{ m}$$

Power of required lens, $P = \frac{1}{f}$

$$P = \frac{1}{-5} = -0.2 \text{ D}$$

∴ The person must wear concave lens of focal length 5 m and power 0.2 D.

6. For a person with Hypermetropia, the near point has moved to 1.5 m. Calculate the focal length of the correction lens in order to make his eyes normal. [TB – 28]

Given **:** d = 1.5 m ,

D (for normal vision) = 25 cm = 0.25 m

Solution : Focal length of the correction lens is,

$$F = \frac{dD}{d-D}$$

$$= \frac{1.5 \times 0.25}{1.5-0.25}$$

$$= \frac{0.375}{1.25}$$

$$f = 0.3 \text{ m}$$

Additional Problems

7. The power of a lens is −2D. Find the focal length of a lens. [PTA – 4]

Given **:** P = −2D

Solution : Power (P) = $\frac{1}{f} = -2\text{D}$

$$f = \frac{1}{-2} = -0.5 \text{ m}$$

∴ Focal length is 0.5 m

8. An object of height 3 cm is placed at 10 cm from a convex lens which produces an image at 20 cm from its optical centre. Calculate the magnification and height of the image produced.

Given **:** h = 3 cm ; u = 10 cm ; v = 20 cm **[PTA – 5]**

Solution : Magnification, m = $\frac{v}{u} = \frac{20}{10} = 2$

Magnification, m = $\frac{h'}{h}$

$$h' = m \times h = 2 \times 3 = 6 \text{ cm}$$

∴ Magnification is 2 and height is 6 cm.

3. THERMAL PHYSICS

1. **Find the final temperature of a copper rod. Whose area of cross section changes from 10 m^2 to 11 m^2 due to heating. The copper rod is initially kept at 90 K. (Coefficient of superficial expansion is 0.0021/ K)**

   Given : $A_o = 10\ m^2$, $A = 11 m^2$, $\Delta A = 11 - 10 = 1\ m^2$

   $T_o = 90$ K, T = ? $\Delta T = T - T_o = T - 90$, $\alpha_A = 0.0021\ K^{-1}$

   Solution : $\frac{\Delta A}{A_o} = \alpha_A \Delta T \Rightarrow \Delta T = \frac{\Delta A}{A_o \alpha_A} = \frac{1}{10 \times 0.0021}$

   $$T - 90 = \frac{1}{0.021} = 47.61$$

   $$T = 47.61 + 90 = 137.6\ K$$

   ∴ Final temperature is **137.6 K**

2. **Calculate the coefficient of cubical expansion of a zinc bar. Whose volume is increased from 0.25 m^3 to 0.3 m^3 due to the change in its temperature of 50 K.**

   Given : $V = 0.3\ m^3$ $V_o = 0.25\ m^3$ $\Delta T = 50$ K

   Solution : $\alpha_v = \frac{\Delta V}{V_o \Delta T} = \frac{V - V_o}{V_o \Delta T}$

   $$\alpha_v = \frac{0.3 - 0.25}{0.25 \times 50} = \frac{0.05}{12.5} = 0.004\ K^{-1}$$

   ∴ The coefficient of cubical expansion is $\mathbf{0.004\ K^{-1}}$.

Example Problems

3. **A container whose capacity is 70 ml is filled with a liquid up to 50 ml. Then, the liquid in the container is heated. Initially, the level of the liquid falls from 50 ml to 48.5 ml. Then we heat more, the level of the liquid rises to 51.2 ml. Find the apparent and real expansion.**

   Given : Level of the liquid L_1 = 50 ml **[TB – 38, 39] [PTA – 6]**

   Level of the liquid L_2 = 48.5 ml

   Level of the liquid L_3 = 51.2 ml

   Solution: Apparent expansion = $L_3 - L_1$ = 51.2 ml – 50 ml = 1.2 ml

   Real expansion = $L_3 - L_2$ = 51.2 ml – 48.5 ml = 2.7 ml

   ∴ Real expansion is 2.7 ml and apparent expansion is 1.2 ml.

4. **Keeping the temperature as constant, a gas is compressed four times of its initial pressure. The volume of gas in the container changing from 20 cc (V_1 cc) to V_2 cc. Find the final volume V_2.**

   Given: Initial pressure (P_1) = P Final Pressure (P_2) = 4 P **[TB – 39] [PTA – 3]**

   Initial volume (V_1) = 20 cc = 20 cm^3 (∵ cc refers to cubic centimeter i.e. cm^3)

   Final volume (V_2) = ?

   Solution : Using Boyle's Law, PV = constant

   $$P_1V_1 = P_2V_2$$

   $$V_2 = \frac{\cancel{P_1}}{\cancel{P_2}} \times V_1 = \frac{P}{4P} \times 20 cm^3 \Rightarrow V_2 = 5\ cm^3\ \textit{i.e.}\ 5\ cc$$

   ∴ Final volume V_2 is 5 cc.

Additional Problems

5. **The length of an aluminium rod at the temperature 303 K is 50 m. What would be its increase in length when it is heated to 323 K? (The linear co-efficient of Aluminium is $\mathbf{23 \times 10^{-6} K^{-1}}$)** **[PTA – 1]**

Given : ΔL = Increase in length, $\Delta T = 323\,K - 303\,K = 20\,K$; $L_0 = 50\,m$, $\alpha_L = 23 \times 10^{-6}\ K^{-1}$

Solution : $\frac{\Delta L}{L_0} = \alpha_L\,\Delta T \Rightarrow \Delta L = \alpha_L \Delta T \times L_0$

$$\Delta L = (23 \times 10^{-6}) \times 20 \times 50 = 0.023$$

∴ Increase in length is **0.023 m**

6. **Convert 80°F temperature into kelvin scale.** **[PTA – 6]**

Given : Temperature = 80°F

Solution: *Fahrenheit to Kelvin,* $K = (F + 460) \times \frac{5}{9} = (80 + 460) \times \frac{5}{9} = \mathbf{300\,K}$

4. ELECTRICITY

1. **An electric iron consumes energy at the rate of 420 W when heating is at the maximum rate and 180 W when heating is at the minimum rate. The applied voltage is 220 V. What is the current in each case?**

Given : V = 220 V, P_{max} = 420 W, P_{min} = 180 W

Solution : P = VI

$$I = \frac{P}{V}$$

$$I_{max} = \frac{P_{max}}{V} = \frac{420}{220} = \frac{21}{11} = 1.909\ A$$

$$I_{min} = \frac{P_{min}}{V} = \frac{180}{220} = \frac{9}{11} = 0.818\ A$$

2. **A 100 watt electric bulb is used for 5 hours daily and four 60 watt bulbs are used for 5 hours daily. Calculate the energy consumed (in kWh) in the month of January.**

Solution : No. of days in January month = 31 days

Energy consumed by one 100 W bulb = P × t × no. of days used × no. of bulbs

= 100 × 5 × 31× 1 = 15500

= 15.5 kWh.

Energy consumed by four 60 W bulb = P × t × no. of days used × no. of bulbs

= 60 × 5 × 31× 4 = 37.2 kWh

∴ Total energy consumed = 15.5 + 37.2 = 52.7 kWh

3. **A torch bulb is rated at 3 V and 600 mA. Calculate it's**

a) power b) resistance c) energy consumed if it is used for 4 hour.

Given : V = 3 V; I = 600 mA = 0.6 A

Solution : **a) Power :** P = VI = 3 × 0.6 = 1.8 watt

b) Resistance : $R = \frac{V}{I} = \frac{3}{0.6} = 5\ \Omega$

c) Energy consumed if it used for 4 hour.

E = power × time = 1.8 × 4 = 7.2 watt hour

4. **A piece of wire having a resistance R is cut into five equal parts.**
a) How will the resistance of each part of the wire change compared with the original resistance?
b) If the five parts of the wire are placed in parallel, how will the resistance of the combination change?
c) What will be the ratio of the effective resistance in series connection to that of the parallel connection?

Solution :

a) length of each part $L' = \frac{L}{5}$ & Resistance of each part, $R' = \frac{\rho L'}{A} = \frac{\rho L}{5A} = \frac{R}{5}$

∴ Resistance of each part is reduced to one-fifth of the original resistance.

b) If the five parts are placed in parallel

$$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R_5}$$

$$\frac{1}{R_P} = \frac{5}{R} + \frac{5}{R} + \frac{5}{R} + \frac{5}{R} + \frac{5}{R} = \frac{25}{R}$$

$$\Rightarrow R_P = \frac{R}{25}$$

∴ Resistance of each part is reduced to one-twenty-fifth of the original resistance.

c) If the five parts are connected in series, Resistance $R_S = R$

$$\frac{R_S}{R_P} = \frac{R}{\frac{R}{25}} = \frac{R \times 25}{R} = \frac{25}{1}$$

∴ Ratio is $R_s : R_p = 25 : 1$

5. **Two resistors when connected in parallel give the resultant resistance of 2 ohm; but when connected in series the effective resistance becomes 9 ohm. Calculate the value of each resistance.**

Given: $R_P = 2\ \Omega$ $R_S = 9\ \Omega$

Solution :

$$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{2} \qquad \text{......... (1)}$$

$$R_s = R_1 + R_2 = 9\ \Omega \qquad \text{......... (2)}$$

$$R_2 = 9 - R_1 \qquad \text{......... (3)}$$

Substitute (3) in (1)

$$\frac{1}{R_1} + \frac{1}{9 - R_1} = \frac{1}{2}$$

$$\frac{9 - \cancel{R_1} + \cancel{R_1}}{R_1\,(9 - R_1)} = \frac{1}{2}$$

$$\frac{9}{R_1(9 - R_1)} = \frac{1}{2}$$

$$18 = 9\,R_1 - R_1^2$$

$$R_1^2 - 9\,R_1 + 18 = 0$$

$$(R_1 - 3)\,(R_1 - 6) = 0$$

$R_1 = 3\ \Omega$ (or) $R_1 = 6\ \Omega$

$R_2 = 9 - 3 = 6\ \Omega$ (or) $R_2 = 9 - 6 = 3\ \Omega$

∴ Resistance of the two resistors are **3 Ω** and **6 Ω.**

6. **How many electrons are passing per second in a circuit in which there is a current of 5 A?**

Given **:** $I = 5$ A ; Time, $t = 1$ s ; $e = 1.6 \times 10^{-19}$ C **[MDL – 19]**

Solution : $I = \frac{Q}{t} = \frac{ne}{t}$ [∵ Q = ne]

$$n = \frac{It}{e} = \frac{5 \times 1}{1.6 \times 10^{-19}} \qquad \Rightarrow n = 3.125 \times 10^{19} \text{ electrons}$$

∴ **3.125×10^{19}** electrons are passing per second.

7. **A piece of wire of resistance 10 ohm is drawn out so that its length is increased to three times its original length. Calculate the new resistance.**

Given **:** $R = 10\ \Omega$; Original length = L; Increased length = 3 L

Solution : If length is increased to 3 times the original length at constant volume, area of cross section is decreased to 3 times the original area. ∴ $A' = \frac{A}{3}$

$$\text{New Resistance, } R' = \frac{\rho L'}{A'} = \frac{\rho 3L}{\frac{A}{3}} = 9\,\frac{\rho L}{A} = 9\,R = 9 \times 10 = 90\ \Omega$$

∴ The new resistance is **90 Ω.**

Example Problems

8. A charge of 12 coulomb flows through a bulb in 5 seconds. What is the current through the bulb? [TB– 43]

[JUN-23,SEP-21,MAY-22]

Given **:** Charge, Q = 12 C, Time, t = 5 s

Solution : $I = \frac{Q}{t} = \frac{12}{5} = 2.4$ A

∴ Current through the bulb I = 2.4 A

Similar Additional Problem : [MDL – 19]

A charge of 10 coulomb flows through a bulb for 5 seconds. What is the current through the bulb?

Solution : $I = \frac{Q}{t} = \frac{10}{5} = 2$ A

9. The work done in moving a charge of 10 C across two points in a circuit is 100 J. What is the potential difference between the points? [TB – 44, 45]

Given: Charge Q = 10 C; Work done W = 100 J

Solution : $V = \frac{W}{Q} = \frac{100}{10} = 10$ V

∴ Potential difference V is 10V

10. Calculate the resistance of a conductor through which a current of 2 A passes, when the potential difference between its ends is 30 V. [TB – 46] [AUG - 2022]

Given : Current through the conductor, I = 2 A,

Potential difference, V = 30 V

Solution : Ohm's law, $R = \frac{V}{I} = \frac{30}{2} = 15\ \Omega$

11. The resistance of a wire of length 10 m is 2 ohm. If the area of cross section of the wire is 2×10^{-7} m², determine its

(i) Resistivity (ii) Conductance

(iii) Conductivity. [TB – 47]

Given **:** Length, L = 10 m

Resistance, R = 2 Ω, Area, A = 2×10^{-7} m²

Solution:

(i) Resistivity $\rho = \frac{RA}{L} = \frac{2 \times 2 \times 10^{-7}}{10}$

$\rho = 4 \times 10^{-8}\ \Omega$ m

(ii) Conductance, $G = \frac{1}{R} = \frac{1}{2} = 0.5$ mho

(iii) Conductivity, $\sigma = \frac{1}{\rho} = \frac{1}{4 \times 10^{-8}}$

$\sigma = 0.25 \times 10^{8}$ mho m^{-1}

12. Three resistors of resistance 5 ohm, 3 ohm and 2 ohm are connected in series with 10 V battery. Calculate their effective resistance and the current flowing through the circuit.

Given **:** $R_1 = 5\ \Omega$, $R_2 = 3\ \Omega$ **[TB – 48]**

$R_3 = 2\ \Omega$, V = 10 V

Solution: $R_s = R_1 + R_2 + R_3$

$R_s = 5 + 3 + 2 = 10\ \Omega$

$I = \frac{V}{R_s} = \frac{10}{10} = 1$ A

∴ The current through the circuit is 1A.

13. An electric heater of resistance 5 Ω is connected to an electric source. If a current of 6 A flows through the heater, then find the amount of heat produced in 5 minutes.[TB – 51] [PTA – 4, SEP - 2020]

Given: R = 5 Ω, I = 6 A

Time, t = 5 minutes = 5 × 60 = 300 s

Solution: Heat produced $H = I^2 Rt$

$H = 6 \times 6 \times 5 \times 300$

H = 54000 J = 54 kJ

∴ The amount of heat produced in 5 minutes is 54000 J (or) 54 kJ.

14. Calculate the current and the resistance of a 100 W, 200 V, electric bulb in an electric circuit? [TB – 54]

Given : Power (P) = 100 W,

Voltage (V) = 200 V

Solution: P = VI

$\therefore I = \frac{P}{V} = \frac{100}{200} = 0.5$ A

Resistance $R = \frac{V}{I} = \frac{200}{0.5} = 400\ \Omega$

15. Three resistors of resistances 1 Ω, 2 Ω and 4 Ω are connected in parallel in a circuit. If a 1 Ω resistor draws a current of 1A. Find the current through the other two resistors. **[TB – 55]**

Given: $R_1 = 1\ \Omega$, $R_2 = 2\ \Omega$, $R_3 = 4\ \Omega$, $I_1 = 1$ A

Solution :

Potential difference across the 1 Ω resistor

$V_1 = I_1R_1 = 1 \times 1 = 1$ V

For resistors in parallel, the potential difference across all the resistors is same.

The current in the 2 Ω resistor is

$$I_2 = \frac{V}{R_2} = \frac{1}{2} = 0.5 \text{ A}$$

The current in the 4 Ω resistor is

$$I_3 = \frac{V}{R_3} = \frac{1}{4} = 0.25 \text{ A}$$

∴ Current through 2 Ω resistor is 0.5 A and that in 4Ω resistor is 0.25 A.

16. Two bulbs are having the ratings as 60 W, 220 V and 40 W, 220 V respectively. Which one has a greater resistance? **[TB – 54]**

Solution:

Electric power $P = \frac{V^2}{R}$

- ❖ For the same value of V, P is inversely proportional to R.
- ❖ Therefore, lesser the power, greater is the resistance.
- ❖ Hence, the bulb with 40 W, 220 V rating has a greater resistance.

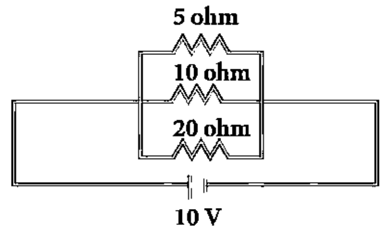
17. In the circuit diagram given below, three resistors R_1, R_2 and R_3 of 5 Ω, 10 Ω and 20 Ω respectively are connected as shown. Calculate, **[TB – 54, 55]**

a) Current through each resistor

b) Total current in the circuit

c) Total resistance in the circuit

a)



Current through each resistor

For resistors in parallel, the potential difference across each resistor is same.

$\Rightarrow V = 10$ V

Current through R_1 is $I_1 = \frac{V}{R_1} = \frac{10}{5} = 2$ A

Current through R_2 is $I_2 = \frac{V}{R_2} = \frac{10}{10} = 1$ A

Current through R_3 is $I_3 = \frac{V}{R_3} = \frac{10}{20} = 0.5$ A

b) Total current in the circuit,

$I = I_1 + I_2 + I_3$

$I = 2 + 1 + 0.5 = 3.5$ A

c) Total resistance in the circuit,

$$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{5} + \frac{1}{10} + \frac{1}{20}$$

$$\frac{1}{R_P} = \frac{4+2+1}{20} = \frac{7}{20}$$

$$R_p = \frac{20}{7} = 2.857\ \Omega$$

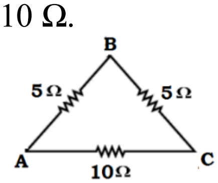
Additional Problems

18. Calculate the effective resistance of given circuit across terminals AC. **[PTA – 2]**

Given : $R_1 = 5\ \Omega$, $R_2 = 5\ \Omega$ are connected in series which is parallel to $R_3 = 10\ \Omega$.

Solution: $R_s = R_1 + R_2 = 5 + 5 = 10\ \Omega$

$$\frac{1}{Rp} = \frac{1}{10} + \frac{1}{10} = \frac{2}{10} = \frac{1}{5} \qquad \Rightarrow R_p = 5\ \Omega$$



∴ Effective resistance across AC, $\mathbf{R_p = 5\ \Omega}$

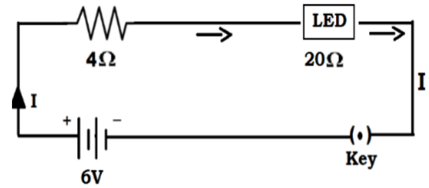
19. A piece of wire having a resistance of 5 ohm cut into five equal parts. If the five parts of the wire are connected in parallel, then find the effective resistance of the combination?

Given: R = **5** Ω, Length of single part $L' = \frac{L}{5}$ **[PTA – 3]**

Solution: $R' = \frac{\rho L'}{A} = \frac{\rho L}{5A} = \frac{R}{5} = \frac{5}{5} = 1\ \Omega$ $\quad (\because R = \frac{\rho L}{A})$

Effective resistance, $R_p = \frac{R'}{5} = \frac{1}{5} = 0.2\ \Omega$

20. **An electric lamp of resistance 20 ohm and a resistance of 4 ohm are connected in series to a 6 v battery as shown in the figure. [PTA – 6]**



a) Find the total resistance of the circuit.

b) Find the current flowing through the circuit.

c) Find the potential difference across the resistor.

Given : $R_1 = 20\ \Omega$, $R_2 = 4\ \Omega$ $V = 6\ V$

Solution:

a) Total Resistance $R_s = R_1 + R_2 = 20\ \Omega + 4\ \Omega \Rightarrow R_s = \mathbf{24\ \Omega}$

b) Current, $I = \frac{V}{R} = \frac{6}{24} = \mathbf{0.25\ A}$

c) Potential difference $V = IR = 0.25 \times 4 = \mathbf{1\ V}$

21. **A charge of 10 coulomb flows through a bulb for 5 seconds. What is the current through the bulb? [MDL – 19]**

Given : $Q = 10\ C$, $t = 5\ s$

Solution : $I = \frac{Q}{t} = \frac{10}{5} = 2\ A$ ∴ The current through the bulb, **I = 2 A**

5. ACOUSTICS

1. **A sound wave has a frequency of 200 Hz and a speed of 400 m s^{-1} in a medium. Find the wavelength of the sound wave.**

Given: $n = 200$ Hz, $v = 400\ m\ s^{-1}$, $\lambda = ?$

Solution :

Velocity, $v = n\lambda$

$$\lambda = \frac{v}{n} = \frac{400}{200}$$

$$\lambda = \mathbf{2\ m}$$

2. **The thunder of cloud is heard 9.8 seconds later than the flash of lightning. If the speed of sound in air is 330 m s^{-1}, what will be the height of the cloud?**

Given : $t = 9.8$ s, $v = 330\ m\ s^{-1}$, $d = ?$

Solution : $v = \frac{\text{height}}{\text{Time}}$

$$\text{height} = v \times t = 330 \times 9.8$$

$$\text{height} = \mathbf{3234\ m}$$

3. **A person who is sitting at a distance of 400 m from a source of sound is listening to a sound of 600 Hz. Find the time period between successive compressions from the source?**

Given : $n = 600$ Hz, $T = ?$

Solution : The time period between successive thecompressions } = The time period of the wave(T).

$$T = \frac{1}{n} = \frac{1}{600} = 0.00166\ s$$

$$T = 1.7 \times 10^{-3}\ \text{seconds}$$

4. **An ultrasonic wave is sent from a ship towards the bottom of the sea. It is found that the time interval between transmission and reception of the wave is 1.6 seconds. What is the depth of the sea, if the velocity of sound in the seawater is 1400 m s^{-1}?**

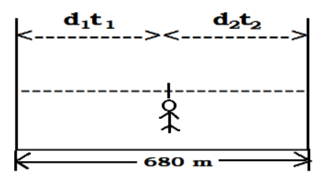
Given : $t = 1.6$ s; $v = 1400$ m s^{-1}

Distance travelled = 2d; Sea Depth = ?

Solution : Velocity, $V = \frac{2d}{t}$

$$d = \frac{V\,t}{2} = \frac{1400 \times 1.6}{2} = \mathbf{1120\ \boldsymbol{m}}$$

5. **A man is standing between two vertical walls 680 m apart. He claps his hands and hears two distinct echoes after 0.9 seconds and 1.1 second respectively. What is the speed of sound in the air?**



Given: $t_1 = 0.9$s, $t_2 = 1.1$s, $d_1+d_2 = 680$m

Solution: $V = \frac{2d}{t} \Rightarrow d = \frac{V\,t}{2}$

$$d_1 + d_2 = \frac{V\times t_1}{2} + \frac{V\times t_2}{2} = \frac{V}{2}(t_1 + t_2)$$

$$\frac{V}{2}(0.9 + 1.1) = 680 \text{ m}$$

$$\frac{V}{2} \times 2 = 680 \text{ m}$$

$$V = \mathbf{680\ m\ s^{-1}}$$

6. **Two observers are stationed in two boats 4.5 km apart. A sound signal sent by one, under water, reaches the other after 3 seconds. What is the speed of sound in the water?**

Given: d = 4.5 km = 4500 m; t = 3 s

Solution : $V = \frac{d}{t} = \frac{4500}{3} = \mathbf{1500\ m\ s^{-1}}$

7. **A strong sound signal is sent from a ship towards the bottom of the sea. It is received back after 1 s. What is the depth of sea given that the speed of sound in water 1450 m s^{-1}?**

Given : V = 1450 m s^{-1} ; t = 1 s

Solution: Velocity = $\frac{2 \times \text{depth}}{\text{time}}$

$$\text{Depth} = \frac{\text{Velocity} \times \text{time}}{2} = \frac{1450 \times 1}{2}$$

$$\text{Depth} = \mathbf{725\ m}$$

8. **Air temperature in the Rajasthan desert can reach 46°$\boldsymbol{C}$. What is the velocity of sound in air at that temperature? (V_0 = 331 m s^{-1})**

$V_0 = 331$ m s^{-1} $\quad$ $T = 46$°C

$V_T = V_0 + 0.61\,T = 331 + 0.61 \times 46 = 359.06$ ms^{-1}

9. **What will be the frequency of sound having 0.20 m as its wavelength, when it travels with a speed of 331 m s^{-1}?**

$$n = \frac{V}{\lambda} = \frac{331}{0.20} = \frac{3310}{2} = 1655 \text{ Hz}$$

Example Problems

10. At what temperature will the velocity of sound in air be double the velocity of sound in air at 0° C?

Given **:** Let, T → Required temperature in ℃. **[TB – 61, 62]**

V_1 and V_2 → Velocity of sound at temperatures T_1K and T_2K respectively.

T_1 = 273 K (0℃) and T_2 = (273 + T) K $\quad V_2 = 2V_1$

Solution : $\frac{V_2}{V_1} = \sqrt{\frac{T_2}{T_1}} = \sqrt{\frac{273+T}{273}} = 2$

$\frac{T+273}{273} = 4 \quad \Rightarrow \quad T = (4 \times 273) - 273$

$T = 1092 - 273 = 819℃$

∴ At 819℃, the velocity of sound in air will be double the velocity of sound in air at 0℃.

11. A source producing a sound of frequency 90 Hz is approaching a stationary listener with a speed equal to (1/10) of the speed of sound. What will be the frequency heard by the listener?

Given **:** $V_s = \frac{1}{10}$ v, n = 90 Hz **[TB – 67] [PTA – 4]**

Solution : When the source is moving towards the stationary listener, the expression for apparent frequency, $n' = \left(\frac{V}{V-V_s}\right)n$

$$n' = \left(\frac{V}{V-\frac{1}{10}v}\right)n = \left(\frac{\cancel{v}}{\frac{(10-1)\cancel{v}}{10}}\right)n = \left(\frac{10}{9}\right)n$$

$$n' = \left(\frac{10}{9}\right) \times 90 = 100 \text{ Hz}$$

∴ The frequency heard by the listener is 100 Hz.

12. A source producing a sound of frequency 500 Hz is moving towards a listener with a velocity of 30 ms^{-1}. The speed of the sound is 330 ms^{-1}. What will be the frequency heard by listener? **[TB – 67, 68] [PTA – 2]**

Given **:** $V = 330\ ms^{-1}$, $V_s = 30\ ms^{-1}$, n = 500 Hz

Solution : When the source is moving towards the stationary listener, the expression for apparent frequency, $n' = \left(\frac{V}{V-V_s}\right)n = \left(\frac{330}{330-30}\right) \times 500$

$$n' = \left(\frac{330}{300}\right) \times 500 = \frac{11}{10} \times 500 = 550 \text{ Hz}$$

∴ The frequency heard by listener is 550 Hz.

13. A source of sound is moving with a velocity of 50 ms^{-1} towards a stationary listener. The listener measures the frequency of the source as 1000 Hz. What will be the apparent frequency of the source when it is moving away from the listener after crossing him? (velocity of sound in the medium is 330 ms^{-1}) **[TB – 68] [MDL – 19]**

Given **:** $V = 330\ ms^{-1}$, $V_s = 50\ ms^{-1}$, n′ = 1000 Hz

Solution : When the source is moving towards the stationary listener, the expression for apparent frequency $n' = \left(\frac{V}{V-V_s}\right)n$

$$1000 = \left(\frac{330}{330-50}\right)n = \left(\frac{330}{280}\right)n \Rightarrow n = \frac{1000 \times 280}{330} = 848.48 \text{ Hz}$$

∴ The actual frequency of the sound is 848.48 Hz

When the source is moving away from the stationary listener, the expression for apparent frequency is,

$$n' = \left(\frac{V}{V+V_s}\right)n = \left(\frac{330}{330+50}\right) \times 848.48 = 736.84 \text{ Hz}$$

∴ The apparent frequency of the sound is 736.84 Hz

14. At what speed should a source of sound move away from a stationary observer so that observer finds the apparent frequency equal to half of the original frequency? [TB – 68] [PTA – 5]

Given : $n' = \frac{n}{2}$

Solution:

When the source is moving away from the stationary listener, the expression for the apparent frequency, $n' = \left(\frac{V}{V+V_s}\right) n$

$$\Rightarrow \frac{n}{2} = \left(\frac{V}{V+V_s}\right) n$$

$$V_s = V$$

15. A source and listener are both moving towards each other with a speed v/10 where v is the speed of sound. If the frequency of the note emitted by the source is f, what will be the frequency heard by the listener? [TB – 68]

Given : $V_l = \frac{v}{10}\ ms^{-1}$

$V_s = \frac{v}{10}\ ms^{-1}, \quad n = f$

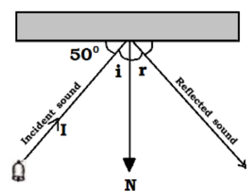
Solution: When source and listener are both moving towards each other,

The apparent frequency, $n' = \left(\frac{V+V_l}{V-V_s}\right) n$

$$n = \left(\frac{V+\frac{v}{10}}{V-\frac{v}{10}}\right) n = \left(\frac{11v}{10} \times \frac{10}{9v}\right) f = \frac{11}{9} f = 1.22\ f$$

Additional Problems

16. From the given figure, calculate angle of reflection of sound. [PTA – 4]



Solution:

Angle of incident sound (i) = 90° – 50° = 40°

Angle of Reflection (r) = angle of incident sound (i)

$\therefore$ r = 40°

17. Calculate the frequency of visible light having wavelength 3000A° travelling in vacuum.

Given : $\lambda = 3000\ \text{Å} = 3000 \times 10^{-10}$m **[PTA – 5]**

Solution : Velocity $(c) = 3 \times 10^{8}\ ms^{-1}$

$$\text{Frequency}(\nu) = \frac{c}{\lambda} = \frac{3\times10^{8}}{3000\times10^{-10}}$$

$$\text{Frequency}(\nu) = \frac{3\times10^{8}}{3\times10^{-7}} = \mathbf{10^{15}\ Hz}$$

18. A strong ultrasonic sound signal is sent from a ship towards the bottom of the sea. It is received by the receiver after 2 s. Calculate the depth of sea? The speed of sound in water 1450 m s^{-1}?

Given : $V = 1450\ ms^{-1}$; $t = 2$ s **[PTA – 5]**

Solution : $\text{Velocity} = \frac{2 \times \text{depth}}{\text{time}} \Rightarrow \text{Depth} = \frac{\text{Velocity} \times \text{time}}{2} = \frac{1450 \times 2}{2} = \mathbf{1450\ m}$

6. NUCLEAR PHYSICS

1. $_{88}Ra^{226}$ experiences three α- decay. Find the number of neutrons in the daughter element.

Three α decay	$_{88}Ra^{226} \rightarrow {}_{z-2}Y^{A-4} + 3\ {}_{2}He^{4}$

Mass number of Parent element = Mass number of 3 α-particles **+** Mass number of daughter element

$$226 = 3\times4 + A = 12 + A$$

$$A = 226 – 12 = 214$$

Atomic number of Parent element = Atomic number of 3 α-particles **+** Atomic number of daughter element

$$88 = 3\times2 + Z = 6 + Z$$

$$Z = 88 – 6 = 82$$

Number of neutrons = A – Z = 214 – 82 = 132

2. **A cobalt specimen emits induced radiation of 75.6 millicurie per second. Convert this disintegration into becquerel (one curie = 3.7×10^{10}Bq)**

$$1 \text{ Curie} = 3.7 \times 10^{10} \text{Bq}$$

$$75.6 \text{ millicurie} = 75.6 \times 10^{-3} \times 3.7 \times 10^{10} = 75.6 \times 3.7 \times 10^{7}$$

$$= 279.72 \times 10^{7} = \mathbf{0.28 \times 10^{10}\ Bq}$$

3. **Mass number of a radioactive element is 232 and its atomic number is 90. When this element undergoes certain nuclear reactions, it transforms into an isotope of lead with a mass number 208 and an atomic number 82. Determine the number of alpha and beta decay that can occur.**

Let a, b be the number of alpha and beta decay respectively.

$$\boxed{{}_{90}X^{232} \rightarrow {}_{82}Pb^{208} + a\ {}_{2}He^{4} + b\ {}_{-1}e^{0}}$$

Comparing mass number

Mass number of 'a' alpha particle = 4a

Mass number of 'b' beta particle = 0

$232 = 208 + 4a + 0 \Rightarrow 4a = 232 - 208$

$4a = 24$

$a = 6$

Comparing Atomic number

Atomic number of 'a' alpha particle = 2a

Atomic number of 'b' beta particle = –b

$90 = 82 + 2a - b \Rightarrow 90 - 82 = 2a - b$

$8 = 2(6) - b$

$b = 12 - 8 = 4$

∴ The number of ***alpha decay is 6*** and number of ***beta decay is 4.***

Example Problems

4. **A radon specimen emits radiation of 3.7×10^{3} GBq per second. Convert this disintegration in terms of curie. (1 curie = 3.7×10^{10} disintegration per second)** **[Ex : 6.2, TB – 85]**

Given : 1 Bq = one disintegration per second,

one curie = 3.7×10^{10} Bq

Solution : $1 \text{ Bq} = \frac{1}{3.7 \times 10^{10}} \text{curie}$

$$\therefore 3.7 \times 10^{3} \text{GBq} = 3.7 \times 10^{3} \times 10^{9} \times \frac{1}{3.7 \times 10^{10}} = \mathbf{100\ curie}$$

5. **${}_{92}U^{235}$ experiences one α - decay and one β - decay. Find number of neutrons in the final daughter nucleus that is formed.** **[Ex : 6.3, TB – 85]**

Let X & Y be the final daughter nucleus.

α – decay : ${}_{92}U^{235} \xrightarrow{\alpha \text{ decay}} {}_{90}X^{231} + {}_{2}He^{4}$

mass number (A) = 235 – 4 = 231

atomic number(Z) = 92 – 2 = 90

β – decay : ${}_{90}X^{231} \xrightarrow{\beta \text{ decay}} {}_{91}Y^{231} + {}_{-1}e^{0}$

mass number (A) = 231 (remains same)

atomic number(Z) = 90 + 1 = 91

No. of neutrons = Mass number – Atomic number

= 231 – 91 = 140

∴ Number of neutrons in the final daughter nucleus is **140.**

6. Identify A, B, C, and D from the following nuclear reactions. **[Ex : 6.1, TB – 85]**

(i) $_{13}Al^{27} + A \longrightarrow {}_{15}P^{30} + B$

(ii) $_{12}Mg^{24} + B \longrightarrow {}_{11}Na^{24} + C$

(iii) $_{92}U^{238} + B \longrightarrow {}_{93}Np^{239} + D$

Solution :

(i) $_{13}Al^{27} + {}_{2}\mathbf{He}^{4} \longrightarrow {}_{15}P^{30} + {}_{0}\mathbf{n}^{1}$

(ii) $_{12}Mg^{24} + {}_{0}\mathbf{n}^{1} \longrightarrow {}_{11}Na^{24} + {}_{1}\mathbf{H}^{1}$

(iii) $_{92}U^{238} + {}_{0}\mathbf{n}^{1} \longrightarrow {}_{93}Np^{239} + {}_{-1}\mathbf{e}^{0}$

$A \longrightarrow \alpha$ particle($_2He^4$)	$B \longrightarrow$ Neutron ($_0n^1$)
$C \longrightarrow$ Proton ($_1H^1$)	$D \longrightarrow$ Electron ($_{-1}e^0$)

7. Calculate the amount of energy released when a radioactive substance undergoes fusion and results in a mass defect of 2 kg.

Given : mass (m) = 2 kg; **[Ex : 6.4, TB – 85]**

Velocity of light (c) = $3 \times 10^8 ms^{-1}$

Solution : **[APR – 2023]**

Einstein's equation, $E = mc^2$

$$E = 2 \times (3 \times 10^8)^2$$

$$E = 1.8 \times 10^{17}\ J\ /\ 18 \times 10^{16} J$$

Additional Problems

8. $_{92}U^{238}$ experiences α decay. Find the number of neutrons in the daughter element. **[SEP – 2021]**

One α decay	$_{92}U^{238} \rightarrow {}_{Z}Y^{A} + {}_{2}He^{4}$ +energy

mass number (A) = 238 – 4 = 234

atomic number(Z) = 92 – 2 = 90

Number of neutrons = A – Z = 234 – 90 = **144**

9. $_{92}U^{235}$ experiences one α decay. Find the number of neutrons in the final daughter nucleus that is formed. **[PTA – 1]**

One α decay	$_{92}U^{235} \rightarrow {}_{Z}Y^{A} + {}_{2}He^{4}$ +energy

mass number (A) = 235 – 4 = 231

atomic number(Z) = 92 – 2 = 90

Number of neutrons = A – Z = 231 – 90 = **141**

10. In the nuclear reaction given below, the nucleus X changes to nucleus Y by the reaction of alpha decay. Then what are the atomic number and mass number of Y? **[PTA – 5]**

One α decay	$_{88}X^{226} \rightarrow {}_{Z}Y^{A} + {}_{2}He^{4}$ +energy

mass number (A) = 226 – 4 = **222**

atomic number(Z) = 88 – 2 = **86**

11. Calculate the amount of energy released when a radioactive substance undergoes fusion and results in a mass defect of 1 kg.

Mass defect (m) = 1 kg **[PTA – 5]**

Velocity (c) = $3 \times 10^8\ m\ s^{-1}$

By Einstein's equation, $E = mc^2$

$E = 1 \times (3 \times 10^8)^2$

$= \mathbf{9 \times 10^{16}\ J}$ **(or)** $\mathbf{0.9 \times 10^{17}\ J}$

7. ATOMS AND MOLECULES

1. How many grams are there in the following? **[PTA – 4]**

i) 2 moles of hydrogen molecule, H_2

Molecular mass of $H_2 = 1 \times 2 = 2$

$$\text{Mass} = \text{No. of moles} \times \text{Molecular mass} = 2 \times 2 = 4\ g$$

ii) 3 moles of chlorine molecule, Cl_2

Molecular mass of $Cl_2 = 35.5 \times 2 = 71$

$$\text{Mass} = \text{No. of moles} \times \text{Molecular mass} = 3 \times 71 = 213$$

iii) 5 moles of sulphur molecule, S_8

Molecular mass of $S_8 = 32 \times 8 = 256$

$$\text{Mass} = \text{No. of moles} \times \text{Molecular mass} = 5 \times 256 = 1280\ g$$

iv) 4 moles of phosphorous molecule, P_4

Molecular mass of $P_4 = 30 \times 4 = 120$

$$\text{Mass} = \text{No. of moles} \times \text{Molecular mass} = 4 \times 120 = 480\ g$$

Note : *In Text Book solved problems (Pg. no. 100, Q.No. I-3), atomic mass of Phosphorus is given as* ***30.*** *But, correct approximate value is* **31.**

2. Calculate the (mass) % of each element in calcium carbonate. **(Atomic mass: C -12, O -16, Ca - 40)**

Molecular mass of $CaCO_3 = 40 + 12 + (16 \times 3) = 100$ g **[JUN – 2023, PTA – 2]**

Elements	Mass of Individual element	$\frac{\text{Mass of element}}{\text{Molecular mass}} \times 100$	Mass percentage of each element
Ca	40	$\frac{40}{100} \times 100$	40%
C	12	$\frac{12}{100} \times 100$	12%
O	3×16 = 48	$\frac{48}{100} \times 100$	48%

3. Calculate the % of oxygen in $Al_2(SO_4)_3$. (Atomic mass: Al -27, O -16, S - 32). **[PTA – 2]**

Molecular mass of $Al_2(SO_4)_3 = (2 \times 27) + (3\times(32 + (4 \times 16))) = 342$ g

% of O in $Al_2(SO_4)_3 = \frac{3 \times 4 \times 16}{342} \times 100 = \frac{192}{342} \times 100 = 56.14\%$

4. Calculate the % relative abundance of B -10 and B -11, if its average atomic mass is 10.804 amu.

Let a_1, a_2 be the % abundance of B-10 and B-11 respectively. $m_1 = 10$, $m_2 = 11$

$$a_1 + a_2 = 100 \quad \Rightarrow \quad a_1 = 100 - a_2$$

$$\text{Average Atomic Mass} = m_1 \times \frac{a_1}{100} + m_2 \times \frac{a_2}{100}$$

$$= 10 \times \frac{(100 - a_2)}{100} + 11 \times \frac{a_2}{100}$$

$$= 10 \times \left(1 - \frac{a_2}{100}\right) + \frac{11a_2}{100}$$

$$= 10 - \frac{10a_2}{100} + \frac{11a_2}{100}$$

$$10.804 = 10 + \frac{a_2}{100} \quad (\because \text{Average Atomic Mass of B} = 10.804 \text{ amu})$$

$$\frac{a_2}{100} = 10.804 - 10 = 0.804$$

$$a_2 = 0.804 \times 100 = 80.4\ \%$$

$$a_1 = 100 - 80.4 = 19.6\ \%$$

$\therefore$ **% abundance of B-10 = 19.6 %** **&** % **abundance of B-11 = 80.4%**

5. Find the percentage of nitrogen in ammonia. **[PTA – 1]**

% of Nitrogen in $NH_3 = \frac{\text{Mass of element}}{\text{Molecular mass}} \times 100 = \frac{14}{17} \times 100 = 82.35\ \%$

6. Calculate the gram molecular mass of calcium carbonate involved in this reaction.

Gram Molecular Mass of $CaCO_3 = (40 \times 1) + (12 \times 1) + (16 \times 3)$

$= 40 + 12 + 48 = 100$ g

7. Calculate the number of water molecule present in one drop of water, which weighs 0.18 g.

Molecular mass of $H_2O = (1 \times 2) + 16 = 18$ g

$$\text{Number of molecules} = \frac{\text{Mass of water}}{\text{Molecular mass}} \times \text{Avogadro number}$$

$$= \frac{0.18}{18} \times 6.023 \times 10^{23}$$

$\therefore$ The No. of water molecules $= 6.023 \times 10^{21}$

8. $N_2 + 3\ H_2 \rightarrow 2\ NH_3$ (The atomic mass of nitrogen is 14, and that of hydrogen is 1)

1 mole of nitrogen (__g) + 3 moles of hydrogen (__ g) → 2 moles of ammonia (__ g)

$$\text{Mass} = \text{No. of moles} \times \text{Molecular mass}$$

$$\text{Mass of } N_2 = 1 \times (14 \times 2) = 28$$

$$\text{Mass of } H_2 = 3 \times (1 \times 2) = 6$$

$$\text{Mass of } NH_3 = 2 \times (14 + (3 \times 1)) = 34$$

1 mole of nitrogen (**28 g**) + 3 moles of hydrogen (**6 g**) → 2 moles of ammonia (**34 g**)

9. Calculate the number of moles in i) 27g of *Al* ii) 1.51×10^{23} molecules of NH_4Cl. [PTA – 5]

i) 27g of Al :

$$\text{Number of moles} = \frac{\text{Mass of } Molecule}{\text{Atomic mass of } Molecule}$$

$$= \frac{27}{27}$$

= 1 mole

ii) 1.51×10^{23} molecules of NH_4Cl :

$$\text{Number of moles} = \frac{\text{Number of Molecules}}{\text{Avogadro number}}$$

$$= \frac{1.51 \times 10^{23}}{6.023 \times 10^{23}}$$

= 0.25 moles

Example Problems

Calculation of Average Atomic Mass

10. Oxygen is the most abundant element in both the Earth's crust and the human body. It exists as a mixture of three stable isotopes in nature as shown in below table. Calculate the atomic mass of oxygen. [TB – 94]

Isotope	Mass (amu)	% abundance
$_8O^{16}$	15.9949	99. 757
$_8O^{17}$	16.9991	0.038
$_8O^{18}$	17.9992	0.205

Atomic mass of oxygen = (15.9949 × 0.99757) + (16.9991 × 0.00038) + (17.9992 × 0.00205)

= 15.999 amu

11. Boron naturally occurs as a mixture of boron-10 (5 protons + 5 neutrons) and boron-11(5 protons + 6 neutrons) isotopes. The percentage abundance of B-10 is 20 and that of B-11 is 80. Calculate the atomic mass of boron. [TB – 94]

$$\text{Atomic mass of boron} = \left(10 \times \frac{20}{100}\right) + \left(11 \times \frac{80}{100}\right)$$

= (10 × 0.20) + (11 × 0.80)

= 2 + 8.8 = 10.8 amu

Calculation of Relative Molecular Mass

12. Sulphuric acid contains 2 atoms of hydrogen, 1 atom of sulphur and 4 atoms of oxygen. Calculate the relative molecular mass of sulphuric acid (H_2SO_4). [TB – 96]

Relative Molecular ***Mass of*** H_2SO_4 =(2×mass of hydrogen)+(1×mass of sulphur)+(4×mass of oxygen)

$$= (2 \times 1) + (1 \times 32) + (4 \times 16) = 98$$

∴ One molecule of H_2SO_4 is 98 times as heavy as $\frac{1}{12^{\text{th}}}$ of the mass of a carbon –12.

13. A water molecule is made of 2 atoms of hydrogen and one atom of oxygen. Calculate the relative molecular mass of water (H_2O). [TB – 96]

Relative Molecular Mass of water = (2 × mass of hydrogen) + (1 × mass of oxygen)

$$= (2 \times 1) + (1 \times 16) = 18$$

∴ One molecule of H_2O is 18 times as heavy as $\frac{1}{12^{\text{th}}}$ of the mass of a carbon –12.

Calculation of Mass percentage composition

14. Find the mass percentage composition of methane (CH_4). [TB – 98]

Molar mass of CH_4 = $12 + (1 \times 4) = 16$ g

Mass % of Carbon = $\frac{12}{16} \times 100$ = 75%

Mass % of Hydrogen = $\frac{4}{16} \times 100$ = 25%

Calculation of Molecular mass

15. Calculate the gram molecular mass of the following. i) H_2O ii) CO_2 iii) $Ca_3(PO_4)_2$

i) H_2O [TB – 99, 100]

Atomic mass of H =1,O=16

Gram Molecular Mass of H_2O

$= (1 \times 2) + (16 \times 1)$

$= 2 + 16 = 18$ g

ii) CO_2 [TB – 100] [SEP-2021]

Atomic mass of C=12,O=16

Gram Molecular Mass of CO_2

$= (12 \times 1) + (16 \times 2)$

$= 12 + 32 = 44$ g

iii) $Ca_3(PO_4)_2$ [TB – 100]

Atomic mass of Ca = 40, P =30, O =16

Gram Molecular Mass of $Ca_3(PO_4)_2$

$= (40 \times 3) + [30 + (16 \times 4)] \times 2$

$= 120 + (94 \times 2) = 120 + 188 = 308$ g

Note : *In Book example problem, atomic mass of Phosphorus is given as* ***30.*** *But, correct approximation value is* **31.**

Calculation based on number of atoms / molecules

16. i) Calculate the number of moles in 46 g of sodium. [TB – 100] [MDL – 19]

Number of moles of Sodium = $\frac{\text{Mass of the element}}{\text{Atomic mass of the element}} = \frac{46}{23}$ = 2 moles

ii) Calculate the number of moles in 5.6 litre of oxygen at S.T.P. [TB – 100]

Number of moles of Oxygen

$= \frac{\text{Given volume of } O_2 \text{ at S.T.P}}{\text{Molar volume at S.T.P}}$

$= \frac{5.6}{22.4}$ = 0.25 mole

iii) Calculate the number of moles of a sample that contains 12.046×10^{23} atoms of iron.

Number of moles of Iron **[TB – 100]**

$= \frac{\text{Number of atoms of iron}}{\text{Avogadro's number}}$

$= \frac{12.046 \times 10^{23}}{6.023 \times 10^{23}}$ = 2 moles

Calculation of mass from mole

17. Calculate the mass of the following : **[TB – 100, 101]**

$$\textbf{No. of moles} = \frac{\text{Mass of Compound}}{\text{Molecular / atomic mass}} = \frac{\text{Number of atoms}}{\text{Avogadro's number}} = \frac{\text{Given volume at STP}}{\text{Molar Volume}}$$

i) 0.3 mole of Aluminium (Atomic mass of Al = 27)

Mass = No. of moles × Atomic mass = 0.3 × 27 = 8.1 g

ii) 2.24 litre of SO_2 gas at S.T.P

Molecular mass of SO_2 = 32 + (16 × 2) = 32 + 32 = 64 g

Number of moles of SO_2 = $\frac{2.24}{22.4}$ = 0.1 mole

Mass of SO_2 = No. of moles × Molecular mass = 0.1 × 64 = 6.4 g

iii) 1.51×10^{23} molecules of water [MDL – 19]

Molecular mass of H_2O = 18

Number of moles = $\frac{1.51\times 10^{23}}{6.023 \times 10^{23}} = \frac{1}{4}$ = 0.25 mole

Number of moles = $\frac{\text{Mass}}{\text{Molecular mass}}$

0.25 = $\frac{\text{mass}}{18}$ ⇒ Mass = 0.25×18 = 4.5g

iv) 5×10^{23} molecules of glucose?

Molecular mass of $C_6H_{12}O_6$(glucose)

$= (12 \times 6) + (1 \times 12) + (16 \times 6) = 180$

Mass of glucose = $\frac{\text{Molecular mass}\times\text{Number of particles}}{\text{Avogadro's number}}$

$= \frac{180\times5\times 10^{23}}{6.023 \times 10^{23}} = 149.43 = 149.43$ g

Calculation based on number of atoms / molecules

$$\textbf{No. of moles} = \frac{\text{Mass of Compound}}{\text{Molecular / atomic mass}} = \frac{\text{Number of atoms}}{\text{Avogadro's number}} = \frac{\text{given volume at STP}}{\text{Molar Volume}}$$

18. i) Calculate the number of molecules in 11.2 litre of CO_2 at S.T.P **[TB – 101]**

Number of moles of CO_2 = $\frac{\text{volume at S.T.P}}{\text{Molar volume}} = \frac{11.2}{22.4}$ = 0.5 mole

Number of molecules of CO_2 = Number of moles of CO_2 × Avogadro's number

$= 0.5 \times 6.023 \times 10^{23} = 3.011\times10^{23}$ molecules

ii) Calculate the number of atoms present in 1 gram of gold (Atomic mass of Au = 198)

Number of atoms of Au

$= \frac{\text{Mass of Au} \times \text{Avogadro's number}}{\text{Atomic mass of Au}}$

$= \frac{1}{198} \times 6.023 \times 10^{23}$

$= 3.042 \times 10^{21}$

iii) Calculate the number of molecules in 54 g of H_2O.

Number of molecules of water

$= \frac{\text{Avogadro number}\times \text{Given mass}}{\text{Gram molecular mass}}$

$= \frac{6.023 \times10^{23} \times54}{18}$

$= 18.069 \times 10^{23}$ molecules

iv) Calculate the number of atoms of oxygen and carbon in 5 moles of CO_2.

1 mole of CO_2 contains 2 moles of oxygen ⇒ 5 moles of CO_2 contain 10 moles of oxygen

Number of atoms of oxygen = Number of moles of oxygen × Avogadro's number

$= 10 \times 6.023 \times10^{23}$

$= 6.023\times10^{24}$ atoms of oxygen

1 mole of CO_2 contains 1 mole of Carbon ⇒ 5 moles of CO_2 contain 5 moles of Carbon

$= 5 \times 6.023 \times10^{23}$

$= 3.011 \times10^{24}$ atoms of carbon

Calculation based on molar volume

19. Calculate the volume occupied by : **[TB – 101]**

$$\textbf{No. of moles} = \frac{\text{Mass of Compound}}{\text{Molecular / atomic mass}} = \frac{\text{Number of atoms}}{\text{Avogadro's number}} = \frac{\text{Given volume at STP}}{\text{Molar Volume}}$$

i) 2.5 mole of CO_2 at S.T.P.

$$2.5 \text{ mole of } CO_2 = \frac{\text{Volume of } CO_2 \text{ at S.T.P}}{22.4}$$

Volume of CO_2 at S.T.P = 22.4×2.5 = 56 litres

ii) 12.046×10^{23} of ammonia gas molecules.

$$\text{Number of moles} = \frac{\text{Number of molecules}}{\text{Avogadro's number}}$$

$$= \frac{12.046 \times 10^{23}}{6.023 \times 10^{23}}$$

= 2 moles

Volume occupied by NH_3

= Number of moles × Molar volume

= 2 × 22.4 = 44.8 litres at S.T.P

iii) 14 g nitrogen gas.

$$\text{Number of moles} = \frac{14}{28}$$

= 0.5 mole

Volume occupied by N_2 at S.T.P,

= number of moles × molar volume

= 0.5 × 22.4

= 11.2 litres

Calculation based on % composition

20. Calculate % of S in H_2SO_4. **[TB – 102] [APR – 2023]**

Molecular mass of H_2SO_4 = (1 × 2) + (32 × 1) + (16 × 4) = 2 + 32 + 64 = 98 g

$$\% \text{ of S in } H_2SO_4 = \frac{\text{Mass of Sulphur}}{\text{Molecular Mass of } H_2SO_4} \times 100$$

$$= \frac{32}{98} \times 100 = 32.65\%$$

Additional Problems

21. Calculate the number of molecules present in the 36 g water. **[MDL – 19]**

$$\text{Number of molecules of water} = \frac{\text{Given mass}}{\text{Gram Molecular Mass}} \times \text{Avogadro number}$$

$$= \frac{36}{18} \times 6.023 \times 10^{23}$$

$$= 12.046 \times 10^{23}$$

22. The mass percentage of carbon is 27.28% and the mass percentage of oxygen is 72.73%. Calculate the molecular mass of that compound. **[PTA – 4]**

$$\text{No. of moles of C} = \frac{\textit{Mass \% of Carbon}}{\textit{Atomic mass of Carbon}} = \frac{27.28}{12} = 2.27 \cong 2$$

$$\text{No. of moles of O} = \frac{\textit{Mass \% of Oxygen}}{\textit{Atomic mass of Oxygen}} = \frac{72.73}{16} = 4.54 \cong 4$$

Molecular formula : C_2O_4 (or) 2 CO_2

Molecular mass = $(2 \times 12) + (4 \times 16) =$ 88g

23. In chemical industries, the following chemical reaction is used to produce ammonia in large scale. $\mathbf{N_2 + 3H_2 \rightleftharpoons 2NH_3}$ **[PTA – 3]**

Based on mole concept, calculate the mass of nitrogen gas and hydrogen gas required in kilogram to produce 1000kg of ammonia by using the above chemical equation.

Mass of NH_3 = 1000 kg = 10^6 g

Molecular mass of NH_3 = 14 + (3 × 1) = 17 g

No. of moles of NH_3 = $\frac{mass\ of\ NH_3\ produced}{molecular\ mass\ of\ NH_3} = \frac{10^6}{17}$

Required Mass of H_2 = No. of moles of H_2 × Molecular mass

$= \frac{10^6}{17} \times \frac{3}{2} \times (2 \times 1) = 176.47$ kg of H_2

Required Mass of N_2 = No. of moles of N_2 × Molecular mass

$= \frac{10^6}{17} \times \frac{1}{2} \times (14 \times 2) = 823.53$ kg of N_2

∴ Required mass of Nitrogen gas = 823.53 kg

Required mass of Hydrogen gas = 176.47 kg

9. SOLUTIONS

1. A solution is prepared by dissolving 45 g of sugar in 180 g of water. Calculate the mass percentage of solute.

Mass percentage of solute = $\frac{\text{Mass of solute}}{\text{Mass of solvent+ mass of solute}} \times 100 = \frac{45}{180+45} \times 100 = \frac{4500}{225} = \mathbf{20\%}$

2. 3.5 litres of ethanol is present in 15 litres of aqueous solution of ethanol. Calculate volume percent of ethanol solution. **[PTA – 2]**

Volume percentage = $\frac{\text{Volume of solute}}{\text{volume of solution}} \times 100 = \frac{3.5}{15} \times 100$ **= 23. 33%**

Example Problems

Example problems based on solubility

3. 1.5 g of solute is dissolved in 15 g of water to form a saturated solution at 298 K. Find out the solubility of the solute at the temperature. **[TB – 131, 132]**

Given : Mass of the solute = 1.5 g ; Mass of the solvent = 15 g

Solution : Solubility of the solute = $\frac{\text{Mass of the solute}}{\text{Mass of the solvent}} \times 100 = \frac{1.5}{15} \times 100$ = 10 g

∴ *Solubility of the solute is **10 g**.*

4. Find the mass of potassium chloride would be needed to form a saturated solution in 60 g of water at 303 K? Given that solubility of the KC*l* is 37/100 g at this temperature. **[TB – 132]**

Given : Mass of KC*l* in 100 g of water in saturated solution = 37 g

Solution : Mass of KC*l* in 60 g of Water in saturated solution $= \frac{37}{100} \times 60 = 22.2$ g

∴ *Mass of potassium chloride is **22.2 g**.*

5. **What is the mass of sodium chloride that would be needed to form a saturated solution in 50 g of water at 30°C. Solubility of sodium chloride is 36 g at 30°C? [TB – 132]**

Given : At 30°C, 36 g of NaC*l* that would be need for dissolve in 100 g of water.

Solution : ∴ Mass of NaC*l* dissolved in 50 g of water $= \frac{36 \times 50}{100} = 18$ g

∴ *Mass of sodium chloride is **18 g***

6. **The solubility of sodium nitrate at 50°C and 30°C is 114 g and 96 g respectively. Find the amount of salt that will be thrown out when a saturated solution of sodium nitrate containing 50 g of water is cooled from 50°C to 30°C? [TB – 132]**

Given : Amount of sodium nitrate dissolved in100 g of water at 50°C is 114 g

Solution : ⇒At 50° C, amount of sodium nitrate dissolving in 50 g of water $= \frac{114 \times 50}{100} = 57$g

⇒At 30° C, amount of sodium nitrate dissolving in 50 g of water $= \frac{96 \times 50}{100} = 48$ g

∴ Amount of sodium nitrate thrown when 50 g of water is cooled from 50°C to 30°C,= 57 g – 48g = **9g**

Example problems based on Mass percentage

7. **A solution was prepared by dissolving 25 g of sugar in 100 g of water. Calculate the mass percentage of solute. [TB – 132] [APR-2023, SEP – 2020]**

Given : Mass of the solute = 25 g ; Mass of the solvent = 100 g

Solution : Mass of the solution = Mass of the solute + Mass of the solvent = 25 + 100 = 125

$$\text{Mass percentage } = \frac{\text{Mass of the solute}}{\text{Mass of the solution}} \times 100 = \frac{25}{25+100} \times 100 = 20\%$$

∴ *Mass percentage of solute is **20%***

8. **16 grams of NaOH is dissolved in 100 grams of water at 25°C to form a saturated solution. Find the mass percentage of solute and solvent. [TB – 132, 133]**

Given : Mass of the solute = 16 g ; Mass of the solvent = 100 g

Solution: Mass of the solution = Mass of the solute + Mass of the solvent = 16 + 100 = 116

$$\text{Mass percentage of solute} = \frac{\text{Mass of the solute}}{\text{Mass of the solution}} \times 100 = \frac{16}{116} \times 100 = 13.79\%$$

Mass percentage of solvent = 100 – Mass percentage of the solute

= 100 – 13.79 = 86.21%

∴ *Mass percentage of solute is **13.79%** and solvent is **86.21%***

9. **Find the amount of urea which is to be dissolved in water to get 500 g of 10% w/w aqueous solution?**

Given : Mass percentage = 10% ; Mass of the solution = 500 g **[TB – 133]**

Solution : Mass percentage (w/w) $= \frac{\text{Mass of the solute}}{\text{Mass of the solution}} \times 100$

$$10 = \frac{\text{Mass of the urea}}{500} \times 100 \Rightarrow = \frac{10 \times 500}{100} = 50 \text{ g}$$

∴ *Mass of urea is **50 g***

Example problems based on Volume percentage

10. A solution is made from 35 ml of methanol and 65 ml of water. Calculate the volume percentage.

Given : Volume of the solute (ethanol) = 35 ml ; Volume of the solvent (water) = 65 ml

Solution : Mass of the solution = Mass of the solute + Mass of the solvent = 35 + 65 = 100

$$\text{Volume percentage} = \frac{\text{Volume of the solute}}{\text{volume of the solution}} \times 100$$

$$= \frac{35}{100} \times 100 = 35\ \%$$ **[TB – 133]**

$\therefore$ *Volume percentage is **35%.***

11. Calculate the volume of ethanol in 200 ml solution of 20% v/v aqueous solution of ethanol.

Given : Volume of solution = 200 ml ; Volume percentage = 20% **[TB – 133]**

Solution : $$\text{Volume percentage} = \frac{\text{Volume of solute}}{\text{volume of solution}} \times 100$$

$$20 = \frac{\text{Volume of ethanol}}{200} \times 100 = \frac{20 \times 200}{100} = 40\ ml$$

$\therefore$ *Volume of ethanol is **40 ml.***

Additional Problems

12. Calculate the mass of water required in grams to dissolve 10 g of sucrose to produce the mass percentage of 10% solution. **[PTA – 3]**

Let, Mass of water = x So, Mass of solution = $x + 10$

$$\text{Mass \%} = \frac{\text{Mass of the solute}}{\text{Mass of the solution}} \times 100$$

$$10 = \frac{10}{x + 10} \times 100$$

$$x + 10 = 100\ \text{g}$$

$$x = 100\ \text{g} - 10\ \text{g} = \mathbf{90\ g}$$

13. Calculate the solubility of a solute at 300 K by dissolving 10 g of solute in 50 g of solvent.

$$\text{Solubility} = \frac{\text{Mass of the solute}}{\text{Mass of the solvent}} \times 100$$

$$= \frac{10}{50} \times 100 = \mathbf{20\ g}$$ **[PTA – 5]**

10. TYPES OF CHEMICAL REACTIONS

1. Lemon juice has a pH 2, what is the concentration of H^+ ions?

Solution :

$$\text{pH} = -\log_{10}[\text{H}^+] = 2$$

$$\text{Log}_{10}[\text{H}^+] = -2$$

$$\Rightarrow [\text{H}^+] = 0.01 \text{ (or) } 10^{-2}$$

$\therefore$ Concentration is 1.0×10^{-2} mole litre^{-1}

2. Calculate the pH of 1.0×10^{-4} molar solution of HNO_3. **[PTA – 1]**

Given : $[\text{H}^+] = 1.0 \times 10^{-4} = 10^{-4}$

Solution : $\text{pH} = -\log_{10}[\text{H}^+]$

$$= -\log_{10}[10^{-4}]$$

$$= -(-4) \log_{10} 10$$

$$\text{pH} = 4(1) = 4 \ (\because \log_{10} 10 = 1)$$

$\therefore$ pH of HNO_3 is 4.

3. What is the pH of 1.0 × 10^{-5} molar solution of KOH? [PTA – 6]

Given : $[OH^-] = 1.0 \times 10^{-5} = 10^{-5}$

Solution :

$$pOH = -\log_{10}[OH^-]$$
$$= -\log_{10}[10^{-5}]$$
$$= -(-5)\log_{10} 10$$
$$(\because \log_{10} 10 = 1)$$
$$pOH = 5(1) = 5$$
$$\because pH + pOH = 14$$
$$pH = 14 - pOH = 14 - 5 = 9$$

∴ pH of the solution is 9.

4. The hydroxide ion concentration of a solution is 1 × 10^{-11} M. What is the pH of the solution? [PTA – 5]

Given : $[OH^-] = 1.0 \times 10^{-11} = 10^{-11}$

Solution :

$$pOH = -\log_{10}[OH^-]$$
$$= -\log_{10}[1 \times 10^{-11}]$$
$$= -(-11)\log_{10} 10$$
$$(\because \log_{10} 10 = 1)$$
$$pOH = 11(1) = 11$$
$$\because pH + pOH = 14$$
$$pH = 14 - pOH$$
$$pH = 14 - 11 = 3$$

∴ pH of the solution of is 3.

Example Problems

5. Calculate the pH of 0.01 M HNO_3. [TB – 150] [APR-23, MDL – 19]

Given : $[H^+] = 0.01$

Solution :

$$pH = -\log_{10}[H^+]$$
$$= -\log_{10}[0.01]$$
$$= -\log_{10}[10^{-2}]$$
$$= -(-2\log_{10} 10)$$
$$pH = 2 \quad (\because \log_{10} 10 = 1)$$

∴ pH of 0.01 molar solution of HNO_3 is 2.

6. The hydroxyl ion concentration of a solution is 1 × 10^{-9} M. What is the pOH of the solution? [TB – 150]

Given : $[OH^-] = 1 \times 10^{-9} = 10^{-9}$

Solution :

$$pOH = -\log_{10}[OH^-]$$
$$= -\log_{10}[1 \times 10^{-9}]$$
$$= -(-9)\log_{10} 10$$
$$(\because \log_{10} 10 = 1)$$
$$pOH = 9(1) = 9$$

∴ pOH of the solution is 9.

7. A solution has a pOH of 11.76. What is the pH of this solution? [TB – 150]

Given :

$$pOH = 11.76$$

Solution :

$$pH + pOH = 14$$
$$pH = 14 - pOH$$
$$\Rightarrow pH = 14 - 11.76$$
$$pH = 2.24$$

8. Calculate the pH of 0.001 molar solution of HC*l*. [TB – 150]

Given :

$[H^+] = 0.001 = 10^{-3}$

Solution :

$$pH = -\log_{10}[H^+]$$
$$= -\log_{10} 10^{-3}$$
$$= -(-3)\log_{10} 10$$
$$pH = 3(1) = 3 \quad (\because \log_{10} 10 = 1)$$

9. What would be the pH of an aqueous solution of sulphuric acid which is 5×10^{-5} mol litre^{-1} in concentration. **[TB – 150]**

Given : *Dissociation of Sulphuric acid in water :* $H_2SO_{4(aq)} \longrightarrow 2H^+_{(aq)} + SO_4^{2-}{}_{(aq)}$

Solution : 1 mole of sulphuric acid contains → 2 mole of H^+ ions in the solution.

1litre of H_2SO_4 contains → 5×10^{-5} moles of H_2SO_4

$$2 \times 5 \times 10^{-5} = 10 \times 10^{-5} \text{(or) } 1 \times 10^{-4}$$

$$[H^+] = 1.0 \times 10^{-4} = 10^{-4}$$

$$pH = -\log_{10}[H^+] = -\log_{10}10^{-4} = -(-4)\log_{10}10$$

$$pH = 4(1) = 4 \; (\because \log_{10}10 = 1)$$

10. Calculate the pH of 1×10^{-4} molar solution of NaOH. **[TB – 150, 151]**

Given : *Dissociation of NaOH in its solution :* $NaOH_{(aq)} \longrightarrow Na^+_{(aq)} + OH^-_{(aq)}$

Solution : 1 mole of NaOH would give 1 mole of OH^- ions.

$$\therefore [OH^-] = 1 \times 10^{-4} \text{ mol litre}^{-1} = 10^{-4}$$

$$pOH = -\log_{10}[OH^-]$$

$$= -\log_{10}[10^{-4}]$$

$$= -(-4)\log_{10}10$$

$$pOH = 4(1) = 4 \quad (\because \log_{10}10 = 1)$$

$$\therefore pH + pOH = 14$$

$$pH = 14 - pOH$$

$$pH = 14 - 4 = 10$$

11. Calculate the pH of a solution in which the concentration of the hydrogen ions is 1.0×10^{-8} mol litre^{-1}. **[TB – 151]**

Given : $[H^+] = 1.0 \times 10^{-8} = 10^{-8}$

Solution : $pH = -\log_{10}[H^+]$

$$= -\log_{10}10^{-8}$$

$$= -(-8)\log_{10}10$$

$$pH = 8(1) = 8 \; (\because \log_{10}10 = 1)$$

12. pH of a solution is 4.5, what is its pOH? **[TB – 151]**

Given : pH + pOH = 14

Solution : pH + pOH = 14

$$4.5 + pOH = 14$$

$$pOH = 14 - 4.5 = 9.5$$

$$\therefore pOH = 9.5$$

Additional Problems

13. From the value of ionic product of water at $25°C$, find out the concentration of hydroxyl ions. (At $25°C$ concentration of hydrogen ions in water is $10^{-7} mol/dm^3$) **[PTA – 4]**

Given : $K_w = 1.00 \times 10^{-14}$ $[H^+] = 1.00 \times 10^{-7}$ $[OH^-] = ?$

Solution : $K_w = [H^+][OH^-]$

$$1.00 \times 10^{-14} = [1.00 \times 10^{-7}][OH^-]$$

$$[OH^-] = \frac{1.00 \times 10^{-14}}{1.00 \times 10^{-7}} = 1.00 \times 10^{-7}$$

$\therefore$ Conc. of hydroxyl ions in water $= 1.00 \times 10^{-7}$