1. **(B)**

Let the temperature of bath be $x°C$.

Then, $3x = \dfrac{9}{5}x + 32$

$\therefore \quad x = \dfrac{80}{3}$

2. **(B)**

If T is the correct value of temperature, then

$$\dfrac{T-0}{100-0} = \dfrac{60-(-5)}{95-(-5)} = \dfrac{65}{100}$$

$\therefore \quad T = 65°C$

3. **(B)**

$$\text{Slope } = \dfrac{100-0}{212-32} = \dfrac{5}{9}$$

4. **(C)**

Let X be the reading on both Celsius and new temperature scale. Then,

$$\dfrac{T_C - 0}{100-0} = \dfrac{T_N - 100}{400-100}$$

$$\Rightarrow \quad \dfrac{X}{100} = \dfrac{X-100}{300}$$

$\therefore \quad X = -50°C$

5. **(B)**

6. **(C)**

The system is isotropic solid. Therefore on heating, x, r and d all increase in the same ratio equal to $\alpha\Delta T$.

7. **(B)**

As $\alpha_{Al} > \alpha_{steel}$, the expansion in aluminum rod is greater.

8. **(A)**

Since, $L_1 - L_2$ is independent of temperature, $\Delta L_1 = \Delta L_2$ at all temperatures.

$$\Rightarrow \quad \alpha_1 L_1 \Delta T = \alpha_2 L_2 \Delta T$$

$$\therefore \quad \alpha_1 L_1 = \alpha_2 L_2$$

9. **(C)**

$$Y = \dfrac{\sigma}{\Delta L / L} = \dfrac{\sigma}{\alpha \Delta T}$$

$$\Rightarrow \quad \frac{Y_1}{Y_2} = \frac{\alpha_2}{\alpha_1} = \frac{3}{2}$$

10. (C)

$$\Delta L = \Delta L_1 + \Delta L_2$$
$$\Rightarrow \quad \alpha\left(L_1 + L_2\right)\Delta T = \alpha_1 L_1 \Delta T + \alpha_2 L_2 \Delta T$$
$$\therefore \quad \alpha = \frac{\alpha_1 L_1 + \alpha_2 L_2}{L}$$

11. (B)

$$\alpha = \frac{\Delta l}{l\,\Delta T} = \frac{0.5 \times 10^{-3}}{2 \times 5} = 0.5 \times 10^4 \ \text{K}^{-1}$$
$$\therefore \quad \gamma = 3\,\alpha = 1.5 \times 10^{-4} \ \text{K}^{-1}$$

12. (D)
$$\Delta d = \alpha d \Delta T = (2 \times 10^{-5}) \times (2 \times 1) \times 100 = 0.004 \ \text{cm}$$

13. (C)
Let ΔR be the clearance between the tape and ground.

$$L = 2\pi R \qquad\qquad \Rightarrow \quad \frac{\Delta R}{R} = \frac{\Delta L}{L} = \alpha \Delta T$$
$$\therefore \quad \Delta R = \alpha R \Delta T = 1.2 \times 10^{-5} \times 6400 \times \left(40 - 10\right) = 2.3 \ \text{km}$$

14. (B)

$$T = 2\pi\sqrt{\frac{l}{g}} \qquad\qquad \Rightarrow \quad \frac{\Delta T}{T} = \frac{1}{2}\frac{\Delta l}{l} = \frac{1}{2}\alpha\Delta\theta$$
$$\therefore \quad \Delta T = \frac{1}{2}T\alpha\Delta\theta$$

15. (C)

$$I = \frac{ML^2}{12} \qquad\qquad \Rightarrow \quad \frac{\Delta I}{I} = \frac{2\Delta L}{L} = 2\alpha\,\Delta T$$
$$\therefore \quad \Delta I = 2I\,\alpha\,\Delta T$$

16. (A)
Let the amount of hot water taken be m. The cold water taken is $60 - m$.
Heat lost = Heat gained
$$\Rightarrow \quad m \times s \times \left(95 - 35\right) = \left(60 - m\right) \times \left(35 - 15\right)$$
$$\therefore \quad m = 15 \ \text{kg}$$

17. (C)
Let the final temperature be T. Then,
$$2 \times 4200 \times \left(60 - T\right) = \left(1 \times 4200 + 200\right) \times \left(T - 30\right)$$
$$\therefore \quad T \approx 50°\text{C}$$

18. (B)

Let m be the mass of water that falls.

It kinetic energy just before reaching the ground is mgh

$$= m \times 10 \times 168 = 1680 \, m \text{ Joules}.$$

$$\Rightarrow \quad \frac{1680m}{2} = ms\Delta T$$

$$\therefore \quad \Delta T = \frac{840}{S} = \frac{840}{4200} = 0.2°C$$

19. **(C)**

Heat produced = Loss in $KE = \frac{1}{2}mv^2$

Specific heat of lead,

$$s = 0.03 \, \text{cal/g}°C = 0.03 \times 10^3 \times 4.2 = 126 \, \text{J/kg}°C$$

Since, half of the heat produced is absorbed by bullet, we have

$$\frac{1}{2}mv^2 = ms\Delta T$$

$$\therefore \quad \Delta T = \frac{v^2}{4s} = \frac{300^2}{4 \times 126} = 178.6°C$$

20. **(B)**

Let m be the mass of mixture.

Heat absorbed by water = Heat lost by steam

$$\Rightarrow \quad 54 \times 1 \times (90-30) = (m-54)\left[536 \times 1(100-90)\right]$$

$$\therefore \quad m \approx 60 \, \text{g}$$
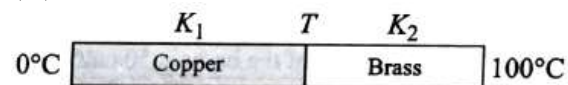
21. **(A)**

For ice to melt completely, heat required is

$$Q_1 = mL = 10 \times 80 = 800 \, \text{cal}$$

Heat released by water to reach $0°C$ is

$$Q_2 = ms\Delta T = 10 \times 1 \times 10 = 100 \, \text{cal}$$

Since, $Q_1 < Q_2$, sufficient heat is not available for complete ice to melt. The temperature of mixture will be 0ºC containing some ice and some water.

22. **(D)**

K_1	T	K_2	
0°C	Copper	Brass	100°C

Let T be the temperature of the junction. Then,

$$\frac{K_1 A}{L}(T-0) = \frac{K_2 A}{L}(100-T)$$

$$\Rightarrow \quad \frac{100-T}{T} = \frac{K_1}{K_2} = 4$$

$$\therefore \quad T = 20°C$$

23. **(B)**

The two layers are in series as the heat flows across the wall. Thermal resistance, $R = \dfrac{L}{KA}$

$\Rightarrow \quad \dfrac{(\Delta T)_A}{(\Delta T)_B} = \dfrac{R_A}{R_B} = \dfrac{K_B}{K_A} = \dfrac{1}{2}$

Also, $(\Delta T)_A + (\Delta T)_B = 36°C$

$\therefore \quad (\Delta T)_A = 12°C$

24. (B)

Thermal resistance, $R = \dfrac{L}{KA}$

$\quad R_A : R_B : R_C = \dfrac{1}{K_A} : \dfrac{1}{K_B} : \dfrac{1}{K_C} = \dfrac{1}{1} : \dfrac{1}{2} : \dfrac{1}{1.5}$

$\Rightarrow \quad (\Delta T)_A : (\Delta T)_B : (\Delta T)_C = R_A : R_B : R_C = 6:3:4$

$\Rightarrow \quad (\Delta T)_A = \dfrac{6}{6+3+4} \times (200-18) = 84°C$

Therefore, temperature of junction of A and B is
$\quad 200 - 84 = 116°C$

25. (B)

Let the temperature of the common junction be T. In steady state, the total heat leaving the junction is zero.

$\Rightarrow \quad \dfrac{3kA}{L}(T-100) + \dfrac{2kA}{L}(T-50) + \dfrac{kA}{L}(T-0) = 0$

$\Rightarrow \quad 3(T-100) + 2(T-50) + T = 0$

$\therefore \quad T = (200/3)°C$

26. (C)

Let R be the thermal resistance of rods. AB and CD. Then the thermal resistance of ring is $2\pi R$.
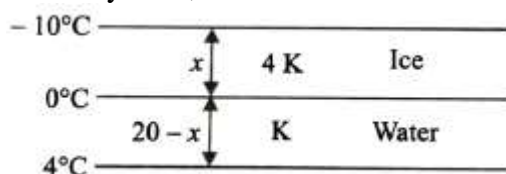
$\quad R_{BC} = \dfrac{\pi R}{2}$

$\quad R_{AC} = R + \dfrac{\pi R}{2} = R\left(1 + \dfrac{\pi}{2}\right)$ and $R_{CD} = R$

It T is the temperature of point C, then

$\quad \dfrac{100-T}{R\left(1 + \dfrac{\pi}{2}\right)} = \dfrac{T-0}{R}$

27. (B)

In steady state, the rate of heat flow is the same through water and ice. So,

$$\frac{KA(4-0)}{20-x} = \frac{4KA(0+10)}{x}$$

$$\Rightarrow \quad \frac{20-x}{x} = \frac{4}{40}$$

$$\therefore \quad x = 18.2 \text{ m}$$

28. (B)

$$P = \frac{nRT}{V} = \frac{m}{M}\frac{RT}{V} \qquad \Rightarrow \quad m = \frac{MV}{RT}P$$

$$\therefore \quad \Delta m = \frac{MV}{RT}\Delta P = \frac{(28\times10^{-3})\times(30\times10^{-3})}{8.31\times273}\times0.5\times10^5$$

$$= 18.5\times10^{-3} \text{ kg} = 18.5 \text{ g}$$

29. (C)

If it takes time t for formation of thickness y of the ice, then $t \propto y^2$.

If for thickness of 1 cm, it takes 7 hours, then for thickness of 2 cm, it takes 28 hours.

For thickness to change from 1 cm to 2 cm, it takes 28 – 7 = 21 hours.

30. (D)

$$P = e\sigma AT^4 = e\sigma 4pr^2 T^4$$

$$\Rightarrow \quad \frac{P_2}{P_2} = \left(\frac{r_2}{r_1}\right)^2 \left(\frac{T_2}{T_1}\right)^4 = \left(\frac{1}{2}\right)^2 (2)^2 = 4$$

$$\therefore \quad P_2 = 4\times450 = 1800 \text{ W}$$

31. (B)

Power radiated by heater (source), $P_s \propto T^4$

Intensity received at distance d is $I = \dfrac{P_s}{4\pi d^2} \propto \dfrac{T^4}{d^2}$

The power absorbed by the foil of area A is

$$P = IA \propto \frac{T^4}{d^2}$$

When both T and d are doubled, P becomes 4 times.

32. (B)

Power radiated by the body, $P \propto T^4$

The power received by detector of area A at distance d is

$$P' \equiv \frac{T^4}{\pi d^2}A \propto \frac{T^4}{d^2}$$

As power received is same, we have

$$\frac{T_1^4}{d_1^2} = \frac{T_2^4}{d_2^2}$$

$$\therefore \quad \frac{d_2}{d_1} = \left(\frac{T_2}{T_1}\right)^2$$

33. (C)

$$P = e\sigma A T^4 \qquad \Rightarrow \quad \frac{\Delta P}{P} = \frac{4\Delta T}{T}$$

$$\Rightarrow \quad \frac{\Delta T}{T} = \frac{1}{4}\left(\frac{\Delta P}{P}\right) = \frac{1}{4} \times 2\% = 0.5\%$$

$$\Rightarrow \quad \Delta T = \frac{0.5}{100} \times (127 + 273) = 2\,K$$

Therefore, the required temperature is
$$(127 + 273) + 2 = 402\,\text{K}$$

34. (B)

According to Newton's law of cooling,

$$\frac{\Delta T}{\Delta t} = k(T - T_0)$$

From $61°C$ to $59°C$, $\quad \frac{2}{4} = k(60 - 30)$

From $51°C$ to $49°C$, $\quad \frac{2}{t} = k(50 - 30)$

From above equations, $\dfrac{t}{4} = \dfrac{30}{20}$

$$\therefore \quad t = 6\,\text{min}.$$

35. (B)

The rate of cooling $(-d\theta/dt)$ is equal to the negative or slope of the curve in $\theta - t$ graph.

At P, $-d\theta/dt = -\tan(\pi - \phi_2) = \tan\phi_2 = K(\theta_1 - \theta_0)$

At Q, $-d\theta/dt = -\tan(\pi - \phi_1) = \tan\phi_1 = K(\theta_1 - \theta_0)$

$$\therefore \quad \frac{\tan\phi_2}{\tan\phi_1} = \frac{\theta_2 - \theta_0}{\theta_1 - \theta_0}$$

36. (B)

$$PV = \frac{m}{M}RT \qquad \Rightarrow \quad m_1 T_1 = m_2 T_2$$

$$\Rightarrow \quad 4T = (4 - 0.8)(T + 50)$$

$$\therefore \quad T = 200\,\text{K}$$

37. (C)

By Wein displacement law, $\lambda_m T = \text{constant}$.

$$\Rightarrow \quad \frac{(\lambda_m)_2}{(\lambda_m)_1} = \frac{T_1}{T_2} = \frac{2000}{3000} = \frac{2}{3}$$

$$\therefore \quad (\lambda_m)_2 = \frac{2}{3}\lambda_m$$

38. (A)

$\lambda_m T = $ constant and $P \propto T^4$

$$\therefore \quad \frac{P_2}{P_1} = \left(\frac{T_2}{T_1}\right)^4 = \left(\frac{\lambda_{m1}}{\lambda_{m2}}\right)^4 = \left(\frac{\lambda_0}{3\lambda_0/4}\right)^4 = \left(\frac{4}{3}\right)^4 = \frac{256}{81}$$

39. (D)

$$\frac{P}{A} = e\sigma T^4 = R$$

For black body, $e = 1$

$$\Rightarrow \quad T = \left(\frac{R}{\sigma}\right)^{1/4}$$

If power radiated is maximum at wavelength λ, then $\lambda T = b$

$$\therefore \quad \lambda \frac{b}{T} = b\left(\frac{\sigma}{R}\right)^{1/4}$$

40. (A)

$\lambda_m T = $ constant and $P = e\sigma A T^4$

$$\Rightarrow \quad \frac{T'}{T} = \frac{\lambda_m}{\lambda'_m} = \frac{\lambda_0}{\lambda_0/2} = 2 \text{ and } \frac{P'}{P} = \left(\frac{T'}{T}\right)^4 = 2^4 = 16$$

$$\therefore \quad P'T' = (16P)(2T) = 32PT$$

41. (C)

$$PV = nRT = \frac{m}{M}RT \qquad \Rightarrow \quad m = \frac{PVM}{RT}$$

$$\Rightarrow \quad \frac{m_{H_2}}{m_{N_2}} = \frac{P_{H_2}}{P_{N_2}} \times \frac{M_{H_2}}{M_{N_2}} = \frac{3.5}{4.5} \times \frac{2}{28} = \frac{1}{18}$$

$$\therefore \quad m_{H_2} = \frac{m_{N_2}}{18} = \frac{18}{18} = 1\,\text{kg}$$

42. (A)

$$v_{\text{rms}} = \sqrt{\frac{3RT}{M}} \qquad\qquad \Rightarrow \quad T = \frac{mv_{\text{rms}}^2}{3R}$$

$$\Rightarrow \quad \frac{T_{\text{He}}}{T_{\text{H}_2}} = \frac{M_{\text{He}}}{M_{\text{O}_2}} \times \left(\frac{v_{\text{He}}}{v_{\text{H}_2}}\right)^2 = \frac{4}{2} \times \left(\frac{5}{7}\right)^2 = \frac{100}{98}$$

$$\therefore \quad T_{\text{He}} = \frac{100}{98} \times 273 = 278.6\,\text{K} = 5.6°\text{C} \approx 6°\text{C}$$

43. (A)

For constant density process, $P \propto T$.

So, when temperature is doubled, pressure is also doubled.

Hence, it increases by 100%.

44. (D)

In graph (i), T is constant. As P increases, volume decreases.

Hence density increases.

In graph (ii), P is constant. As T increases, volume also increases. Hence density decreases.

In graph (iii), $P \propto T$. So, volume is constant. Hence density is also constant.

45. (A)

As the impact is elastic, $\left|\overrightarrow{p_1}\right| = \left|\overrightarrow{p_2}\right| = p = mv$

The impulse per molecule is the magnitude of change in momentum of the molecule equal to
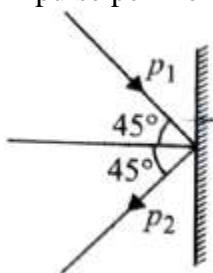
$$2mv\cos 45° = 2 \times 3.32 \times 10^{-27} \times 19^3 \times \frac{1}{\sqrt{2}}$$
$$= 4.7 \times 10^{-24} \text{ ms}^{-1}$$

46. (C)

Translational kinetic energy of the molecule is $K = \frac{3}{2}kT$ and is independent of type of gas. The temperature of both gases is same. Therefore, translational KE of N_2 is same as that of O_2. *i.e.*, 0.048 eV.

47. (A)

$$P = \frac{mv_{rms}^2}{3V} = \frac{M}{3V} \times \frac{3RT}{M} = \frac{2}{3V} \times \frac{3}{2}RT = \frac{2E}{3V}$$

Therefore, $E = \frac{3}{2}RT$ refers to translations kinetic energy per mole.

48. (A)

When gas is heated, its pressure increases. The force exerted by gas on piston B towards right is greater than force exerted on piston A towards left. Since the string is inextensible, both pistons move towards right.

49. (D)

Total translational energy $= \frac{3}{2}nRT = \frac{3}{2}PV$.

This energy is not dependent on gas atomocity as for all gases there are 3 degrees of freedom for translational motion.

50. (B)
$$v_{rms} = \sqrt{\frac{3RT}{M}} \qquad \Rightarrow \quad \log v_{rms} = \frac{1}{2}\log T + \frac{1}{2}\log\left(\frac{3R}{M}\right)$$
The graph is a straight line with slope equal to 0.5.

51. (A)
$$P\left(\frac{m}{\rho}\right) = nRT \qquad \Rightarrow \quad P = \left(\frac{nRT}{m}\right)\rho$$
Slope of the graph is $\dfrac{nRT}{m}$.

Higher slope corresponds to higher temperature.
$$\therefore \quad T_1 > T_2$$

52. (B)
$$nRT = PV = \frac{Pm}{\rho} \qquad \Rightarrow \quad \rho = \frac{m}{n}\frac{P}{RT} = \frac{M}{R}\frac{P}{T}$$
$$\Rightarrow \quad \rho_A = \frac{M}{R}\frac{P_0}{T_0} \qquad \therefore \quad \rho_B = \frac{M}{R}\frac{3P_0}{2T_0} = \frac{3}{2}\rho_A = \frac{3}{2}\rho_0$$

53. (A)
When $V = b$, $P = \dfrac{a}{\left[1+\left(\dfrac{b}{b}\right)^2\right]} = \dfrac{a}{2}$

$$\therefore \quad T = \frac{PV}{nR} = \frac{\left(\dfrac{a}{2}\right)b}{1\times R} = \frac{ab}{2R}$$

54. (B)

55. (B)
When the vessel suddenly stops, the loss in kinetic energy increases the gas temperature.

Hence, $\dfrac{1}{2}mv^2 = nC_V\Delta T$

$$\Rightarrow \quad \frac{1}{2}mv^2 = \frac{m}{M}\times\frac{R}{\gamma-1}\times\Delta T$$

$$\therefore \quad \Delta T = \frac{Mv^2(\gamma-1)}{2R}$$

56. (B)
On heaving water from $0°C$ to $40°C$, volume decreases.
Thus work done is negative.
Now, $\Delta Q = \Delta U + \Delta W$

At constant pressure, $\Delta Q = nC_P\Delta T$

$\Rightarrow nC_P\Delta T = nC_V\Delta T + \Delta W$ or $C_P - C_V = \dfrac{\Delta W}{n\Delta T}$

Here, $\Delta W < 0$ and $\Delta T > 0$

$\Rightarrow C_P - C_V < 0$

$\therefore C_P < C_V$

57. (C)

$\gamma = \dfrac{C_P}{C_V} = \dfrac{(f/2)R + R}{(f/2)R} = \dfrac{f+2}{f}$

$\Rightarrow f\gamma = f + 2$

$\therefore f = \dfrac{2}{\gamma - 1}$

58. (A)

$U = nC_V T = n \times \dfrac{R}{\gamma - 1} \times T = \dfrac{PV}{\gamma - 1}$

59. (D)

At constant pressure, $\dfrac{\Delta U}{\Delta Q} = \dfrac{1}{\gamma} = \dfrac{5}{7}$.

60. (C)

At constant pressure, $\dfrac{\Delta U}{\Delta Q} = \dfrac{1}{\gamma} = \dfrac{1}{1.4}$

$\Rightarrow \Delta U = \dfrac{100}{1.4} = 71.4\,\text{J}$

$\therefore \Delta W = \Delta Q - \Delta U = 100 - 71.4 = 28.6\,\text{J}$

61. (B)

$\gamma = \dfrac{f+2}{f} = \dfrac{6+2}{6} = \dfrac{4}{3}$

At constant pressure, $\dfrac{\Delta U}{\Delta Q} = \dfrac{1}{\gamma} = \dfrac{3}{4}$ and $\Delta Q = \Delta U + 25$

$\therefore \Delta Q = 100\,\text{J}$

62. (B)

Total internal energy remains constant. Thus, Loss of energy by O_2 = Gain in energy by He

$\Rightarrow n_1 C_{V_1}\Delta T_1 = n_2 C_{V_2}\Delta T_2$

$\Rightarrow \dfrac{16}{32} \times \dfrac{5R}{2} \times (37 - T) = \dfrac{2}{4} \times \dfrac{3R}{2} \times (T - 29)$

$\Rightarrow 5(37 - T) = 3(T - 29)$

$\therefore T = 34°\text{C}$

63. (B)

Heat absorbed to convert 5 kg of water to steam.

$$\Delta Q = mL = 5 \times 2.3 \times 10^6 = 11.5 \times 10^6 \text{ J}$$

Work done, $\Delta W = P\Delta V = 10^5 \times (5 \times 1.671 - 5 \times 0.001)$

$$= 0.835 \times 10^6 \text{ J}$$

$$\therefore \quad \Delta U = \Delta Q - \Delta W = (11.5 - 0.835) \times 10^6 = 10.66 \times 10^6 \text{ J}$$

64. **(B)**
For an adiabatic process, $T_1 V_1^{\gamma-1} = T_2 V_2^{\gamma-1}$

$$\therefore \quad T_2 = \left(\frac{V_1}{V_2}\right)^{\gamma-1} T = \left(\frac{4}{3}\right)^{1.5-1} T = \frac{2T}{\sqrt{3}}$$

65. **(D)**
Sudden process is an adiabatic process, in which

$$T_1 V_1^{\gamma-1} = T_2 V_2^{\gamma-1}$$

$$\Rightarrow \quad T_2 = T_1 (V_1/V_2)^{\gamma-1} = 290 \times 10^{\gamma-1}$$

$$\therefore \quad \frac{(T_2)_{\text{mono}}}{(T_2)_{\text{dia}}} = \frac{290 \times 10^{5/3-1}}{290 \times 10^{7/5-1}} = \frac{10^{2/3}}{10^{2/5}} = 10^{4/15}$$

66. **(C)**
In an adiabatic process, $PV^\gamma = \text{constant}$

$$\Rightarrow \quad \frac{\delta P}{P} + \gamma \frac{\delta V}{V} = 0$$

$$\therefore \quad \frac{\delta V}{V} = -\frac{1}{\gamma} \frac{\delta P}{P}$$

67. **(B)**

$$PV^\gamma = \text{constant} \qquad \Rightarrow \quad \frac{nRT}{V} V^\gamma = \text{constant}$$

$$\Rightarrow \quad TV^{\gamma-1} = \text{constant} \quad \Rightarrow \quad \frac{\Delta T}{T} + (\gamma-1)\frac{\Delta V}{V} = 0$$

$$\Rightarrow \quad \frac{\Delta V}{V} = -\frac{\Delta T}{(\gamma-1)T} \quad \therefore \quad \alpha = \frac{\Delta V/V}{\Delta T} = \frac{1}{(1-\gamma)T}$$

68. **(B)**
Slope of plot 2 is greater which means that the adiabatic constant γ of 2 is greater. Therefore, plots 1 and 2 correspond respectively to O_2 and He.

69. **(B)**

$$\Delta W = \text{Area} = \frac{1}{2}\pi ab$$

where, a and b are the two axes of the ellipse.

$$\therefore \quad \Delta W = \frac{1}{2}\pi(1\text{L})(1\text{atm}) = \frac{\pi}{2}\text{atm-L}$$

70. (C)
$$W_{ABCD} = W_{AB} + W_{BC} + W_{CD}$$
$$= P_0(V_0 - 2V_0) + 0 + 2P_0(3V_0 - V_0)$$
$$= 3P_0V_0$$

71. (B)
The given process if drawn in *PV* diagram (with *P* on vertical axis) shall be clockwise. Hence, ΔW is positive.

$$\Delta W = \text{Area} = \frac{1}{2}(10-5)(4-2) = 5 \text{ J}$$

$\Delta U = 0$ since, the process is cyclic.

∴ $\Delta Q = \Delta U + \Delta W = 5 \text{ J}$

72. (B)
$$\Delta Q_{iaf} = \Delta U_{iaf} + \Delta W_{iaf}$$
$$\Rightarrow \quad 50 = \Delta U_{iaf} + 20$$
$$\Rightarrow \quad \Delta U_{iaf} = 30 \text{ cal}$$
$$\Delta Q_{ibf} = \Delta U_{ibf} + \Delta W_{ibf}$$
and $\Delta U_{ibf} = \Delta U_{iaf} = 30 \text{ cal}$
$$\Rightarrow \quad 36 = 30 + \Delta W_{ibf}$$
∴ $\Delta W_{ibf} = 6 \text{ cal}$

73. (A)
$$PV = nRT \text{ or } T = \frac{PV}{nR}$$
At the end of processes, process 1 has highest pressure and hence highest temperature.
So, ΔU for process 1 is maximum.
∴ $\Delta U_1 > \Delta U_2 > \Delta U_3$

74. (D)
Area enclosed by *OBC* is equal to area enclosed by *ODA*. Also work done by system for *ODA* is positive and for *OBC* is negative. Therefore, the net work done in one cycle is zero.

75. (C)
The path in *P-V* diagram is a straight line.
$$\Rightarrow \quad P = mV + c$$
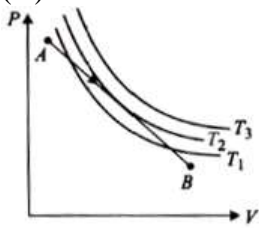where, *m* is the slope and *c* is the *y* intercept.
$$\Rightarrow \quad \frac{nRT}{V} = mV + c \qquad \Rightarrow \quad T = \frac{mV^2}{nR} + \frac{cV}{nR}$$
Therefore, path in *T-V* diagram is a parabola.
Also, $P = m\dfrac{nRT}{P} + c \quad \Rightarrow \quad t = \dfrac{p^2}{mnR} - \dfrac{cP}{mnR}$
Therefore, path in *T-P* diagram is also a parabola.

76. (D)

In figure shown, the isotherms corresponding to temperature T_1, T_2 and T_3 are drawn.

Here, $T_1 < T_2 < T_3$. Clearly, during the process, the temperature first increases and then decreases.

77. (2)

If the block ticks n seconds in a day, then

$$n \times 2\pi \sqrt{\frac{l}{g}} = \text{constant or } n^{1/2} = \text{constant}$$

$$\Rightarrow \quad \frac{\Delta n}{n} + \frac{1}{2} \frac{\Delta l}{l} = 0$$

or $\quad \frac{\Delta n}{n} = -\frac{1}{2} \alpha \Delta T$ or $-2 \frac{\Delta n}{n\alpha} = T - T_0$

where, T_0 is the temperature at which the clock gives correct time and T is the temperature at which the clock is running.

Clock runs faster by 5 sec at 15ºC

$$\Rightarrow \quad \frac{-2 \times 5}{n\,\alpha} = 15 - T_0 \qquad \text{..... (1)}$$

Clock runs slow by 10 sec at 30ºC

$$\Rightarrow \quad \frac{-2 \times (-10)}{n\,\alpha} = 30 - T_0 \qquad \text{..... (2)}$$

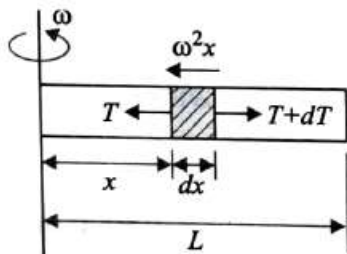From (1) and (2), $\dfrac{2}{n\,\alpha}(10+5) = 30 - 15$

$$\Rightarrow \quad \alpha = \frac{2}{n} = \frac{2}{24 \times 3600} = 2.3 \times 10^{-5} / {}^{\circ}C$$

T_0 the nearest integer in $10^{-5} / {}^{\circ}C$, $\alpha = 2$.

78. (3)

Consider an element of length dx at distance x from the axis of rotation. Its mass is $dm = \rho A\,dx$. The net force acting on it is

$$T - (T + dT) = dm\,\omega^2\, x \qquad \Rightarrow \quad -dT = \rho A\,\omega^2\, x\,dx$$

$$\Rightarrow \quad \int_0^T dT = -\rho A \omega^2 \int_L^x x\, dx$$

$$\Rightarrow \quad T = \frac{1}{2}\rho A \omega^2 \left(L^2 - x^2\right)$$

The increase in length of this element is

$$dl = \frac{T}{AY}dx = \frac{1}{2}\frac{\rho\omega^2}{Y}\left(L^2 - x^2\right)dx$$

The total increase in length is

$$\Delta L = \frac{1}{2}\frac{\rho\omega^2}{T}\int_0^L \left(L^2 - x^2\right)dx = \frac{\rho\omega^2 L^3}{3Y}$$

To keep the rod at constant length, this must be the reduction in length due to decrease in temperature.

So, $\dfrac{\Delta L}{L} = \alpha\,\Delta T$

$$\Rightarrow \quad \Delta T = \frac{\Delta L}{\alpha L} = \frac{1}{\alpha L} \times \frac{\rho\omega^2 L^3}{3Y} = \frac{\rho\omega^2 L^2}{3Y\alpha}$$

$$\therefore \quad k = 3$$

79. **(4)**

Heat gained by ice to reach 100ºC is
$$Q = 270\times 80 + 270\times 1 \times 200 = 270\times 180\,\text{cal}$$

If m grams of steam is condensed, then
$$Q = mL_v \text{ or } 270\times 180 = m\times 540 \text{ or } m \geq 90\,\text{g}.$$

The mass of boiling water which is finally produced is
$$270 + 90 = 360\,\text{g} = (90\times 4)\,\text{g}$$

$$\therefore \quad N = 4$$

80. **(9)**

Let the temperature of furnace be T.

Heat absorbed by water and calorimeter = Heat released by iron

$$\Rightarrow \quad (240 + 10)\times 1 \times (60 - 20) = 100\times 0.11\times(T - 60)$$

$$\Rightarrow \quad T = 969°\text{C} = (100\times 9 + 69)°\text{C}$$

$$\therefore \quad N = 9$$

81. **(3)**

The rate of heat transfer is

$$\frac{T_2 - T_1}{\dfrac{x}{KA} + \dfrac{4x}{(2K)A}} = \frac{KA(T_2 - T_1)}{3x}$$

$$\therefore \quad f = 3$$

82. **(4)**

Let $T(r)$ be the temperature at distance r from the centre and $R(r)$ be the thermal resistance of shell of inner radius r_0 and outer radius r. Then,

$$R(r) = \int_{r_0}^{r} \frac{dr}{K(4\pi r^2)} = \frac{1}{4\pi K}\left(\frac{1}{r_0} - \frac{1}{r}\right)$$

$$\Rightarrow \quad R\left(\frac{3r_0}{2}\right) = \frac{1}{12\pi K r_0} \text{ and } R(2r_0) = \frac{1}{8\pi K r_0}$$

As the heat current is same throughout,

$$H = \frac{2T_0 - T(3r_0/2)}{R(3r_0/2)} = \frac{R(3r_0/2)}{R(2r_0)} = \frac{2}{3}$$

$$\Rightarrow \quad \frac{2T_0 - T(3r_0/2)}{T_0} = \frac{R(3r_0/2)}{R(2r_0)} = \frac{2}{3}$$

$$\Rightarrow \quad T\left(\frac{3r_0}{2}\right) = \frac{4}{3}T_0$$

$$\Rightarrow \quad a - 2 = 4 \text{ and } b + 1 = 3$$
$$\Rightarrow \quad a = 6 \text{ and } b = 2$$
$$\therefore \quad a - b = 4$$

83. **(9)**

The power (P) of electric heater is equal to the heat dissipated through the walls of the room.

$$P = \frac{20 - (-10)}{\dfrac{2.5\times10^{-2}}{0.125\times137} + \dfrac{10^{-2}}{1.5\times137} + \dfrac{25\times10^{-2}}{1\times137}}$$

$$= \frac{30\times137\times10^2}{20 + \dfrac{2}{3} + 25} = \frac{30\times137\times100\times3}{137}$$

$$= (1000\times9)\,\text{Watts}$$

$$\therefore \quad x = 9$$

84. **(7)**

$$\Delta W = \frac{1}{2}(2P_0 + P_0)(2V_0 - V_0) = \frac{3}{2}P_0V_0 = \frac{3}{2}nRT_1$$

$$= \frac{3}{2}\times1\times\frac{25}{3}\times320 = 4000 = 4\times10^3 \text{ J}$$

$$\therefore \quad a + b = 4 + 3 = 7$$

85. **(5)**

For a polytropic process, ($PV^\alpha = \text{const.}$)

$$\Delta W = \frac{nR\Delta T}{1-\alpha}$$

$$\Delta Q = \Delta U + \Delta W$$

$$\Rightarrow \quad nC\Delta T = nC_v\Delta T + \frac{nR\Delta T}{1-\alpha}$$

$$\Rightarrow \quad \frac{5}{4}R = \frac{3}{2}R + \frac{R}{1-\alpha}$$

$$\therefore \quad \alpha = 5$$

86. (6)

$$\Delta W = \Delta W_{AB} + \Delta W_{BC} + \Delta W_{CD} + \Delta W_{DA}$$
$$= nRT_1 \ln(V_0/2V_0) + 0 + 2nRT_2 \ln(2V_0/V_0) + 0$$
$$= (nR\ln 2)(T_2 - T_1)$$
$$= 4\times10^{-3} R \ln 2 (600 - 300) = \frac{6R\log_e 2}{5}$$
$$\therefore \quad x = 6$$

87. (8)

Let the initial pressure and volume in each part be P and V respectively. Let P_1 and P_2 be the final pressures and V_1 and V_2 be the corresponding final volumes in the left and right parts respectively.

Then, $PV^{\gamma} = P_1 V_1^{\gamma} = P_2 V_2^{\gamma}$

$$\therefore \quad \frac{P_1}{P_2} = \left(\frac{V_2}{V_1}\right)^{\gamma} = 4^{3/2} = 8$$

88. (0)

As $PV = nRT$ and both cylinders always have same value of P, n and T, the volume of both will always remains same.
Hence, the piston will not shift.
$$\therefore \quad \Delta V = 0$$

89. (5)

Let x be the instantaneous length of gas in tube. Then the instantaneous pressure of gas is
$$P = P_0 + \rho g(l_0 + 4l_0 - x) = 2\rho g l_0 + 5 g l_0 - \rho g x$$
$$= \rho g(7l_0 - x)$$

$$\therefore \quad \Delta W = \int PA\,dx = \frac{3}{\rho} \times \rho g \int_{l_0}^{4l_0} (7l_0 - x)\,dx$$
$$= 3g\left(21l_0^2 - \frac{15}{2}l_0^2\right)$$
$$= 3g \times \frac{27}{2}l_0^2 = \frac{81}{2} g \times \left(\frac{1}{9}\right)^2 = \frac{g}{2} = 5\,\text{J}$$

90. (4)
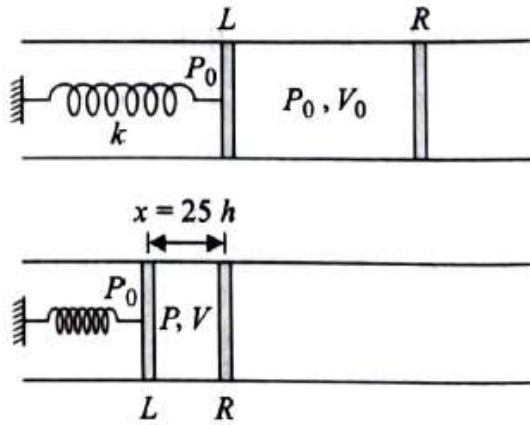
If the final length of air column is $x = 25h$ cm, then the spring has also got compressed by x.

In the final position, $PA = P_0A + kx$

As the process is isothermal,

$$P_0V_0 = PV = PAx = (P_0A + kx)x$$

$\Rightarrow kx^2 + P_0Ax - P_0V_0 = 0$

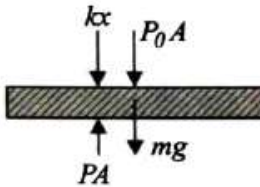$\Rightarrow 10^3x^2 + 10^5 \times (100 \times 10^{-4})x - 10^5 \times (2000 \times 10^{-4}) = 0$

$\Rightarrow x^2 + x - 2 = 0$

$\Rightarrow (x+2)(x-1) = 0$

$\Rightarrow x = 1\,m = 25 \times 4\,cm$

$\therefore h = 4$

91. (5)

Let P be the pressure of water vapour when the displacement of piston is x. Then,

$$PA = mg + P_0A + kx$$

Work done by water vapour,

$$\Delta W = \int_0^h PA\,dx$$

$$= \int_0^h (mg + P_0A + kx)\,dx$$

$$= mgh + P_0Ah + \frac{1}{2}kh^2$$

$$= 60 \times 10 \times 0.04 + 10^5 \times 50 \times 10^{-4} \times 0.04 + 0.5 \times 50 \times 10^3 \times (0.04)^2$$

$$= 84\,J$$

$\Rightarrow \Delta U = \Delta Q - \Delta W = 134 - 84 = 10 \times 5\,J$

$\therefore K = 5$

1. (D)

    (d) Using $V_{rms} = \sqrt{\dfrac{3RT}{M}} \Rightarrow V_{rms} \propto \dfrac{1}{\sqrt{M}}$

    $\dfrac{v_{rms \, (helium)}}{v_{rms \, (argon)}} = \sqrt{\dfrac{M_{argon}}{M_{helium}}} = \sqrt{\dfrac{40}{4}} = \sqrt{10} \approx 3.16$

2. (B)
    In free expansion of ideal gas temperature do not change as there is no change in internal energy. But, in free expansion of real gas potential energy increases, so kinetic energy decreases and therefore temperature decreases.

3. (C)
    $\dfrac{\text{Reading on any scale} - \text{LFP}}{\text{UFP} - \text{LFP}} = \text{constant for all scales}$

    $\dfrac{340 - 273}{373 - 273} = \dfrac{°Y - (-160)}{-50 - (-160)} \Rightarrow \dfrac{67}{100} = \dfrac{y + 160}{110}$

    $\therefore \ Y = -86.3° \, Y$

4. (D)
    When radius is decreases by ΔR,
    $4\pi R^2 \Delta R \rho L = 4\pi T [R^2 - (R - \Delta R)^2]$
    $\Rightarrow \rho R^2 \Delta RL = T[R^2 - R^2 + 2R\Delta R - \Delta R^2]$
    $\Rightarrow \rho R^2 \Delta RL = T2R\Delta R \qquad [\Delta R \text{ is very small}]$
    $\Rightarrow R = \dfrac{2T}{\rho L}$

5. (D)
    As the surrounding is identical, vessel is identical time taken to cool both water and liquid (from 30ºC to 25ºC) is same 2 minutes, therefore

    $\left(\dfrac{dQ}{dt}\right)_{water} = \left(\dfrac{dQ}{dt}\right)_{liquid}$

    or, $\quad \dfrac{(m_w C_w + W)\Delta T}{t} = \dfrac{(m_\ell C_\ell + W)\Delta T}{t}$

    (W = water equivalent of the vessel)

    or, $\quad m_w C_w = m_\ell C_\ell$

    $\therefore$ Specific heat of liquid, $C_\ell = \dfrac{m_w C_w}{m_\ell}$

    $= \dfrac{50 \times 1}{100} = 0.5 \, \text{kcal/kg}$

6. (C)
    According to Newton's law of cooling, the rate of loss of heat is directly proportional to the difference oi temperature of the body and surroundings.

    $$\frac{dQ}{dt} = k(T_2 - T_1) \qquad \text{...(i)}$$

    and $dQ = msdT_2$

    $$\therefore \quad \frac{dQ}{dt} = \frac{msdT_2}{dt} \qquad \text{...(ii)}$$

    From Eqs. (i) and (ii), we get

    $$-\frac{msd\,T_2}{dt} = k(T_2 - T_1)$$

    $$\frac{-dT}{T_2 - T_1} = -\frac{k}{ms}dt = -Kdt \qquad \left[\therefore K = \frac{k}{ms}\right]$$

    On integrating, we get

    $$\log_e(T_2 - T_1) = -Kt + C$$

    or $\quad T_2 = T_1 + C'e^{Kt} \qquad$ [where, $C' = e^C$]

    This variation is correctly represented in option (C).

7. (B)
    Heat is extracted from the source in path DA and AB is

    $$\Delta Q = \frac{3}{2}R\left(\frac{P_0V_0}{R}\right) + \frac{5}{2}R\left(\frac{2P_0V_0}{R}\right)$$

    $$\Rightarrow \frac{3}{2}P_0V_0 + \frac{5}{2}2P_0V_0 = \left(\frac{13}{2}\right)P_0V_0$$

8. (C)

    $$v_{rms} = \sqrt{\frac{3\rho v}{\text{mass of the gas}}}$$

9. (A)

    $$\because \quad C = \sqrt{\frac{3RT}{M}}$$

    $$(1930)^2 = \frac{3 \times 8.314 \times 300}{M}$$

    $$M = \frac{3 \times 8.314 \times 300}{1930 \times 1930} \approx 2 \times 10^{-3} \text{ kg}$$
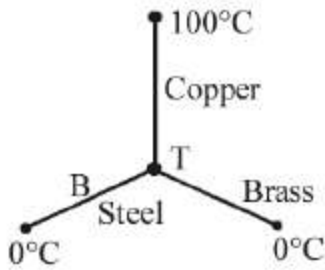
    The gas is H_2.

10. (C)
    Rate of heat flow is given by,

    $$Q = \frac{KA(\theta_1 - \theta_2)}{l}$$

    Where, K = coefficient of thermal conductivity, l = length of rod and A = area of cross-section of rod

If the junction temperature is T, then

$$Q_{Copper} = Q_{Brass} + Q_{Steel}$$

$$\frac{0.92 \times 4(100 - T)}{46}$$

$$= \frac{0.26 \times 4 \times (T - 0)}{13} + \frac{0.12 \times 4 \times (T - 0)}{12}$$

$$\Rightarrow 200 - 2T = 2T + T \Rightarrow T = 40°C$$

$$\therefore Q_{Copper} = \frac{0.92 \times 4 \times 60}{46} = 4.8 \, cal/s$$

11. (C)

In the given problem, fall in temperature of sphere,

$$dT = (3T_0 - 2T_0) = T_0$$

Temperature of surrounding, $T_{surr} = T_0$

Initial temperature of sphere, $T_{initial} = 3T_0$

Specific heat of the material of the sphere varies as,

$c = \alpha T^3$ per unit mass ($\alpha = a$ constant)

Applying formula,

$$\frac{dT}{dt} = \frac{\sigma A}{McJ}\left(T^4 - T_{surr}^4\right)$$

$$\Rightarrow \frac{T_0}{dt} = \frac{\sigma 4\pi R^2}{M\alpha(3T_0)^3 J}\left[(3T_0)^4 - (T_0)^4\right]$$

$$\Rightarrow dt = \frac{M\alpha 27 T_0^4 J}{\sigma 4\pi R^2 \times 80 T_0^4}$$

Solving we get,

Time taken for the sphere to cool down temperature $2T_0$,

$$t = \frac{M\alpha}{16\pi R^2 \sigma}\ln\left(\frac{16}{3}\right)$$

12. (B)

By Newton's law of cooling

$$\frac{\theta_1 - \theta_2}{t} = -\left[\frac{\theta_1 - \theta_2}{2} - \theta_0\right]$$

Where θ_0 is the temperature of surrounding.

Now, hot water cools from 60ºC to 50ºC in minutes,

$$\frac{60-50}{10} = -K\left[\frac{60+50}{2} - \theta_0\right] \qquad ...(i)$$

Again, it cools from 50°C to 42°C in next 10 minutes

$$\frac{50-42}{10} = -K\left[\frac{50+42}{2} - \theta_0\right] \qquad ...(ii)$$

Diving equations (i) by (ii) we get

$$\frac{1}{0.8} = \frac{55-\theta_0}{46-\theta_0}$$

$$\frac{10}{8} = \frac{55-\theta_0}{46-\theta_0}$$

$$460 - 10\theta_0 = 440 - 8\theta_0$$

$$2\theta_0 = 20$$

$$\theta_0 = 10°C$$

13. (A)

As we know,

$$\Delta Q = \Delta u + \Delta w \qquad \text{(Ist law of thermodynamics)}$$

$$\Rightarrow \Delta Q = \Delta u + P\Delta v$$

or $\quad 150 = \Delta u + 100(1-2)$

$$= \Delta u - 100$$

$$\therefore \quad \Delta u = 150 + 100 = 250\,J$$

14. (D)

In cyclic process, change in total internal energy is zero.

$$\Delta U_{cyclic} = 0$$

$$\Delta U_{BC} = nC_v\Delta T = 1 \times \frac{5R}{2}\Delta T$$

Where, C_v = molar specific heat at constant volume.

For BC. $\Delta T = -200\,K$

$$\therefore \ \Delta U_{BC} = -500\,R$$

15. (C)

Given : Work done, W = 830 J

No. of moles of gas, $\mu = 2$

For diatomic gas $\gamma = 1.4$

Work done during an adiabatic change

$$W = \frac{\mu R(T_1 - T_2)}{\gamma - 1}$$

$$\Rightarrow 830 = \frac{2 \times 8.3(\Delta T)}{1.4 - 1} = \frac{2 \times 8.3(\Delta T)}{0.4}$$

$$\Rightarrow \Delta T = \frac{830 \times 0.4}{2 \times 8.3} = 20\,K$$

16. (B)

Given: $Q_1 = 1000\,J$, $Q_2 = 600\,J$

$T_1 = 127°C = 400\,K$

$T_2 = ?$

$\eta = ?$

Efficiency of Carnot engine,

$\eta = \dfrac{W}{Q_1} \times 100\%$

Or, $\eta = \dfrac{Q_2 - Q_1}{Q_1} \times 100\%$

Or, $\eta = \dfrac{1000 - 600}{1000} \times 100\%$

$\eta = 40\%$

Now, for Carnot cycle $\dfrac{Q_2}{Q_1} = \dfrac{T_2}{T_1}$

$\dfrac{600}{1000} = \dfrac{T_2}{400}$

$T_2 = \dfrac{600 \times 400}{1000}$

$\quad = 240\,K$

$\quad = 240 - 273$

$\therefore\ T_2 = -33°C$

17. (B)

As $P\,t = mC\Delta T$

So, $P \times 10 \times 60 = mC\,100$ ...(i)

and $P \times 55 \times 60 = mL$ ...(ii)

Dividing equation (i) by (ii), we get

$\dfrac{10}{55} = \dfrac{C \times 100}{L}$

$\therefore\ L = 550\,cal./g.$

18. (A)

$\tau = \dfrac{1}{\sqrt{2}\,\pi d^2 \left(\dfrac{N}{V}\right)\sqrt{\dfrac{3RT}{M}}}$

$\tau \propto \dfrac{V}{\sqrt{T}}$

As, $TV^{\gamma-1} = K$

So, $\tau \propto V^{\gamma+1/2}$

Therefore, $q = \dfrac{\gamma+1}{2}$

19.   (A)

As, $P = \dfrac{1}{3}\left(\dfrac{U}{V}\right)$

But $\dfrac{U}{V} = KT^4$

So, $P = \dfrac{1}{3}KT^4$ or $\dfrac{uRT}{V} = \dfrac{1}{3}KT^4$ [As $PV = uRT$]

$\dfrac{4}{3}\pi R^3 T^3 = $ constant

Therefore, $T \propto \dfrac{1}{R}$

20.   (B)
In VT graph
ab process : Isobaric, temperature increases.
bc process : Adiabatic, pressure decreases.
cd process : Isobaric, volume decreases.
da process : Adiabatic, pressure increases.

21.   (D)
The entropy change of the body in the two cases is same as entropy is a state function.

22.   (C)

(c) Pressure, $P = \dfrac{1}{3}\dfrac{mN}{V}V_{rms}^2$

or, $P = \dfrac{(mN)T}{V}$

If the gas mass and temperature are constant then
$P \propto (V_{rms})^2 \propto T$
So, force $\propto (V_{rms})^2 \propto T$
i.e., Value of $q = 1$

23.   (D)
Volume of water does not change, no work is done on or by the system (W = 0)
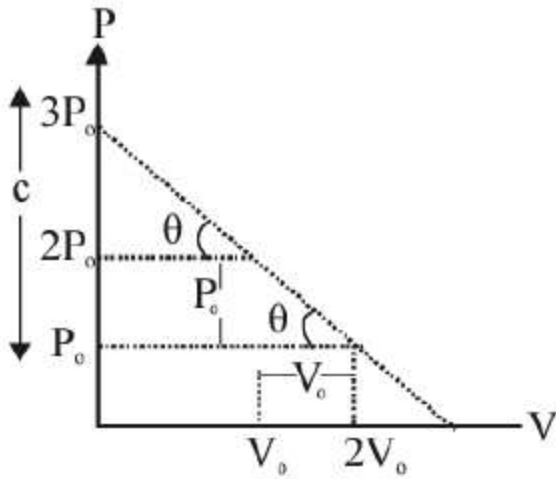According to first law of thermodynamics
Q = DU + W
For isochoric process Q = DU
$\Delta U = \mu c dT = 2 \times 4184 \times 20 = 16.7$ kJ

24.   (C)
The equation for the line is

$P = \dfrac{-P_0}{V_0} V + 3P$ $\qquad$ [slope $= \dfrac{-P_0}{V_0}$, $c = 3P_0$]

$PV_0 + P_0V = 3P_0V_0$ $\qquad$ ...(i)

But $PV = nRT$

$\therefore$ $P = \dfrac{nRT}{V}$ $\qquad$ ...(ii)

From (i) & (ii)

$\dfrac{nRT}{V} V_0 + P_0V = 3P_0V_0$

$\therefore$ $nRTV_0 + P_0V^2 = 3P_0V_0V$ $\qquad$ ...(iii)

For temperature to be maximum $\dfrac{dT}{dV} = 0$

Differentiating e.q. (iii) by 'V' we get

$nRV_0 \dfrac{dT}{dV} + P_0(2V) = 3P_0V_0$

$\therefore$ $nRV_0 \dfrac{dT}{dV} = 3P_0V_0 - 2P_0V$

$\dfrac{dT}{dV} = \dfrac{3P_0V_0 - 2P_0V}{nRV_0} = 0$

$V = \dfrac{3V_0}{2}$ $\qquad$ $\therefore$ $P = \dfrac{3P_0}{2}$ $\quad$ [From (i)]

$\therefore$ $T_{max} = \dfrac{9P_0V_0}{4nR}$ $\qquad$ [From (iii)]

25. $\quad$ (A)

Efficiency of heat engine is given by

$h = \dfrac{w}{Q} = 1 - \dfrac{C_V}{C_P} = \dfrac{R}{C_P} = \dfrac{R}{\dfrac{5R}{2}} = \dfrac{2}{5}$ $\qquad$ ($\because$ $C_p - C_v = R$)

For monoatomic gas $C_P = \dfrac{5}{2}R$.

26. (D)

$\Delta H = mL = 5 \times 336 \times 10^3 = Q_{sink}$

$$\frac{Q_{sink}}{Q_{source}} = \frac{T_{sink}}{T_{source}}$$

$$\therefore \; Q_{source} = \frac{T_{source}}{T_{sink}} \times Q_{sink}$$

Energy consumed by freezer

$$\therefore \; w_{output} = Q_{source} - Q_{sink} = Q_{sink}\left(\frac{T_{source}}{T_{sink}} - 1\right)$$

Given: $T_{source} = 27°C + 273 = 300\,K$,

$T_{sink} = 0°C + 273 = 273\,K$

$$W_{output} = 5 \times 336 \times 10^3 \left(\frac{300}{273} - 1\right) = 1.67 \times 10^5\,J$$

27. (D)

For a polytropic process

$$C = C_V + \frac{R}{1-n} \qquad \therefore \; C - C_V = \frac{R}{1-n}$$

$$\therefore \; 1 - n = \frac{R}{C - C_V} \qquad \therefore \; 1 - \frac{R}{C - C_V} = n$$

$$\therefore \; n = \frac{C - C_V - R}{C - C_V} = \frac{C - C_V - C_P + C_V}{C - C_V}$$

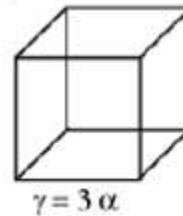$$= \frac{C - C_P}{C - C_V} \; (\because C_P - C_V = R)$$

28. (C)

As we know, Bulk modulus

$$K = \frac{\Delta P}{\left(\frac{-\Delta V}{V}\right)} \quad \Rightarrow \quad \frac{\Delta V}{V} = \frac{P}{K}$$

$$V = V_0\left(1 + \gamma\Delta t\right)$$

$$\frac{\Delta V}{V_0} = \gamma\Delta t \qquad \therefore \; \frac{P}{K} = \gamma\Delta t \quad \Rightarrow \quad \Delta t = \frac{P}{\gamma K} = \frac{P}{3\alpha K}$$

$\gamma = 3\alpha$

29. (C)

Due to thermal exp., change in length $(\Delta\ell) = \ell\alpha\Delta T$ … (i)

$$\text{Young's modulus (Y)} = \frac{\text{Normal stress}}{\text{Longitudinal strain}}$$

$$Y = \frac{F/A}{\Delta\ell/\ell} \quad \Rightarrow \quad \frac{\Delta\ell}{\ell} = \frac{F}{AY}$$

$$\Delta\ell = \frac{F\ell}{AY}$$

From equation (i), $\dfrac{F\ell}{AY} = \ell\alpha\Delta T$

$F = AY\alpha\Delta T$

30. **(D)**

According to principle of calorimetry,

$Q_{given} = Q_{used}$

$0.2 \times S \times (150-40) = 150 \times 1 \times (40-27) + 25 \times (40-27)$

$0.2 \times S \times 110 = 150 \times 13 + 25 \times 13$

Specific heat of aluminium

$S = \dfrac{13 \times 25 \times 7}{0.2 \times 110} = 434 \text{ J/kg-}°C$

31. **(D)**

According to principle of calorimetry,

Heat lost = Heat gain

$100 \times 0.1(T-75) = 100 \times 0.1 \times 45 + 170 \times 1 \times 45$

$10T - 750 = 450 + 7650 = 8100 \Rightarrow T - 75 = 810$

$T = 885°C$

32. **(B)**

Work-done (W) = P_0V_0

According to principle of calorimetry

Heat given $= Q_{AB} = Q_{BC}$

$= nC_V dT_{AB} + nC_P dT_{BC}$

$= \dfrac{3}{2}(nRT_B - nRT_A) + \dfrac{5}{2}(nRT_C - nRT_B)$

$= \dfrac{3}{2}(2P_0V_0 - P_0V_0) + \dfrac{5}{2}(4P_0V_0 - 2P_0V)$

$= \dfrac{13}{2}P_0V_0$

Thermal efficiency of engine $(\eta) = \dfrac{W}{Q_{given}} = \dfrac{2}{13} = 0.15$

33. **(C)**

From P-V graph,

$P \propto \dfrac{1}{V}$, T = constant and Pressure is increasing from 2 to 1

So, Option (C) represents correct T-P graph.

34. **(A)**

Energy associated with N moles of diatomic gas,

$U_i = N\dfrac{5}{2}RT$

Energy associated with n moles of monoatomic gas

$$= n\frac{3}{2}RT$$

Total energy when n moles of diatomic gas converted into monoatomic $\left(U_f\right) = 2n\frac{3}{2}RT + (N-n)RT$

$$= \frac{1}{2}nRT + \frac{5}{2}NRT$$

Now, change in total kinetic energy of the gas

$$\Delta U = Q = \frac{1}{2}nRT$$

35.   (A)

As we know, $C_p - C_v = R$ where C_p and C_v are molar specific

or, $C_p - C_v = \dfrac{R}{M}$

For hydrogen $(M = 2)\, C_P - C_v = a = \dfrac{R}{2}$

For nitrogen $(M = 28)\, C_p - C_v = b = \dfrac{R}{28}$

$\therefore\ \dfrac{a}{b} = 14$ or, a = 14 b

36.   (D)

The ratio of specific heats at constants pressure (C_p) and constant volume (C_v)

$$\frac{C_p}{C_v} = \gamma = \left(1 + \frac{2}{f}\right)$$

where f is degree of freedom

$$\frac{C_p}{C_v} = \left(1 + \frac{2}{5}\right) = \frac{7}{5}$$

37.   (A)

According to Newton's law of cooling,

$$\left(\frac{\theta_1 - \theta_2}{t}\right) = K\left(\frac{\theta_1 + \theta_2}{2} - \theta_0\right)$$

$$\left(\frac{60 - 50}{10}\right) = K\left(\frac{60 + 50}{2} - 25\right) \qquad ...(i)$$

and, $\left(\dfrac{50 - \theta}{10}\right) = K\left(\dfrac{50 + \theta}{2} - 25\right) \qquad ...(ii)$

Dividing eq. (i) by (ii),

$$\frac{10}{(50 - \theta)} = \frac{60}{\theta} \ \Rightarrow\ \theta = 42.85°C \cong 43°C$$

38. (A)

Equation of the BC

$$P = P_0 - \frac{2P_0}{V_0}(V - 2V_0)$$

Using PV = nRT

Temperature, $T = \dfrac{P_0 V - \dfrac{2P_0 V^2}{V_0} + 4P_0 V}{1 \times R}$ ($\because$ n = 1 mole given)

$$T = \frac{P_0}{F}\left[5V - \frac{2V^2}{V_0}\right]$$

$$\frac{dT}{dV} = 0 \Rightarrow 5 - \frac{4V}{V_0} = 0 \Rightarrow V = \frac{5}{4}V_0$$

$$T = \frac{P_0}{R}\left[5 \times \frac{5V_0}{4} - \frac{2}{V_0} \times \frac{25}{16}V_0^2\right] = \frac{25}{8}\frac{P_0 V_0}{R}$$

39. (A)

(a) Given: Temperature of cold body, T_2 = 250 K
temperature of hot body; T_1 = 300 K
Heat received, Q_2 = 500 cal work done, W = ?

$$\text{Efficiency} = 1 - \frac{T_2}{T_1} = \frac{W}{Q_2 + W} \Rightarrow 1 - \frac{250}{300} = \frac{W}{Q_2 + W}$$

$$W = \frac{Q_2}{5} = \frac{500 \times 4.2}{5}J = 420 \text{ J}$$

40. (C)

(c) In an adiabatic process
$TV^{\gamma-1}$ = Constant   or, $T_1 V_1^{\gamma-1} = T_2 V_2^{\gamma-1}$

For monoatomic gas $\gamma = \dfrac{5}{3}$

$$(300)V^{2/3} = T_2(2V)^{2/3} \Rightarrow T_2 = \frac{300}{(2)^{2/3}}$$

T_2 = 189 K (final temperature)

Change in internal energy $\Delta U = n\dfrac{f}{2}R\,\Delta T$

$$= 2\left(\frac{3}{2}\right)\left(\frac{25}{3}\right)(-111) = -2.7 \text{ kJ}$$

41. (B)
Using formula,

$$\gamma_{\text{mixture}} = \left(\frac{C_p}{C_v}\right)_{\text{mix}} = \frac{\dfrac{n_1\gamma_1}{\gamma_1 - 1} + \dfrac{n_2\gamma_2}{\gamma_2 - 1}}{\dfrac{n_1}{\gamma_1 - 1} + \dfrac{n_2}{\gamma_2 - 1}}$$

Putting the value of $n_1 = 2$, $n_2 = n$, $\left(\dfrac{C_p}{C_v}\right)_{\text{mix}} = \dfrac{3}{2}$

$\gamma_1 = \dfrac{5}{3}$, $\gamma_2 = \dfrac{7}{5}$ and solving we get, $n = 2$

42. (Bonus)

$\Delta_{\text{temp}} = \Delta_{\text{load}}$ and $A = \pi r^2 = \pi\left(10^{-3}\right)^2 = \pi \times 10^{-6}$

$$L\alpha\Delta T = \frac{FL}{AY}$$

or $0.2 \times 10^{-5} \times 20 = \dfrac{F \times 0.2}{\left(\pi \times 10^{-6}\right) \times 10^{11}}$

$\therefore \quad F = 20\pi N \qquad \therefore \quad m = \dfrac{f}{g} = 2\pi = 6.288 \text{ kg}$

43. (A)
Change in length in both rods are same i.e.
$\Delta\ell_1 = \Delta\ell_2$

$\ell\alpha_1\Delta\theta_1 = \ell\alpha_2\Delta\theta_2$

$\dfrac{\alpha_1}{\alpha_2} = \dfrac{\Delta\theta_2}{\Delta\theta_1} \qquad \left[\because \dfrac{\alpha_1}{\alpha_2} = \dfrac{4}{3}\right]$

$\dfrac{4}{3} = \dfrac{\theta - 30}{180 - 30}$

$\theta = 230°C$

44. (A)
Young's modulus $Y = \dfrac{\text{stress}}{\text{strain}} = \dfrac{F/A}{A(\Delta\ell/\ell)}$

Using, coefficient of linear expansion,

$\alpha = \dfrac{\Delta\ell}{\ell\Delta T} \implies \dfrac{\Delta\ell}{\ell} = \alpha\Delta T$

$\therefore \quad Y = \dfrac{F}{A(\alpha\Delta T)}$

45. (A)

$$M\,C_{ice} \times (10) + M_1 L = M_2 C_\omega (50)$$

or $\quad M_1 \times C_{ice} (= 0.5) \times 10 + M_1 L = M_2 \times 1 \times 50$

$$\Rightarrow \quad L = \frac{50 M_2}{M_1} - 5$$

46. (A)

(a) $N = \int \rho (dv)$

$$= \int_0^\infty n_0 e^{-\alpha r^4} \times 4\pi r^2 dr = 4\pi n_0 \int_0^r r^2 (e^{-\alpha r^4}) dr$$

As $\int_0^\infty r^n e^{-r^m} dr = \frac{n!}{\alpha^{n+1/m}}$

[**Note:** For more details refer to gamma integration]

$\propto n_0\, a^{-3/4}$

47. (A)

$$H_1 = H_2 \quad \theta_2 \boxed{\begin{array}{c|c} d & \theta & 3d \\ \hline 3k & k \end{array}} \theta_1$$

or $(3k)A\left(\dfrac{\theta_2 - \theta}{d}\right) = kA\left(\dfrac{\theta - \theta_1}{3d}\right)$ or $\theta = \left(\dfrac{\theta_1 + 9\theta_2}{10}\right)$
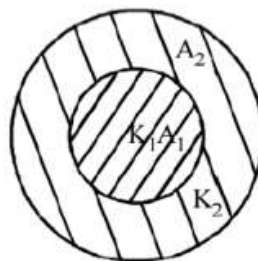
48. (D)
Effective thermal conductivity of system

$$K_{eq} = \frac{K_1 A_1 + K_2 A_2}{A_1 + A_2}$$

$$= \frac{K_1 \pi R^2 + K_2 \left[\pi (2R)^2 - \pi R^2\right]}{\pi (2R)^2}$$

$$= \frac{K_1 (\pi R^2) + K_2 (3\pi R^2)}{4\pi R^2} = \frac{K_1 + 3K_2}{4}$$

49. (D)
Let m gram of ice is added.
From principal of calorimeter heat gained (by ice) = heat lost (by water)

$\therefore \quad 20 \times 2.1 \times m + (m - 20) \times 334 = 50 \times 4.2 \times 40$
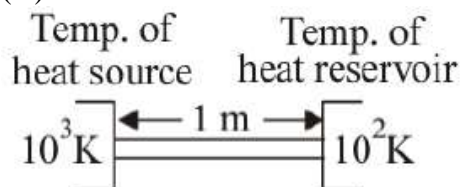
$376m = 8400 + 6680$

$m = 40.1$

50. (C)
Heat loss = Heat gain = $mS\Delta\theta$

So, $m_A S_A \Delta\theta_A = m_B S_B \Delta\theta_B$

$\Rightarrow \quad 100 \times S_A \times (100 - 90) = 50 \times S_B \times (90 - 75)$

$2S_A = 1.5 S_B \quad \Rightarrow \quad S_A = \frac{3}{4} S_B$

Now, $100 \times S_A \times (100 - \theta) = 50 \times S_B \times (\theta - 50)$

$2 \times \left(\frac{3}{4}\right) \times (100 - \theta) = (\theta - 50)$

$300 - 3\theta = 2\theta - 100$

$400 = 5\theta \Rightarrow \theta = 80°C$

51. (A)

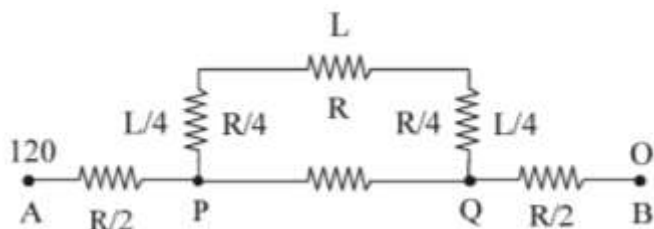Temp. of heat source   Temp. of heat reservoir

$10^3 K$ ← 1 m → $10^2 K$

Energy flux, $\frac{1}{A}\left(\frac{dQ}{dt}\right) = \frac{k\Delta T}{\ell}$

$= \frac{(0.1)(900)}{1} = 90 \text{ W/m}^2$

52. (C)

Let specific heat of unknown metal be 's' according to principle of calorimetry, heat lost

= Heat gain $m \times s\Delta\theta = m_1 s_{brass}\left(\Delta\theta_1 + m_2 s_{water} + \Delta\theta_2\right)$

$\Rightarrow \quad 192 \times S \times (100 - 21.5) = 128 \times 394 \times (21.5 - 8.4)$

Solving we get, $= 240 \times 4200 \times (21.5 - 8.4)$

$S = 916 \text{ J kg}^{-1}\text{ K}^{-1}$

53. (A)

$\frac{\Delta T_{AB}}{R_{AB}} = \frac{120}{\frac{8}{5}R} = \frac{120 \times 5}{8R}$

In steady state temperature difference between P and Q,

$\Delta T_{PQ} = \frac{120 \times 5}{8R} \times \frac{3}{5}R = \frac{360}{8} = 45°C$

54. (B)

Rate of heat loss $= mS\left(\dfrac{dT}{dt}\right) \propto \dfrac{1}{\rho S}$

$-\dfrac{dT}{dt} = \dfrac{e\sigma \times A \times T^4}{\rho \times Vol. \times S} \Rightarrow -\dfrac{dT}{dt} \propto \dfrac{1}{\rho S}$

$\dfrac{\left(-\dfrac{dT}{dt}\right)_A}{\left(-\dfrac{dT}{dt}\right)_B} = \dfrac{\rho_B}{\rho_A} \times \dfrac{S_B}{S_A} = \dfrac{10^3}{8 \times 10^2} \times \dfrac{4000}{2000}$

$\Rightarrow \left(-\dfrac{dT}{dt}\right)_A > \left(\dfrac{-dT}{dt}\right)_B$

So, A cools down at faster rate.

55. (A)

ΔU remains same for both paths ACB and ADB
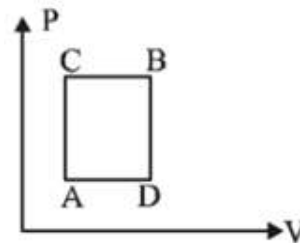
$\Delta Q_{ACB} = \Delta W_{ACB} + \Delta U_{ACB}$

$\Rightarrow 60J = 30J + \Delta U_{ACB}$

$\Rightarrow U_{ACB} = 30\,J$

$\therefore \Delta U_{ADB} = \Delta U_{ACB} = 30\,J$

$\Delta Q_{ADB} = \Delta U_{ADB} + \Delta W_{ADB}$

$= 10J + 30J = 40J$

56. (B)

$\Delta U_{ac} = -\left(\Delta U_{ca}\right) = -(-180) = 180\,J$

$Q = 250 + 60 = 310\,J$

Now, $Q = \Delta U + W$

or $\quad 310 = 180 + W$

or $\quad W = 130\,J$

57. (C)

As the process is isochoric so,

$Q = nc_v \Delta T = \dfrac{67.2}{22.4} \times \dfrac{3R}{2} \times 20 = 90\,R = 90 \times 8.31 \simeq 748\,J$

58. (B)

We have given,

$P = P_0\left[1 - \dfrac{1}{2}\left(\dfrac{V_0}{V}\right)^2\right]$

When $V_1 = V_0 \Rightarrow P_1 = P_0\left[1 - \dfrac{1}{2}\right] = \dfrac{P_0}{2}$

When $V_2 = 2V_0$

$1 \Rightarrow P_2 = P_0\left[1 - \dfrac{1}{2}\left(\dfrac{1}{4}\right)\right] = \left(\dfrac{7P_0}{8}\right)$

$$\Delta T = T_2 - T_1 = \left| \frac{P_1 V_1}{nR} - \frac{P_2 V_2}{nR} \right| \quad \left[\because T = \frac{PV}{nR} \right]$$

$$\Delta T = \left| \left(\frac{1}{nR} \right) (P_1 V_1 - P_2 V_2) \right| = \left(\frac{1}{nR} \right) \left| \left(\frac{P_0 V_0}{2} - \frac{7 P_0 V_0}{4} \right) \right|$$

$$= \frac{5 P_0 V_0}{4 nR} = \frac{5 P_0 V_0}{4R} \qquad (\because n = 1)$$

59. (C)
Internal energy depends only on initial and final state
So, $\Delta U_A = \Delta U_B$
Also $\Delta Q = \Delta U + W$
As $W_A > W_B \implies \Delta Q_A > \Delta Q_B$

60. (B)
Suppose amount of water evaporated be M gram.
Then (150 – M) gram water concerted into ice.
So, heat consumed in evaporation = Heat released in fusion
$$M \times L_v = (150 - M) \times L_s$$
$$M \times 2.1 \times 10^6 = (150 - M) \times 3.36 \times 10^5$$
$$\implies M = 20\,g$$

61. (D)
a $\to$ Isobaric, b $\to$ Isothermal, c $\to$ Adiabatic, d $\to$ Isochoric

62. (B)
Total work done by the gas during the cycle is equal to area of triangle ABC.
$$\therefore \quad \Delta W = \frac{1}{2} \times 4 \times 5 = 10\,J$$

63. (B)
Equation of adiabatic change is
$$PV^{\gamma - 1} = \text{constant}$$
Put $\gamma = \frac{7}{5}$, we get: $\gamma - 1 = \frac{7}{5} - 1$
$$\therefore \quad x = \frac{2}{5}$$

64. (B)
Work done,
$$W = P\Delta V = nR\Delta T = \frac{1}{2} \times 8.31 \times 70 \simeq 291\,J$$

65. (B)
Using, $n = 1 - \dfrac{T_2}{T_1}$

$$n = \frac{1}{6} = 1 - \frac{T_2}{T_1} \text{ and } \frac{T}{3} = 1 - \frac{T_2 - 62}{T_1}$$

On solving, we get

$T_1 = 99°C$ and $T_2 = 37°C$

66. **(B)**

According to question, $\eta_1 = \eta_2 = \eta_3$

$\therefore\ 1 - \frac{T_2}{T_1} = 1 - \frac{T_3}{T_2} = 1 - \frac{T_4}{T_3}$ [$\because$ Three engines are equally efficient]

$\Rightarrow\ \frac{T_2}{T_1} = \frac{T_3}{T_2} = \frac{T_4}{T_3}$

$\Rightarrow T_2 = \sqrt{T_1 T_3}$ ...(i)

$T_3 = \sqrt{T_2 T_4}$ ...(ii)

From (i) and (ii)

$T_2 = \left(T_1^2 T_4\right)^{1/3}$

$T_3 = \left(T_1 T_4^2\right)^{1/3}$

67. **(D)**

$$\eta_A = \frac{T_1 - T_2}{T_1} = \frac{W_A}{Q_1} \text{ and } \eta_B = \frac{T_2 - T_3}{T_2} = \frac{W_B}{Q_2}$$

According to question,

$W_A = W_B$

$\therefore \frac{Q_1}{Q_2} = \frac{T_1}{T_2} \times \frac{T_2 - T_3}{T_1 - T_2} = \frac{T_1}{T_2}$
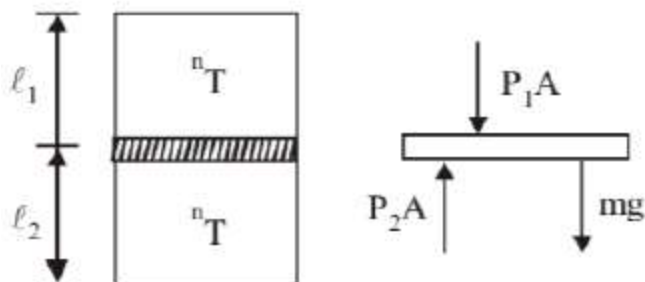
$\therefore T_2 = \frac{T_1 + T_3}{2}$

$= \frac{600 + 400}{2} = 500K$

68. **(D)**

(d) Clearly from figure,

$$P_2 A = P_1 A + mg$$

or, $\dfrac{nRT \cdot A}{A \ell_2} = \dfrac{nRT \cdot A}{A \ell_1} + mg$

$$\Rightarrow \quad nRT \left(\dfrac{1}{\ell_2} - \dfrac{1}{\ell_1} \right) = mg$$

$$\therefore \quad m = \dfrac{nRT}{g} \left(\dfrac{\ell_1 - \ell_2}{\ell_1 \cdot \ell_2} \right)$$

69.   (C)

(c) $V_{rms} = \sqrt{\dfrac{3RT}{M}}$

$$\dfrac{v_1}{v_2} = \sqrt{\dfrac{T_1}{T_2}} = \dfrac{(273 + 127)}{(273 + 237)} = \sqrt{\dfrac{400}{500}} = \sqrt{\dfrac{4}{5}} = \dfrac{2}{\sqrt{5}}$$

$$\therefore v_2 = \dfrac{\sqrt{5}}{2} v_1 = \dfrac{\sqrt{5}}{2} \times 200 = 100\sqrt{5} \text{ m/s}.$$

70.   (Bonus)

(Bouns) Rate of change of momentum during collision

$$= \dfrac{mv - (-mv)}{\Delta t} = \dfrac{2mv}{\Delta t} N$$

so pressure $P = \dfrac{N \times (2mv)}{\Delta t \times A}$

$$= \dfrac{10^{22} \times 2 \times 10^{-26} \times 10^4}{1 \times 1} = 2 \, N/m^2$$

71.   (C)

(c) $v_{rms} = v_e$

$$\sqrt{\frac{3RT}{M}} = 11.2 \times 10^3 \quad \text{or} \quad \sqrt{\frac{3kT}{m}} = 11.2 \times 10^3$$

or $\sqrt{\dfrac{3 \times 1.38 \times 10^{-23} T}{2 \times 10^{-3}}} = 11.2 \times 10^3 \qquad \therefore T = 10^4 \, K$

72.   (A)

(a) Using $\dfrac{V_{1rms}}{V_{2rms}} = \sqrt{\dfrac{M_2}{M_1}}$

$\dfrac{V_{rms}(He)}{V_{rms}(Ar)} = \sqrt{\dfrac{M_{Ar}}{M_{He}}} = \sqrt{\dfrac{40}{4}} = 3.16$

73.   (C)

(c) $[C_v]_{min} = \dfrac{n_1[C_{v_1}] + n_2[C_{v_2}]}{n_1 + n_2}$

$= \left[\dfrac{2 \times \dfrac{3R}{2} + 3 \times \dfrac{5R}{2}}{2 + 3} \right]$

$= 2.1 \, R = 2.1 \times 8.3 = 17.4 \, \text{J/mol–k}$

74.   (B)

$$F = \frac{C_v}{C_p} = \frac{1}{r} = \frac{1}{(7/5)} = \frac{5}{7}$$

or $\dfrac{W}{Q} = 1 - \dfrac{5}{7} = \dfrac{2}{7}$ or $Q = \dfrac{7}{2} W = \dfrac{7 \times 10}{2} = 35 \, J$

75.   (C)

(c) $V = 25 \times 10^{-3}\,m^3$, $N = 1$ mole of O_2

$T = 300\,K$

$V_{rms} = 200\,m/s$

$\therefore \lambda = \dfrac{1}{\sqrt{2}N\pi r^2}$

Average time $\dfrac{1}{\tau} = \dfrac{<V>}{\lambda} = 200.N\pi r^2.\sqrt{2}$

$= \dfrac{\sqrt{2} \times 200 \times 6.023 \times 10^{23}}{25 \times 10^{-3}}.\pi \times 10^{-18} \times 0.09$

The closest value in the given option is $= 10^{10}$

76. **(C)**

Amount of heat required (Q) to raise the temperature at constant volume

$Q = nC_v\Delta T$ ...(i)

Amount of heat required (Q_1) at constant pressure

$Q_1 = nC_P\Delta T$ ...(ii)

Dividing equation (ii) by (i), we get

$\therefore \dfrac{Q_1}{Q} = \dfrac{C_p}{C_v}$

$\Rightarrow Q_1 = (Q)\left(\dfrac{7}{5}\right) \qquad \left(\because \gamma = \dfrac{C_p}{C_v} = \dfrac{7}{5}\right)$

77. **(B)**

$\gamma_A = \dfrac{C_P}{C_V} = \dfrac{29}{22} = 1.32 < 1.4$ (diatomic) and $\gamma_B = \dfrac{30}{21} = \dfrac{10}{7} = 1.43 > 1.4$

Gas A has more than 5-degrees of freedom.

78. **(A)**

Energy of the gas, $E = \dfrac{f}{2}nRT = \dfrac{f}{2}PV = \dfrac{f}{2}\left(3\times10^6\right)(2) = f\times3\times10^6$

Considering gas in monoatomic i.e., $f = 3$

Energy, $E = 9\times10^6\,J$

79. **(B)**

Using, $\tau = \dfrac{1}{2n\,\pi d^2\,V_{avg}}$

$\therefore t \propto \dfrac{\sqrt{T}}{P} \qquad \left[\because n = \dfrac{\text{no. of molecules}}{\text{Volume}}\right]$

or $\dfrac{t_1}{6\times10^{-8}} = \dfrac{\sqrt{500}}{2P} \times \dfrac{P}{\sqrt{300}} \approx 4\times10^{-8}$

80. (A)

$U = \dfrac{f_1}{2}n_1RT + \dfrac{f_2}{2}n_2RT$

Considering translational and rotational modes, degrees of freedom $f_1 = 5$ and $f_2 = 3$

$\therefore \quad u = \dfrac{5}{2}(3RT) + \dfrac{3}{2}\times 5RT$

$U = 15RT$

81. (C)

(c) Thermal energy of N molecule

$= N\left(\dfrac{3}{2}kT\right) = \dfrac{N}{N_A}\dfrac{3}{2}RT = \dfrac{3}{2}(nRT) = \dfrac{3}{2}PV$

$= \dfrac{3}{2}P\left(\dfrac{m}{\rho}\right) = \dfrac{3}{2}P\left(\dfrac{2}{8}\right) = \dfrac{3}{2}\times 4\times 10^4 \times \dfrac{2}{8} = 1.5\times 10^4$ J

therefore, order $= 10^4$ J

82. (C)

(c) Heat transferred,

$\qquad Q = nC_v \Delta T$ as gas in closed vessel

To double the rms speed, temperature should be 4 times i.e., T'

$= 4T$ as $v_{rms} = \sqrt{3RT/M}$

$\therefore \ Q = \dfrac{15}{28}\times\dfrac{5\times R}{2}\times(4T - T)$

$\left[\because \dfrac{CP}{CV} = \gamma_{diatomic} = \dfrac{7}{5} \& C_p - C_v = R\right]$

or, $Q = 10000$ J $= 10$ kJ

83. (A)

Let L_1' and L_2' be the lengths of the wire when temperature is changed by $\Delta T°C$.

At T°C.

$L_{eq} = L_1 + L_2$

At $T + \Delta°C$

$L_{eq}' = L_1' + L_2'$

$\therefore \ L_{eq}(1 + \alpha_{eq}\Delta T) = L_1(1 + \alpha_1\Delta T) + L_2(1 + \alpha_2\Delta T) \quad \left[\because L' = L(1 + \alpha\Delta T)\right]$

$$\Rightarrow (L_1 + L_2)(1 + \alpha_{eq}\Delta T) = L_1 + L_2 + L_1\alpha_1\Delta T + L_2\alpha_2\Delta T$$

$$\Rightarrow \alpha_{eq} = \frac{\alpha_1 L_1 + \alpha_2 L_2}{L_1 + L_2}$$

84. (A)

Change in length of the metal wire ($\Delta\ell$) when its temperature is changed by ΔT is given by

$\Delta\ell = \ell\alpha\Delta T$

Here, $\alpha =$ Coefficient of linear expansion

Here, $\Delta\ell = 0.02\%$, $\Delta T = 10°C$

$$\therefore \ \alpha = \frac{\Delta\ell}{\ell\Delta T} = \frac{0.02}{100 \times 10} \ \Rightarrow \ \alpha = 2 \times 10^{-5}$$

Volume coefficient of expansion, $\gamma = 3\alpha = 6 \times 10^{-5}$

$$\therefore \ \rho = \frac{M}{V}$$

$$\frac{\Delta V}{V} \times 100 = \gamma\Delta T = \left(6 \times 10^{-5} \times 10 \times 100\right) = 6 \times 10^{-2}$$

Volume increase by 0.06% therefore density decrease by 0.06% .

85. (A)

According to question, one half of its kinetic energy is converted into heat in the wood.

$$\frac{1}{2}mv^2 \times \frac{1}{2} = ms\Delta T$$

$$\Rightarrow \ \Delta t = \frac{v^2}{4 \times s} = \frac{210 \times 210}{4 \times 4.2 \times 0.3 \times 1000} = 87.5°C$$

86. (A)

Here ice melts due to water.

Let the amount of ice melts $= m_{ice}$

$$m_w s_w \Delta\theta = m_{ice} L_{ice} \quad \therefore \ m_{ice} = \frac{m_w s_w \Delta\theta}{L_{ice}}$$

$$= \frac{0.2 \times 4200 \times 25}{3.4 \times 10^5} = 0.0617 \text{ kg} = 61.7 \text{ g}$$

87. (A)

Heat given by water $= m_w C_w \left(T_{mix} - T_w\right)$

$$= 200 \times 1 \times (31 - 25)$$

Heat taken by steam $= m L_{stem} + m C_w \left(T_s - T_{mix}\right)$

$$= m \times 540 + m(1) \times (100 - 31) = m \times 540 + m(1) \times (69)$$

From the principal of calorimeter,

Heat lost = Heat gained

$$\therefore \ (200)(31 - 25) = m \times 540 + m(1)(69)$$

$$\Rightarrow 1200 = m(609) \Rightarrow m \approx 2 .$$

88. (D)

(d) Using, $\gamma_{mixture} = \dfrac{n_1 C_{p_1} + n_2 C_{p_2}}{n_1 C_{v_1} + n_2 C_{v_2}}$

$\Rightarrow \dfrac{n_1}{\gamma_1 - 1} + \dfrac{n_2}{\gamma_2 - 1} = \dfrac{n_1 + n_2}{\gamma_m - 1} \Rightarrow \dfrac{3}{\dfrac{4}{3} - 1} + \dfrac{2}{\dfrac{5}{3} - 1} = \dfrac{5}{\gamma_m - 1}$

$\Rightarrow \dfrac{9}{1} + \dfrac{2 \times 3}{2} = \dfrac{5}{\gamma_m - 1} \Rightarrow \gamma_m - 1 = \dfrac{5}{12} \Rightarrow \gamma_m = \dfrac{17}{12} = 1.42$

89. (B)

From Newton's Law of cooling,

$\dfrac{T_1 - T_2}{t} = K\left[\dfrac{T_1 + T_2}{2} - T_0\right]$

Here, $T_1 = 50°C$, $T_2 = 40°C$ and $T_0 = 20°C$, $t = 600S = 5$ minutes

$\Rightarrow \dfrac{50 - 40}{5 \text{ min}} = K\left(\dfrac{50 + 40}{2} - 20\right)$ ...(i)

Let T be the temperature of sphere after next 5 minutes.

Then $\dfrac{40 - T}{5} + k\left(\dfrac{40 + T}{2} - 20\right)$ ...(ii)

Dividing Eqn. (ii) by (i), we get

$\dfrac{40 - T}{10} = \dfrac{40 + T - 40}{50 + 40 - 40} = \dfrac{T}{50}$

$\Rightarrow 40 - T = \dfrac{T}{5} \Rightarrow 200 - 5T = T$

$\therefore T = \dfrac{200}{6} = 33.3°C$

90. (B)

Temperature change ΔT is same for all three processes

$A \to B$; $A \to C$ and $A \to D$

$\Delta U = nC_V \Delta T = $ same

$E_{AB} = E_{AC} = E_{AD}$

Work done, $W = P \times \Delta V$

$AB \to$ volume is increasing $\Rightarrow W_{AB} > 0$

$AD \to$ volume is decreasing $\Rightarrow W_{AD} < 0$

$AC \to$ volume is constant $\Rightarrow W_{AC} = 0$

91. (C)

In adiabatic process

$PV^\gamma = $ constnat

$$\therefore \ P\left(\frac{m}{\rho}\right)^{\gamma} = \text{constant} \qquad \left(\because V = \frac{m}{\rho}\right)$$

As mass is constant

$$\therefore \quad P \propto \rho^{\gamma}$$

If P_i and P_f be the initial and final pressure of the gas and ρ_i and ρ_f be the initial and final density of the gas. Then

$$\frac{P_f}{P_i} = \left(\frac{\rho_f}{\rho_i}\right)^{\gamma} = (32)^{7/5}$$

$$\Rightarrow \frac{nP_i}{P_i} = \left(2^5\right)^{7/5} = 2^7$$

$$\Rightarrow n = 2^7 = 128 \ .$$

92. (B)

Bursting of helium balloon is irreversible and in this process $\Delta Q = 0$, so adiabatic.
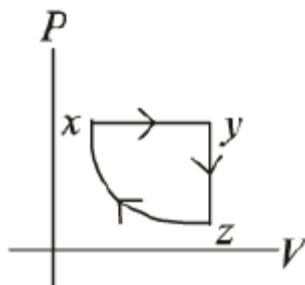
93. (A)

From the corresponding V-T graph given in question,

Process $xy \rightarrow$ Isobaric expansion,

Process $yz \rightarrow$ Isochoric (Pressure decreases)

Process $zx \rightarrow$ Isothermal compression

Therefore, corresponding PV graph is as shown in figure

94. (B)

Given, $V_1 = 1$ litre, $P_1 = 1$ atm

$V_2 = 3$ litre, $\gamma = 1.40$,

Using, $PV^{\gamma} = \text{constant} \ \Rightarrow \ P_1 V_1^{\gamma} = P_2 V_2^{\gamma}$

$$\Rightarrow \ P_2 = P_1 \times \left(\frac{1}{3}\right)^{1.4} = \frac{1}{4.6555} \text{ atm}$$

$$\therefore \text{ work done, } W = \frac{P_1 V_1 - P_2 V_2}{\gamma - 1}$$

$$= \frac{\left(1 \times 1 - \frac{1}{4.6555} \times 3\right) 1.01325 \times 10^5 \times 10^{-3}}{0.4} = 90.1 \text{ J}$$

Closest value of W = 90.5 J

95. (Bonus)

We know that Relaxation time,

$$T \propto \frac{V}{\sqrt{T}} \qquad \ldots(i)$$

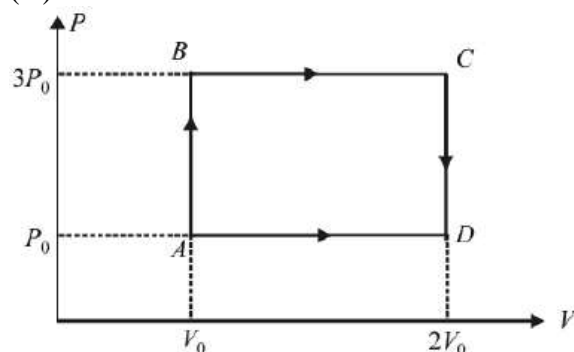Equation of adiabatic process is

$$TV^{\gamma-1} = \text{constant}$$

$$\Rightarrow T \propto \frac{1}{V^{\gamma-1}}$$

$$\Rightarrow T \propto V^{1+\frac{\gamma-1}{2}} \qquad \text{using (i)}$$

$$\Rightarrow T \propto V^{\frac{1+\gamma}{2}}$$

$$\Rightarrow \frac{T_f}{T_i} = \left(\frac{2V}{V}\right)^{\frac{1+\gamma}{2}} = (2)^{\frac{1+\gamma}{2}}$$

96. (A)

From the figure,

Work, $W = 2P_0V_0$

Heat given, $Q_{in} = W_{AB} + W_{BC} = n \cdot C_V \Delta T_{AB} + nC_P \Delta T_{BC}$

$$= n\frac{3R}{2}(T_B - T_A) + \frac{n5R}{2}(T_C - T_B) \qquad \left(\because C_V = \frac{3R}{2} \text{ and } C_P = \frac{5R}{2}\right)$$

$$= \frac{3}{2}(P_B V_B - P_A V_A) + \frac{5}{2}(P_C V_C - P_B V_B)$$

$$= \frac{3}{2} \times [3P_0V_0 - P_0V_0] + \frac{5}{2}[6P_0V_0 - 3P_0V_0]$$

$$= 3P_0V_0 + \frac{15}{2}P_0V_0 = \frac{21}{2}P_0V_0$$

Efficiency, $\eta = \dfrac{W}{Q_{in}} = \dfrac{2P_0V_0}{\dfrac{21}{2}P_0V_0} = \dfrac{4}{21}$

97. (C)

Efficiency, $\eta = \dfrac{\text{Work done}}{\text{Heat absorbed}} = \dfrac{W}{\Sigma Q}$

$$= \frac{Q_1 + Q_2 + Q_3 + Q_4}{Q_1 + Q_3} = 0.5$$

Here, $Q_1 = 1915$, $Q_2 = -40\,J$ and $Q_3 = 125\,J$

$\therefore \quad \dfrac{1915 - 40 + 125 + Q_4}{1915 + 125} = 0.5$

$\Rightarrow 1915 - 40 + 125 + Q_4 = 1020$

$\Rightarrow Q_4 = 1020 - 2000$

$\Rightarrow Q_4 = -Q = -980\,J$

$\Rightarrow Q = 980\,J$

98. **(D)**

For Carnot refrigerator

Efficiency $= \dfrac{Q_1 - Q_2}{Q_1}$

Where,

Q_1 = heat lost from surrounding

Q_2 = heat absorbed from reservoir at low temperature.

Also, $\dfrac{Q_1 - Q_2}{Q_1} = \dfrac{w}{Q_1}$

$\Rightarrow \dfrac{1}{10} = \dfrac{w}{Q_1}$

$\Rightarrow Q_1 = w \times 10 = 100\,J$

So, $Q_1 - Q_2 = w$

$\Rightarrow Q_2 = Q_1 - w$

$\Rightarrow 100 - 10 = Q_2 = 90\,J$

99. **(B)**

Let Q_H = Heat taken by first engine

Q_L = Heat rejected by first engine

Q_2 = Heat rejected by second engine

Work done by 1st engine = work done by 2nd engine

$W = Q_H - Q_L = Q_L - Q_2 \Rightarrow 2Q_L = Q_H + Q_2$

$2 = \dfrac{\theta_L}{\theta_L} + \dfrac{\theta_2}{\theta_L}$

Let T be the temperature of cold reservoir of first engine.

Then in Carnot engine.

$\dfrac{Q_H}{Q_L} = \dfrac{T_1}{T}$ and $\dfrac{Q_L}{Q_2} = \dfrac{T}{T_2}$

$\Rightarrow 2 = \dfrac{T_1}{T} + \dfrac{T_2}{T}$ using (i)

$\Rightarrow 2T = T_1 + T_2 \Rightarrow T = \dfrac{T_1 + T_2}{2}$

100. **(D)**

(I) **Adiabatic process :** No exchange of heat takes place with surroundings.

$$\Rightarrow \Delta Q = 0$$

(II) **Isothermal process :** Temperature remains constant

$$\therefore \Delta T = 0 \Rightarrow \Delta U = \frac{f}{2} nR\Delta T \Rightarrow \Delta U = 0$$

No change in internal energy $[\Delta U = 0]$.

(III) Isochoric process volume remains constant

$$\Delta V = 0 \Rightarrow W = \int P \cdot dV = 0$$

Hence work done is zero.

(IV) In isobaric process pressure remains constant.

$$W = P \cdot \Delta V \neq 0$$

$$\Delta U = \frac{f}{2} nR\Delta T = \frac{f}{2} [P\Delta V] \neq 0$$

$$\therefore \Delta Q = nC_p \Delta T \neq 0$$

101. (A)

(a) Given : $\text{K.E.}_{mean} = \frac{3}{2} kT = 4 \times 10^{-14}$

$P = 2$ cm of Hg, $V = 4$ cm^3

$$N = \frac{PV}{KT} = \frac{P\rho g V}{KT} \frac{2 \times 13.6 \times 980 \times 4}{\frac{8}{3} \times 10^{-14}} \simeq 4 \times 10^{18}$$

102. (C)

(c) Total degree of freedom $f = 3 + 2 = 5$

Total energy, $U = \frac{nfRT}{2} = \frac{5RT}{2}$

And $\gamma = \frac{C_p}{C_v} = 1 + \frac{2}{f} = 1 + \frac{2}{5} = \frac{7}{5}$

103. (B)

(b) Mean free path, $\lambda = \dfrac{1}{\sqrt{2}\pi n d^2}$

where, d = diameter of the molecule

n = number of molecules per unit volume

But, mean time of collision, $\tau = \dfrac{\lambda}{v_{rms}}$

But $v_{rms} = \sqrt{\dfrac{3kT}{R}}$ $\quad \therefore \tau = \dfrac{\lambda}{\sqrt{\dfrac{3kT}{m}}} \Rightarrow t \propto \dfrac{1}{\sqrt{T}}$

104. **(C)**

As we known,

$$\gamma = \frac{C_p}{C_v} = 1 + \frac{2}{f}, \text{ where } f = \text{degree of freedom}$$

(A) Monatomic, $f = 3$

$\therefore \quad \gamma = 1 + \dfrac{2}{3} = \dfrac{5}{3}$

(B) Diatomic rigid molecules, $f = 5$

$\therefore \quad \gamma = 1 + \dfrac{2}{5} = \dfrac{7}{5}$

(C) Diatomic non-rigid molecules, $f = 7$

$\therefore \quad \gamma = 1 + \dfrac{2}{7} = \dfrac{9}{7}$

(D) Triatomic rigid molecules, $f = 6$

$\therefore \quad \gamma = 1 + \dfrac{2}{6} = \dfrac{4}{3}$

105. **(D)**

(d) Here degree of freedom, $f = 3 + 3 = 6$ for triatomic non-linear molecule.

Internal energy of a mole of the gas at temperature T,

$$U = \frac{f}{2}nRT = \frac{6}{2}RT = 3RT$$

106. **(B)**

(b) Let C_p and C_v be the specific heat capacity of the gas at constant pressure and volume.

At constant pressure, heat required

$$\Delta Q_1 = nC_p\Delta T$$
$$\Rightarrow 160 = nC_p \cdot 50 \qquad \text{...(i)}$$

At constant volume, heat required

$$\Delta Q_2 = nC_v\Delta T$$
$$\Rightarrow 240 = nC_v \cdot 100 \qquad \text{...(ii)}$$

Dividing (i) by (ii), we get

$$\frac{160}{240} = \frac{C_p}{C_v} \cdot \frac{50}{100} \Rightarrow \frac{C_p}{C_v} = \frac{4}{3}$$

$$\gamma = \frac{C_p}{C_v} = \frac{4}{3} = 1 + \frac{2}{f} \qquad \text{(Here, } f = \text{degree of freedom)}$$

$$\Rightarrow f = 6.$$

107.　(A)

Total energy of the gas mixture,

$$E_{mix} = \frac{f_1 n_1 RT_1}{2} + \frac{f_2 n_2 RT_2}{2}$$

$$= 3 \times \frac{5}{2}RT + \frac{5}{2} \times 3RT = 15RT$$

108.　(A)

(a) As we know mean free path

$$\lambda = \frac{1}{\sqrt{2}\left(\dfrac{N}{V}\right)\pi d^2}$$

Here,　N = no. of molecule
　　　　V = volume of container
　　　　d = diameter of molecule

But $PV = nRT = nNKT$

$$\Rightarrow \frac{N}{V} = \frac{P}{KT} = n \quad \Rightarrow \lambda = \frac{1}{\sqrt{2}}\frac{KT}{\pi d^2 P}$$

For constant volume and hence constant number density n of gas

molecules $\dfrac{P}{T}$ is constant.

So mean free path remains same.
As temperature increases no. of collision increases so relaxation time decreases.

109.　(D)

(d) Specific heat of gas at constant volume

$C_v = \dfrac{1}{2} fR$; f = degree of freedom

For gas A (diatomic)

$f = 5$ (3 translational + 2 rotational)

$\therefore C_v^A = \dfrac{5}{2} R$

For gas B (diatomic) in addition to (3 translational + 2 rotational)
2 vibrational degree of freedom.

$\therefore \quad C_v^B = \dfrac{7}{2} R$ Hence $\dfrac{C_v^A}{C_v^B} = \dfrac{\frac{5}{2}R}{\frac{7}{2}R} = \dfrac{5}{7}$

110.　(Bonus)

(Bonus) Mean free path of a gas molecule is given by

$\lambda = \dfrac{1}{\sqrt{2}\pi d^2 n}$

Here, n = number of collisions per unit volume
d = diameter of the molecule
If average speed of molecule is v then

Mean free time, $\tau = \dfrac{\lambda}{v}$

$\Rightarrow \tau = \dfrac{1}{\sqrt{2}\pi n d^2 v} = \dfrac{1}{\sqrt{2}\pi n d^2} \sqrt{\dfrac{M}{3RT}}$ $\left(\because v = \sqrt{\dfrac{3RT}{M}} \right)$

$\therefore \quad \tau \propto \dfrac{\sqrt{M}}{d^2} \quad \therefore \quad \dfrac{\tau_1}{\tau_2} = \dfrac{\sqrt{M_1}}{d_1^2} \times \dfrac{d_2^2}{\sqrt{M_2}}$

$= \sqrt{\dfrac{40}{140}} \times \left(\dfrac{0.1}{0.07}\right)^2 = 1.09$

111.　(C)

Relaxation time $(\tau) \propto \dfrac{\text{mean free path}}{\text{speed}} \Rightarrow \tau \propto \dfrac{1}{v}$ and, $v \propto \sqrt{T}$

$\therefore \quad \tau \propto \dfrac{1}{\sqrt{T}}$

Hence, graph between τ v/s $\dfrac{1}{\sqrt{T}}$ is a straight line which is correctly depicted by graph shown in option (C).

112.　(A)

(a) Helium is a monoatomic gas and Oxygen is a diatomic gas.

For helium, $C_{V_1} = \frac{3}{2}R$ and $C_{P_1} = \frac{5}{2}R$

For oxygen, $C_{V_2} = \frac{5}{2}R$ and $C_{P_2} = \frac{7}{2}R$

$$\gamma = \frac{N_1 C_{P_1} + N_2 C_{P_2}}{N_1 C_{V_1} + N_2 C_{V_2}} \Rightarrow \gamma = \frac{n.\frac{5}{2}R + 2n.\frac{7}{2}R}{n.\frac{3}{2}R + 2n.\frac{5}{2}R} = \frac{19nR \times 2}{2(13nR)}$$

$$\therefore \left(\frac{C_P}{C_V}\right)_{mixture} = \frac{19}{13}$$

113. (C)

(c) Given, $U = 3PV + 4$

$\because \quad U = \frac{f}{2}nRT = \frac{f}{2}PV$

$\therefore \quad \frac{f}{2}PV = 3PV + 4$ or, $f = 6 + \frac{8}{PV}$

So $f_{min} = 6$

Hence the gas is polyatomic.

114. (C)

(c) $PT^3 = $ constant

$\left(\frac{nRT}{v}\right)T^3 = $ constant

$T^4 V^{-1} = $ constant

[using $PV = nRT$]

Taking log both sides

$4lnT - 1lnv = ln$ constant

differention w.r.t v

$4\frac{dT}{T} = \frac{dv}{V}$ ...(i)

$dV = V\gamma\Delta T$ ...(ii)
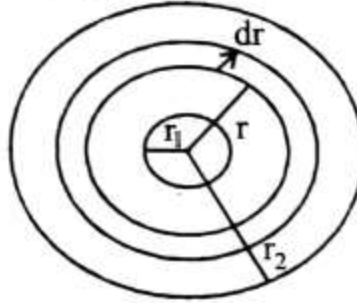
from (i) & (ii)

$\gamma = \frac{4}{T}$

115. (A)

(a) Resistance of spherical shell of thickness dr and radius r is

$$dR = \frac{dr}{K(4\pi r^2)} \quad \left[\text{using } R = \frac{1}{K}\frac{\ell}{A} \right]$$

Total resistance

$$R = \int_{r_1}^{r_2} \frac{dr}{K(4\pi r^2)}$$

$$\Rightarrow R = \frac{1}{4\pi K}\left(\frac{1}{r_1} - \frac{1}{r_2} \right)$$

$$\text{current} = \frac{\theta_2 - \theta_1}{R} = \frac{4\pi K r_1 r_2}{r_2 - r_1}(\theta_2 - \theta_1)$$

116. **(A)**

(a) From the conservation of energy
Change in potential energy = Heat energy

$$\Rightarrow mgh = mc\Delta T \Rightarrow \Delta T = \frac{gh}{c} = \frac{10 \times 63}{4200 J/kgC} = 0.147°C$$

117. **(C)**

(c) Let m be the mass of each liquid, s_1, s_2 and s_3 be the specific heat of x, y and z.
When x and y are mixed
Heat gained by x = Heat lost by y

$$ms_1(16 - 10) = ms_2(20 - 16) \Rightarrow s_1 = \frac{2}{3}s_2 \qquad ...(i)$$

When y and z are mixed
Heat gained by y = Heat lost by z
$$ms_2(26 - 20) = ms_3(30 - 26)$$

$$\Rightarrow s_2 \times 6 = s_3 \times 4 \Rightarrow s_3 = \frac{3}{2}s_2 \qquad ...(ii)$$

From (i) and (ii)

$$s_3 = \frac{3}{2} \times \frac{3}{2}s_1 = \frac{9}{4}s_1$$

When x and z are mixed, let the final temperature be θ
$$m_1 s_1 (\theta - 10) = ms_3 (30 - \theta)$$

$$\Rightarrow \theta - 10 = \frac{9}{4}(30 - \theta) \quad \left(\because \frac{s_3}{s_1} = \frac{9}{4} \right) \Rightarrow \theta = 23.84°C$$

118. (B)

    (b) From, $Q = nC\Delta T$

$$\Rightarrow \frac{dQ}{dt} = nC\frac{dT}{dt}$$

Rate of heat is same for both gases

i.e., $\dfrac{dQ_1}{dt} = \dfrac{dQ_2}{dt}$

or, $n_1 C_1 \left(\dfrac{dT}{dt}\right)_1 = n_2 C_2 \left(\dfrac{dT}{dt}\right)_2$

$$\therefore \frac{C_1}{C_2} = \frac{\left(\dfrac{dT}{dt}\right)_2}{\left(\dfrac{dT}{dt}\right)_1} = \frac{\dfrac{90}{6}}{\dfrac{120}{3}} = \frac{90 \times 3}{120 \times 6} = \frac{3}{8}$$

119. (B)

    (b) In adiabatic process $PV^\gamma = $ constant

    Differentiating both sides, we get

$$\Rightarrow (P)(\gamma)V^{\gamma-1}dV + V^\gamma dP = 0$$

$$\Rightarrow dP = \frac{-\gamma P}{V}dV \Rightarrow \frac{dP}{P} = -\frac{\gamma dV}{V}$$

120. (C)

    (a) Given, $PV^{1/2} = $ constant

    From $PV = nRT$

$$P \propto \frac{T}{V} \quad \therefore \quad \frac{T}{V} \times V^{1/2} = \text{constant} \Rightarrow T \propto \sqrt{V}$$

$$\therefore \frac{T_2}{T_1} = \sqrt{\frac{V_2}{V_1}} = \sqrt{\frac{2}{1}} = \sqrt{2} \quad [\because V_2 = 2V_1 \text{ Given}]$$

121. (C)

Heat and work depends on the path taken to reach a specific value. Hence, heat and work are path functions.

122. (A)

(a) Efficiency of heat engine

$$\eta = 1 - \frac{T_s}{T} \Rightarrow \frac{1}{4} = 1 - \frac{T_s}{T} \qquad [T_s \rightarrow \text{sink temperature}]$$

$$\Rightarrow 4T_s = 3T \text{ or, } T_s = \frac{3}{4}T \qquad \text{...(i)}$$

$$\Rightarrow \frac{1}{2} = 1 - \frac{T_s - 58}{T} \qquad \text{...(ii)}$$

From equation (i) & (ii)

$$\frac{3}{4} = \frac{58}{T} + \frac{1}{2} \Rightarrow \frac{1}{4} = \frac{58}{T} \Rightarrow T = 232$$

$$\therefore T_s = \frac{3}{4}T = 174°C$$

123. (A)

(a) Coefficient of performance $= \dfrac{\theta_2}{W} = \dfrac{T_L}{T_H - T_L}$

$$\Rightarrow \frac{\dfrac{d\theta_2}{dt}}{\dfrac{dW}{dt}} = \frac{263}{298 - 263} = \frac{263}{35}$$

$$\Rightarrow \frac{d\theta_2}{dt} = \frac{263}{35} \times \frac{dW}{dt} = \frac{263}{35} \times 35 \Rightarrow \frac{d\theta_2}{dt} = 263\,\text{watt}$$

124. (D)

(d) $\dfrac{W}{Q} = \left(1 - \dfrac{T_1}{T_2}\right) \Rightarrow \dfrac{1200}{Q} = \left(1 - \dfrac{400}{800}\right)$

$\therefore$ Amount of heat energy supplied to the engine from the source, $Q = 2400$ J.

125. (A)

(a) Given $\dfrac{dp}{dv} = -ap$

Integrating both sides we get

$$\Rightarrow \int\limits_{p_0}^{p} \frac{dp}{P} = -a\int\limits_{0}^{v} dv \Rightarrow \ell n\left(\frac{p}{p_0}\right) = -av \Rightarrow p = p_0 e^{-av}$$

Using ideal gas equation $pv = nRT$

$$T = \frac{pv}{nR} = \frac{p_0 v e^{-ev}}{R} \quad (\because n = 1)$$

$$\frac{dT}{dv} = 0 \Rightarrow \frac{p_0}{R}\left\{e^{-av} + ve^{-av}(-a)\right\}$$

$$\Rightarrow \frac{p_0 e^{-av}}{R}\left\{1 - ay\right\} = 0 \Rightarrow v = \frac{1}{a}$$

$$\therefore T_{max} = \frac{p_0 1}{Rae} = \frac{p_0}{Rae}$$

126. **(C)**

(c) Given,
Volume of cylinder, $V = 4 \times 10^{-3}\,\text{m}^3$
$n = 1 + 2 = 3$ moles
Temperature of the mixture, $T = 400K$

From ideal gas equation

$$\Rightarrow \quad PV = nRT \Rightarrow P = \frac{nRT}{V}$$

$$\Rightarrow P = \frac{3 \times 8.3 \times 400}{4 \times 10^{-3}} \Rightarrow P = 24.9 \times 10^5\,\text{Pa}$$

127. **(C)**

(c) From the ideal gas equation,
$PV = nRT$
$\Rightarrow \quad PV = CT$
Therefore, PV v/s T graph is straight line.

128. **(A)**

(a) Root mean square speed is given by

$$v_{rms} = \sqrt{\frac{3KT}{M}} \Rightarrow v_{rms} \propto \frac{1}{M}$$

$$\therefore \frac{(v_{rms})_{O_2}}{(v_{rms})_{H_2}} = \sqrt{\frac{M_{H_2}}{M_{O_2}}} \Rightarrow \frac{(v_{rms})_{O_2}}{(v_{rms})_{H_2}} = \sqrt{\frac{2}{32}} = \frac{1}{4}$$

$$\Rightarrow (v_{rms})_{H_2} = 4 \times (v_{rms})_{O_2} \qquad \left(\because (v_{rms})_{O_2} = 160 \, m/s \right)$$

$$= 4 \times 160 = 640 \text{ m/s}$$

129. (A)

(a) Root mean square velocity is given by

$$V_{rms} = \sqrt{\frac{3RT}{M}} \Rightarrow V_{rms} \propto \frac{1}{\sqrt{M}} \Rightarrow V_H > V_O > V_C$$

130. (C)

(c) Total kinetic energy $= \frac{f}{2} PV = \frac{3}{2} PV$

According the question $\frac{3}{2} PV = N \times 2 \times 10^{-9} J$

$$\Rightarrow \quad \frac{3}{2} \times 2 \times 10^5 \times 1000 \times 10^{-6} = N \times 2 \times 10^{-9}$$

$$\Rightarrow \quad N = \frac{3}{4} \times 2 \times \frac{10^5 \times 10^3 \times 10^{-6}}{10^{-9}} = \frac{3}{2} \times 10^{11} = 1.5 \times 10^{11}$$

131. (D)

(d) RMS speed of gas molecule at NTP

$$V_{rms} = \sqrt{\frac{3RT}{M}}$$

Average speed of gas molecule at NTP

$$V_{avg} = \sqrt{\frac{8RT}{\pi M}}$$

The required ratio

$$\Rightarrow \quad \frac{V_{rms}}{V_{avg}} = \sqrt{\frac{3\pi}{8}}$$

132. (D)

(d) Here, initial internal energy = Final internal energy

$$\frac{F_1}{2}n_1RT_1 + \frac{F_2}{2}n_2RT_2 = \frac{F_1}{2}n_1RT + \frac{F_2}{2}n_2RT$$

or $\quad T = \dfrac{n_1F_1T_1 + n_2F_2T_2}{n_1F_1 + n_2F_2}$

133. **(D)**

(d) Given, temperature of oxygen molecules, $T = 27°C$
Pressure of oxygen

$$l_{mean} = \frac{RT}{\sqrt{2}\pi d^2 N_A P} = \frac{1.38 \times 300 \times 10^{-23}}{\sqrt{2} \times 3.14 \times (0.3 \times 10^{-9})^2 \times 1.01 \times 10^5}$$

$= 102 \times 10^{-9}$ m $= 102$ nm

134. **(A)**

(a) At constant pressure, $dU = nC_V dT = n\dfrac{5}{2}RdT$

$dQ = nC_P dT = n\left(\dfrac{7R}{2}\right)dT$ and $dW = nRdT$

$\therefore dU : dQ : dW = \dfrac{5}{2} : \dfrac{7}{2} : 1 = 5 : 7 : 2.$

135. **(C)**

(c) According to Equi-partition law each degree of
freedom contributes $\dfrac{1}{2}k_B T$

Average energy = $f\left(\dfrac{1}{2}K_B T\right)$

$\therefore$ Average energy $= 3 \times \dfrac{1}{2}k_B T = \dfrac{3}{2}k_B T$

$[\because f_{monoatomic} = 3]$

136. **(3)**

(3) $(C_v)_{mix}$ of two mixed is given as,

$$(C_v)_{mix} = \frac{n_1 C_{v_1} + n_2 C_{v_2}}{n_1 + n_2} = \frac{1.\dfrac{3R}{2} + 3.\dfrac{5R}{2}}{1+3} = \frac{9R}{4} = \frac{\alpha^2}{4}R$$

$\Rightarrow \alpha = 3$

137. **(A)**

As the rods are identical, so they have same length (ℓ) are area of cross-section (A). They are connected in series. So, heat current will be same for all rods.

Heat current $= \left(\dfrac{\Delta Q}{\Delta t}\right)_{AB} = \left(\dfrac{\Delta Q}{\Delta t}\right)_{BC} = \left(\dfrac{\Delta Q}{\Delta t}\right)_{CD}$

$\Rightarrow \dfrac{(100-70)K_1 A}{\ell} = \dfrac{(70-20)K_2 A}{\ell} = \dfrac{(20-2)K_3 A}{\ell}$

$\Rightarrow K_1(100-70) = K_2(70-20) = K_3(20-0)$

$\Rightarrow K_1(30) = K_2(50) = K_3(20)$

$\Rightarrow \dfrac{K_1}{10} = \dfrac{K_2}{6} = \dfrac{K_3}{15} \Rightarrow K_1 : K_2 : K_3 = 10:6:15$

$\Rightarrow K_1 : K_3 = 2:3$

138. (D)

(d) We know that

$\Delta l = l_0 \propto \Delta T$

$\Rightarrow (6.241 - 6.230) = 6.230 \times 1.4 \times 10^{-5} \times \Delta T$

$\Rightarrow 0.011 = 6.230 \times 1.4 \times 10^{-5} \times \Delta T$

$\Rightarrow \Delta T = 126.1 \Rightarrow T_f - 27 = 126.1 \Rightarrow T_f = 153.11\ °C.$
So nearest option is (d).

139. (B)

(b) We have $\Delta V = V_0\ \lambda \Delta T$

$\Delta V = a^3 .(3\alpha)\ \Delta T$

Now, $6a^2 = 24$ [$\because$ Total surface area of cube $= 6a^2$]
$\Rightarrow a^2 = 4 \Rightarrow a = 2$

So, $\Delta V = 2^3(3 \times 5 \times 10^{-4}) \times 10 = 1200 \times 10^{-4}\ m^3$
$= 1200 \times 10^2\ cm^3 = 1.2 \times 10^5\ cm^3$

140. (C)

(c) In series $\dfrac{dQ}{dt} = $ constant

$\Rightarrow \dfrac{T_1 - T_2}{R} = $ constant $\Rightarrow \dfrac{450 - T}{\dfrac{l_s}{K_s A_s}} = \dfrac{T - 0}{\dfrac{l_c}{K_c A_c}}$

$\Rightarrow \dfrac{450 - T}{\dfrac{l_s}{l_c} \cdot \dfrac{K_c}{K_s} \cdot \dfrac{A_c}{A_s}} = T \Rightarrow \dfrac{450 - T}{2.9 \cdot \dfrac{1}{2}} = T$

$\Rightarrow 450 - T = 9T \Rightarrow 450 = 10T \Rightarrow T = 45\ °C$

141. (B)

(b) Given that latent heat of fusion of ice $L, = 3.4 \times 10^5 \, Jkg^{-1}$

Thermal conductivity of insulation wall, $K = 0.05 \, Wm^{-10}C^{-1}$

Change in temperature, $\Delta T = 40°C$

Area of ice cube, $A = 2(0.6 \times 0.5 + 0.5 \times 0.2 + 0.2 \times 0.6)$

$= 2(0.3 + 0.1 + 0.12) = 1.04 \, m^2$

We have

$$\frac{dQ}{dt} = \frac{KA\Delta T}{\ell} = \frac{0.05 \times 1.04 \times 40}{10^{-2}} = 2.08 \times 10^2 \, J/s$$

$$\frac{dQ}{dt} = mL \Rightarrow 2.08 \times 10^2 = m \times 3.4 \times 10^5$$

$$m = \frac{2.08}{3.4 \times 10^3} = 0.61 \times 10^{-3} \, kg/s = 61 \times 10^{-5} \, Kg/s$$

142. (C)

(c) Number of moles of gas, $n = \frac{44.8}{22.4} = 2$

$$\Delta Q = nC_V \, \Delta T \; \left[\because V = \text{constant} \Rightarrow C = C_V \right]$$

$$= 2 \cdot \frac{3}{2} R \times 20 = 60 \, R = 60 \times 8.3 = 498 \, J.$$

143. (B)

(b) 40% of $K.E = ms \, \Delta T + mL_f$

$$\Rightarrow \frac{40}{100} \times \frac{1}{2} mV^2 = ms(327 - 127) + mL_f$$

$$\Rightarrow \frac{20}{100} \times V^2 = 200S + L_f \Rightarrow \frac{1}{5} V^2 = 200 \times 125 + 2.5 \times 10^4$$

$$\Rightarrow V^2 = 1000 \times 125 + 2.5 \times 10^4 \times 5$$

$$\Rightarrow V^2 = 250000 \Rightarrow V = 500 \, m/s$$

144. (C)

(c) Here, heat lost by Cu block = Heat gain by ice

$$\Rightarrow M_{cu} \cdot S_{cu} (T_{500} - T_0) = M_{ice} L_f$$

$$\Rightarrow M_{ice} = \frac{M_{cu} \cdot S_{cu}(T_{500} - T_0)}{L_f} = \frac{5 \times 390 \times 500}{335 \times 10^3} = 2.9 \, kg$$

145. (B)

(b) As Q = constant in series

So, $Q_{M1} = Q_{M2}$

$$\Rightarrow \frac{(100-80)}{\frac{16}{k_1 A}} = \frac{80-0}{\frac{8}{k_2 A}} \quad \left[\because Q = \frac{T_1 - T_2}{\frac{l}{kA}}\right]$$

$$\Rightarrow \frac{20}{16} \times k_1 A = \frac{80}{8} k_2 A \Rightarrow k_2 = \frac{20 \times 8}{16 \times 80} k_1$$

$$\Rightarrow k_2 = \frac{k_1}{8} \Rightarrow k_1 = 8k_2 = 8k.$$

146. (C)

(c) According to question

$\frac{1}{4} \times$(K.E. of Hammer) = Heat energy received by nail

$$\Rightarrow \frac{1}{4} \times \frac{1}{2} m_h v_h^2 = m_n s_n \Delta T$$

$$\Rightarrow \frac{1}{8} \times 1.5 \times 60^2 = 0.1 \times 420 \times \Delta T$$

$$\Rightarrow \Delta T = \frac{1.5 \times 60^2}{8 \times 0.1 \times 420} = 16.07\,°C$$

147. (B)

(b) In complete cycle

$\Delta Q = \Delta W \qquad [\because \Delta U_{cylce} = 0]$

$\Rightarrow 40 + 0 - 60 = 0 - 50 + W_{CA}$

$\Rightarrow -20 = -50 + W_{CA} \Rightarrow W_{CA} = 30\,J$

148. (B)

(b) Work down by the gas = Area under the curve
The work done by the gas from D to E,

$$W_{DE} = \frac{1}{2}(600+300)\,3\,J = 1350\,J$$

The work done by the gas from E to F,
$$W_{EF} = -300 \times 3 = -900\,J$$
The total work done by the gas from D to E to F will be
$$W_{DEF} = 1350\,J - 900\,J = 450\,J$$

149. **(A)**

(a) Given that change in temperature $\Delta T = 40\,K$
Number of moles $n = 40\,mol$
$R = 8.3\,JK^{-1}\,mol^{-1}$

For monoatomic gas $C_v = \frac{3}{2}R$

The increase in the internal energy of the gas will be,

$$\Delta U = nC_v\Delta T = n\frac{3}{2}R\Delta T = 7 \times \frac{3}{2} \times 8.3 \times 40$$

$$\Rightarrow \quad \Delta U = 5810\,J$$

150. **(C)**

(c) For monoatomic gas, $\gamma = \frac{5}{3}$

For an adiabatic process, $PV^\gamma = $ constant
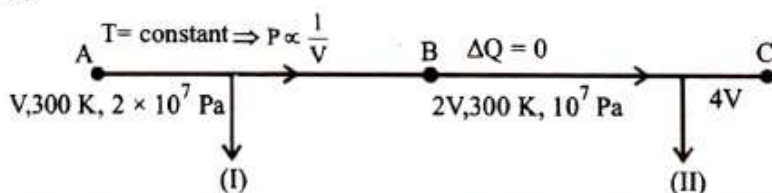For an adiabatic process, $PV^\gamma = P'(V')^\gamma$

$$\Rightarrow PV^{5/3} = P'\left(\frac{V}{8}\right)^{5/3} \quad \left(\text{Given, } V' = \frac{V}{8}\right)$$

$$\Rightarrow P' = (8)^{5/3} P = (2)^5 P = 32\,P$$

151. **(B)**

(b)

T = constant $\Rightarrow P \propto \dfrac{1}{V}$

A   →   B   ΔQ = 0   →   C

V, 300 K, 2×10^7 Pa   2V, 300 K, 10^7 Pa   4V

(I)   (II)

For AB or Process (I)   **For BC or Process (II)**

$$P \propto \frac{1}{V} \Rightarrow P_2 = P_1\left(\frac{V_1}{V_2}\right)$$ $PV^\gamma = \text{Constant}$

$$= 2 \times 10^7 \times \left(\frac{1}{2}\right)$$ $$P_2 = P_1\left(\frac{V_1}{V_2}\right)^\gamma = 10^7\left(\frac{1}{2}\right)^{1.5}$$

$$= 10^7 \, \text{Pa}$$ $$= 3.53 \times 10^6 \, \text{Pa}$$

---

152. (B)

(b) Work done in any process is given as

$$w = \frac{P_2V_2 - P_1V_1}{1-x}$$

In adiabatic process,

$$P_2V_2^\gamma = P_1V_1^\gamma$$

$$P_2 = P_1\left(\frac{V_1}{V_2}\right)^\gamma = 75\left(\frac{1200}{150}\right)^{\frac{5}{3}} = 75(8)^{\frac{5}{3}}$$

$$= 75 \times 32 = 2400 \, \text{kPa}]$$

Here, $x = \gamma$

So, $w = \dfrac{P_2V_2 - P_1V_1}{1-\gamma} = \left(\dfrac{2400 \times 150 - 75 \times 1200}{1 - \dfrac{5}{3}}\right) \times 10^{-3}$

$$= 405000 \times 10^{-3} = 405 \, \text{J}$$

---

153. (C)

(c) Efficiency, $\eta = 1 - \dfrac{T_L}{T_H}$

Given $\eta = 50\%$ $\therefore$ $\dfrac{1}{2} = 1 - \dfrac{T_L}{T_H}$

when η increases 30% then,

$$\frac{1}{2}(1.3) = 1 - \left(\frac{T_L - 40}{T_H}\right) \Rightarrow \frac{1}{2}(1.3) = \frac{1}{2} + \frac{40}{T_H}$$

$$\therefore T_H = 266.7 \, \text{K}$$

154. (C)

(c) Efficiency of Carnot's heat engine,

$$\eta = 1 - \frac{T_2}{T_1}$$

In first case, $T_1 = 300\,K$, $T_2 = 100\,K$

$$\therefore \quad \eta = 1 - \frac{100}{300} = \frac{2}{3}$$

In second case efficiency, $\eta_{net} = \eta_1 + \eta_2 - \eta_1\eta_2$

For $T_1 = 300\,K$, $T_2 = 200\,K$

$$\eta_1 = 1 - \frac{200}{300} = \frac{1}{3}$$

$$\eta_2 = 1 - \frac{100}{200} = \frac{1}{2} \quad \because T_1 = 200\,K, T_2 = 100\,K$$

$$\therefore \quad \eta_{net} = \frac{1}{3} + \frac{1}{2} - \frac{1}{6} = \frac{2}{3}$$

$\eta(\text{first case}) = \eta(\text{second case})$

155. (B)

(b) Efficiency of heat engine is given as $\eta = 1 - \frac{T_L}{T_H}$

For $T_1 = 447\,°C$ and $T_2 = 147\,°C$

$$\eta_1 = 1 - \frac{147 + 273}{447 + 273} = 1 - \frac{420}{720} \Rightarrow \eta_1 = \frac{300}{720}$$

For $T_1 = 947\,°C$ and $T_2 = 47\,°C$

$$\eta_2 = 1 - \frac{47 + 273}{947 + 273} = 1 - \frac{320}{1220} \Rightarrow \eta_2 = \frac{900}{1220}$$

so, $\dfrac{\eta_1}{\eta_2} = \dfrac{300}{720} \times \dfrac{1220}{900} = \dfrac{122}{72 \times 3} \Rightarrow \dfrac{\eta_1}{\eta_2} = 0.56$

156. (A)

(a) We have

$$\eta = 1 - \frac{T_{sink}}{T_{source}} = 1 - \frac{273}{373} = \frac{100}{373} = 0.2681$$

So, $\% \, \eta = 26.81\%$

157. (B)

(b) Initially, $\eta = 0.25$

$$1 - \frac{T_{sink}}{T_{source}} = 0.25 \Rightarrow 0.75 = \frac{T_{sink}}{T_{source}}$$

$$T_{source} = \frac{T_{sink}}{0.75} = \frac{300}{0.75} = 400\,K$$

Finally, $\eta = 0.25 + 100\%$ of 0.25

$\eta = 0.5$

$$\Rightarrow \quad 1 - \frac{T_{sink}}{T'_{source}} = 0.5 \Rightarrow 0.5 = \frac{300}{T'_{source}} \Rightarrow T'_{source} = 600\,K$$

$\therefore \Delta T = (600 - 400)\,K = 200\,K = 200\,°C$

158. (C)

(c) $\eta = \dfrac{W}{Q_{absorbed}} \Rightarrow W = \eta\, Q_{absorbed}$

$$= \left(1 - \frac{T_{sink}}{T_{source}}\right) Q_{absorbed} = \left(1 - \frac{400}{1000}\right) 5000\,Kcal$$

$$= \frac{6}{10} \times 5000\ Kcal = 3000\ Kcal$$

$$= 3000 \times 10^3 \times 4.2\,J\,[\because 1\ cal = 4.2 J] = 12.6 \times 10^6\,J$$

159. (D)

(d) At constant volume

$P \propto T$

So, $T_2 = T_1 \times \dfrac{P_2}{P_1} = 273 \times \dfrac{180}{100} = 273 \times \dfrac{9}{5} \approx 491 K$

160. (C)

(c) Number of moles $(n) = n_h + n_0$

$$= \frac{16}{2} + \frac{128}{32} = 8 + 4 = 12$$

At STP, 1 moles occupy 22.4 l

So, 12 moles occupy $(22.4 \times 12)l$

i.e. 268.8l

i.e. $268.8 \times 10^3 cm^3$

i.e. $27 \times 10^4 cm^3$

161. (B)

(b) By ideal gas equation

$PV = nRT$

$$n = \frac{PV}{RT} = \frac{10^5 \times 2000 \times 10^{-6}}{8.314 \times 300} = 0.08$$

So, $n_h + n_0 = 0.08$ ...(i)

as, $m = 0.76g$

$\Rightarrow 2n_h + 32n_0 = 0.76$

$\Rightarrow n_h + 16n_0 = 0.38$ ...(ii)

Substracting (i) from (ii), we get

$15n_0 = 0.30 \Rightarrow n_0 = 0.02$

So, $n_h = 0.08 - n_0 = 0.08 - 0.02 = 0.06$

Therefore, $\dfrac{n_h}{n_0} = \dfrac{0.06}{0.03} = \dfrac{2}{1}$

162. (C)

(c) The roat mean square speed of smoke particles is given by

$$v_{rms} = \sqrt{\frac{3kT}{m}} = \sqrt{\frac{3 \times 1.38 \times 10^{-23} \times 293}{5 \times 10^{-17}}} \approx 15\ mm/s$$

163. (D)

(d) Due to random motion of gas molecules, average momentum $P_{avg} = 0$, so P_{avg} do not depend on temperature.

$$v_{rms} = \sqrt{\frac{3RT}{M}}$$

When temperature is doubled, $T_{rms} = 2T$

$$M_{new} = \frac{M}{2}$$

$$\frac{v_{new}}{v} = \frac{\sqrt{\frac{2T}{M/2}}}{\sqrt{\frac{T}{M}}} \qquad (\therefore v_{new} = 2v)$$

164.   (C)

(c) $v_{rms} = \sqrt{\frac{3RT}{M_0}}$ and, $v_{rms_f} = 2v_{rms_i} \Rightarrow \sqrt{\frac{T_f}{T_i}} = 2$

$\Rightarrow T_f = 4T_i = 1200 \text{ k}$

Now, $T_f = 1200K$, $T_i = 300K$, $n = \frac{14}{28} = \frac{1}{2}$

So, $Q = nC_v\Delta T = \frac{1}{2} \times \frac{5R}{2} \times 900$

$Q = 9360 \text{ J}$

165.   (C)

(c) $v_{rms} = \sqrt{\frac{3RT}{M_0}}$

$v_{rms} \propto \frac{T}{\sqrt{M_0}}$. As T and M_0 are same for both gas. So, V_{rms} will be same and point (A) is correct.

As, $PV = NKT$

as, V and T is constant $\Rightarrow P \propto N$

$\Rightarrow \frac{P_1}{P_2} = \frac{N_1}{N_2} \Rightarrow \frac{P_1}{P_2} = \frac{1}{4}$ So, point (B) is correct

As point (A) and (B) is correct. So (C) and (D) must be wrong.

166.   (B)

(b) Speed of sound is given as

$$v_s = \sqrt{\frac{\gamma RT}{M}} \quad \text{and,} \quad v_{rms} = \sqrt{\frac{3RT}{M}}$$

So, $\dfrac{v_s}{v_{rms}} = \sqrt{\dfrac{g}{3}} = \dfrac{1}{\sqrt{2}} \Rightarrow \dfrac{\gamma}{3} = \dfrac{1}{2} \Rightarrow \gamma = \dfrac{3}{2}$

As we know

$$\gamma = 1 + \frac{2}{f_{mix}} \quad \text{and} \quad f_{mix.} = \frac{2 \times 3 + n \times 5}{n+2} = \frac{6 + n \times 5}{(n+2)}$$

$$\gamma = 1 + \frac{2(n+2)}{6 + n \times 5} = \frac{6 + 5n + 2n + 4}{6 + 5n} \Rightarrow \gamma = \frac{7n + 10}{6 + 5n} = \frac{3}{2}$$

$$\Rightarrow 14n + 20 = 18 + 15n \Rightarrow n = 2$$

167. **(A)**

(a) $C_v = \dfrac{nR}{2}, \quad C_p = \dfrac{(n+2)R}{2} \quad (\because C_p - C_v = R)$

$$\frac{C_v}{C_p} = \frac{n}{n+2}$$

168. **(B)**

(b) Here, the entire external kinetic energy of gases will be converted to internal energy.

i.e. $\dfrac{1}{2}(nM)V^2 = nC_V \Delta T$

$$\frac{1}{2}nMV^2 = \frac{nR}{\gamma - 1}\Delta T$$

$$\Delta T = \frac{MV^2(\gamma - 1)}{2R} = \frac{MV^2 \times 0.4}{2R} = \frac{MV^2}{5R}$$

169. **(None)**

(None) Average kinetic energy per molecule $= \dfrac{f}{2}KT$

$$\frac{Av.K.E_{Ar}}{Av.K.E_{O_2}} = \frac{\frac{3}{2}KT}{\frac{5}{2}KT} = \frac{3}{5}$$

170. **(40)**

Using the principal of calorimetry

$$M_{ice}L_f + m_{ice}(40 - 0)C_w = m_{stream}L_v + m_{steam}(400 - 40)C_w$$

$$\Rightarrow M(540) + M \times 1 \times (100 - 40) = 200 \times 80 + 200 \times 1 \times 40$$

$$\Rightarrow 600M = 24000 \Rightarrow M = 40\,g$$

171. (5)

Using ideal gas equation, $PV = nRT$

$\Rightarrow P_1 V_1 = nR \times 250 \qquad [\because T_1 = 250\,K] \qquad \dots(i)$

$P_2(2V_1) = \dfrac{5n}{4}R \times 2000 \qquad [\because T_2 = 2000\,K] \qquad \dots(ii)$

Dividing eq. (i) by (ii)m

$\dfrac{P_1}{2P_2} = \dfrac{4 \times 250}{5 \times 2000} \Rightarrow \dfrac{P_1}{P_2} = \dfrac{1}{5}$

$\therefore \dfrac{P_2}{P_1} = 5.$

172. (150)

In first case, from ideal equation

$PV = nRT$

$P\Delta V + V\Delta P = 0 \qquad$ (As temperature is constant)

$\Delta V = -\dfrac{\Delta P}{P}V \qquad \dots(i)$

In second case, using ideal gas equation again

$P\Delta V = -nR\Delta T$

$\Delta V = -\dfrac{nR\Delta T}{P} \qquad \dots(ii)$

Equating (i) and (ii), we get

$\dfrac{nR\Delta T}{P} = -\dfrac{\Delta P}{P}V \Rightarrow \Delta T = \Delta P \dfrac{V}{nR}$

Comparing the above equation with $|\Delta T| = C|\Delta P|$, we have

$C = \dfrac{V}{nR} = \dfrac{\Delta T}{\Delta P} = \dfrac{300\,K}{2\,atm} = 150\,K/atm$

173. (41)

Room mean square speed is given by

$v_{rms} = \sqrt{\dfrac{3RT}{M}}$

Here, M = Molar mass of gas molecule

T = temperature of the gas molecule

We have given $v_{N_2} = v_{H_2}$

$\therefore \sqrt{\dfrac{3RT_{N_2}}{M_{N_2}}} = \sqrt{\dfrac{3RT_{H_2}}{M_{H_2}}} \Rightarrow \dfrac{T_{H_2}}{2} = \dfrac{573}{28} \Rightarrow T_{H_2} = 41\,K$

174. (20.00)

(20.00)

Volume capacity of beaker, $V_0 = 500$ cc

$$V_b = V_0 + V_0 \gamma_{beaker} \Delta T$$

When beaker is partially filled with V_m volume of mercury,

$$V_b^1 = V_m + V_m \gamma_m \Delta T$$

Unfilled volume $(V_0 - V_m) = (V_b - V_m^1)$

$$\Rightarrow V_0 \gamma_{beaker} = V_m \gamma_M \quad \therefore V_m = \frac{V_0 \gamma_{beaker}}{\gamma_M}$$

or, $V_m = \dfrac{500 \times 6 \times 10^{-6}}{1.5 \times 10^{-4}} = 20$ cc.

175. (60.00)

(60.00) Volume, $V = lbh$

$$\therefore \gamma = \frac{\Delta V}{V} = \frac{\Delta \ell}{\ell} + \frac{\Delta b}{b} + \frac{\Delta h}{h}$$

(γ = coefficient of volume expansion)
$\Rightarrow \gamma = 5 \times 10^{-5} + 5 \times 10^{-6} + 5 \times 10^{-6}$
$= 60 \times 10^{-6}/°C$

$\therefore$ Value of $C = 60.00$

176. (8791)

Given,
Heat absorbed, $Q_2 = mL = 80 \times 100 = 8000$ Cal
Temperature of ice, $T_2 = 273$ K
Temperature of surrounding,
$T_1 = 273 + 27 = 300$ K

Efficiency $= \dfrac{w}{Q_2} = \dfrac{Q_1 - Q_2}{Q_2} = \dfrac{T_1 - T_2}{T_2} = \dfrac{300 - 273}{273}$

$\Rightarrow \dfrac{Q_1 - 8000}{8000} = \dfrac{27}{273} \Rightarrow Q_1 = 8791$ Cal

177. (600.00)

(600.00) Given; $T_1 = 900\ K$, $T_2 = 300K$, $W = 1200\ J$

Using, $1 - \dfrac{T_2}{T_1} = \dfrac{W}{Q_1}$

$\Rightarrow 1 - \dfrac{300}{900} = \dfrac{1200}{Q_1}$

$\Rightarrow \dfrac{2}{3} = \dfrac{1200}{Q_1} \Rightarrow Q_1 = 1800$

Therefore heat energy delivered by the engine to the low

178. **(46)**
For adiabatic process, $TV^{\gamma-1} =$ constant

or, $T_1 V_1^{\gamma-1} = T_2 V_2^{\gamma-1}$

$T_1 = 20°C + 273 = 293\ K$, $V_2 = \dfrac{V_1}{10}$ and $\gamma = \dfrac{7}{5}$

$T_1 (V_1)^{\gamma-1} = T_2 \left(\dfrac{V_1}{10}\right)^{\gamma-1}$

$\Rightarrow 293 = T_2 \left(\dfrac{1}{10}\right)^{2/5} \Rightarrow T_2 = 293(10)^{2/5} \simeq 736\ K$

$\Delta T = 736 - 293 = 443\ K$

During the process, change in internal energy

$\Delta U = NC_V \Delta T = 5 \times \dfrac{5}{2} \times 8.3 \times 443 \simeq 46 \times 10^3\ J = X\ kJ$

$\therefore\ X = 46 \cdot$

179. **(1818)**

(1818) For an adiabatic process,
$TV^{\gamma-1} = $ constant

$\therefore \quad T_1 V_1^{\gamma-1} = T_2 V_2^{\gamma-1}$

$\Rightarrow \quad T_2 = (300) \times \left(\dfrac{V_1}{\dfrac{V_1}{16}} \right)^{1.4-1} \qquad \Rightarrow \quad T_2 = 300 \times (16)^{0.4}$

Ideal gas equation, $PV = nRT$

$\therefore \quad V = \dfrac{nRT}{P}$

$\Rightarrow \quad V = kT$ (since pressure is constant for isobaric process)

So, during isobaric process

$V_2 = kT_2$ ...(i)

$2V_2 = kT_f$ ...(ii)

Dividing (i) by (ii)

$\dfrac{1}{2} = \dfrac{T_2}{T_f}$

$T_f = 2T_2 = 300 \times 2 \times (16)^{0.4} = 1818\ K$

180. (266.67)

Here work done on gas and heat supplied to the gas are zero.
Let T be the final equilibrium temperature of the gas in the vessel.
Total internal energy of gases remain same.

i.e., $u_1 + u_2 = u'_1 + u'_2$

or $\quad n_1 C_v \Delta T_1 + n_2 C_v \Delta T_2 = (n_1 + n_2) C_v T$

$\Rightarrow \quad (0.1) C_v (200) + (0.05) C_v (400) = (0.15) C_v T$

$\therefore \quad T = \dfrac{800}{3} = 266.67\ K$

181. (8)

(8) Original length $= l_0 (1 + \alpha \Delta T)$
Compression $= l_0 \alpha \Delta T$

$\therefore \quad$ stress $= \gamma$(strain) $= \dfrac{\gamma l_0 \alpha \Delta T}{l_0 (1 + \alpha \Delta T)} = \gamma \alpha \Delta T$

$[\because \alpha$ is very small$]$

So, F = Stress × Area = $\gamma\alpha A\Delta T$

$\Rightarrow F = (10 \times 10^{-4})(2 \times 10^{11})(10^{-5})(400)$

$\Rightarrow F = 8 \times 10^5 \, N = x \times 10^5 \, N \Rightarrow x = 8$

182. (5)

(5) Elastic energy stored, $= \dfrac{Y}{2}(\text{strain})^2 \times \text{area} \times \text{length}$

∴ Elastic energy stored, per unit length

$= \dfrac{Y}{2}(\text{strain})^2 \times \text{area}$

$= \dfrac{Y}{2}(\alpha\Delta T)^2 \times A \left[\because \text{strain} = \dfrac{\Delta\ell}{\ell} = \alpha\Delta T\right]$

$= \dfrac{10^{11}}{2} \times (10^{-5} \times 10)^2 \times 10^{-2} = \dfrac{10^{11}}{2} \times (10^{-4})^2 \times 10^{-2} = 5 \, J/m$

183. (2)

(2) [As AB & CD identical]

$R_{AB} = R_{CD} = 10 \, Kw^{-1}$

$R_{AC} = R_{CB} = 5 \, kw^{-1}$

[As AC = BC]
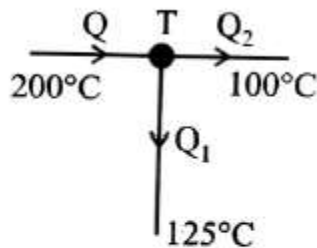
$R_{AC} = R_{CB} = 5 \, kw^{-1}$

at point C

$Q = Q_1 + Q_2$

$\dfrac{200 - T}{5} = \dfrac{T - 125}{10} + \dfrac{T - 100}{5} \Rightarrow T = 145°C$

$\Rightarrow P = \dfrac{145 - 125}{10} w = \dfrac{20}{10} w \Rightarrow P = 2w$

184. (57)

(57) By Newton's law of cooling

$$\frac{\Delta T}{\Delta t} = -C\left(T_{avg} - T_s\right)$$

In first 5 minutes time,

$$\frac{-10°C}{5 \text{ min}} = -C(70°C - 25°C) \Rightarrow C = \frac{2}{45} \text{ min}^{-1}$$

In next 5 minutes time,

$$\frac{T - 65}{5 \text{ min}} = -C\left(\frac{T + 65}{2} - 25\right) = -\left(\frac{2}{45}\right)\left(\frac{T + 15}{2}\right)$$

$$\Rightarrow 9(T - 65) = -(T + 15) \Rightarrow 10T = 570$$

$$\therefore T = 57°C$$

185. (17258)

(17258) In isothermal process, work done

$$W = nRT\ell n\left(\frac{V_2}{V_1}\right) = 1 \times 8.3 \times 300 \, \ell n\left(\frac{4}{2}\right)$$

$$= 1 \times 8.3 \times 300 \times \ell n2 = 2490 \times 0.6931$$

or $W = 17258 \times 10^{-1} \text{ J}$

[**Note :** There is anamoly in problem as $PV = nRT$]

186. (25.00)

(25.00) From first law of thermodynamics

$$Q = \Delta U + \Delta W = \Delta U + \frac{Q}{5}$$

$$\Rightarrow \quad \Delta U = \frac{4Q}{5} \Rightarrow \frac{5R}{2}\Delta T = \frac{4}{5}Q \qquad \left[\because \Delta U = \frac{f}{2}nR\Delta T\right]$$

or, $\dfrac{Q}{\Delta T} = \dfrac{\dfrac{5R}{2}}{\dfrac{4}{5}} = \dfrac{25R}{8}$

Therefore molar heat capacity of the gas during the

process $C = \dfrac{Q}{\Delta T} = \dfrac{25}{8}R$ $\therefore$ $x = 25$

187. (60.00)

(60.00) $V = KT^{2/3}$

$TV^{-2/3} = $ cons.

Comparing it with $TV^{m-1} = $ cons.

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

So, $\omega = \dfrac{nR\Delta T}{1-m} = \dfrac{1R \times 90}{1-\left(-\dfrac{1}{2}\right)} = 60R \quad \therefore x = 60$

188. (50)

(50) Given : $P = KV^3$

$\Rightarrow PV^{-3} = $ Constant (K) $\therefore \gamma = -3$.

Work done, $W = \dfrac{nR(T_1 - T_2)}{\gamma - 1} = \dfrac{nR(100 - 300)}{-3 - 1}$

or, $W = \dfrac{200nR}{4} = 50\, nR$

189. (500)

(500) Given,

Heat taken, $Q_1 = 300\,J$

Heat delivered, $Q_2 = 240\,J$

Work done by heat engine, $W = Q_1 - Q_2 = 300 - 240 = 60J$

Efficiency $= \dfrac{W}{Q_{in}} = \dfrac{60}{300} = 1 - \dfrac{T_2}{T_1}$

$\Rightarrow \dfrac{1}{5} = 1 - \dfrac{400}{T_1} \Rightarrow \dfrac{400}{T_1} = \dfrac{4}{5} \Rightarrow T_1 = 500\,K.$

190. (−113)

(−113) Efficiency, $\eta = 1 - \dfrac{T_{Sink}}{T_{Source}}$

$0.6 = 1 - \dfrac{T_{Sink}}{400}$ [$\because T_{Source} = 127 + 273 = 400\,k$]

$400 - T_{Sink} = 240 \Rightarrow T_{Sink} = 160\,k$

$\therefore T_{Sink} = 160 - 273 = -113°C$

191. (25)

(25) In isobaric process, pressure does not change.

$\therefore$ Change in internal energy, $\Delta U = nC_v\Delta T = \dfrac{5nR\Delta T}{2}$

Workdone, $W = nR\Delta T$

$\therefore \dfrac{\Delta U}{W} = \dfrac{5nR\Delta T}{nR\Delta T} = \dfrac{5}{2} = \dfrac{x}{10} \Rightarrow x = 25.00$

192.   (400)

(400) rms speed of molecule is $v_{rms} = \sqrt{\dfrac{3RT}{M}}$

$\therefore v_{rms} \propto \sqrt{T}$

Now,

$\therefore \dfrac{(v_{rms})_2}{(v_{rms})_1} = \sqrt{\dfrac{T_2}{T_1}}$

$T_1 = 300K$ and $T_2 = 400K$

$\therefore \dfrac{(v_{rms})_2}{(v_{rms})_1} = \sqrt{\dfrac{400}{300}} = \dfrac{2}{\sqrt{3}}$

$\Rightarrow (v_{rms})_2 = \dfrac{2}{\sqrt{3}}(v_{rms})_1 = \dfrac{2}{\sqrt{3}} \times 200 = \dfrac{400}{\sqrt{3}}$ m/s

193.   (3600)

(3600) Here, $nC_v\Delta T = \dfrac{1}{2}mv^2$

For monoatomic gas, $C_v = \dfrac{3}{2}R$

$\Rightarrow \Delta T = \dfrac{1}{2}\left(\dfrac{m}{n}\right) \cdot \dfrac{2}{3R}(30)^2$

Lets assume mass per mole $= 4$ kg/mol

$= \dfrac{1}{2} \times 4 \times \dfrac{2}{3R} \times 30 \times 30 = \dfrac{3600}{3R}$

$\therefore X = 3600.$

194.   (25)

(25) As this is a case of free expansion.

So, $\Delta V = 0 \Rightarrow \Delta T = 0$

So, $T_i = T_f = T$

Now, $(n_1 + n_2)_{initial} = (n_1 + n_2)_{final}$

$$\Rightarrow \frac{P_1 V_1}{RT} + \frac{P_2 V_2}{RT} = \frac{PV_1}{RT} + \frac{PV_2}{RT}$$

$$\Rightarrow P = \frac{P_1 V_1 + P_2 V_2}{V_1 + V_2} = 2.55\, atm$$

195. (60)

(60) For no change in length

$\Rightarrow \Delta \ell_{Iron} = \Delta \ell_{Brass}$

$\Rightarrow \ell_I \alpha_I \Delta T = \ell_B \alpha_B \Delta T \Rightarrow \ell_I \times 1.2 \times 10^{-5} = 40 \times 1.8 \times 10^{-5}$

$$\Rightarrow \ell_I = \frac{40 \times 1.8}{1.2} = \frac{40 \times 3}{2} = 60\, cm$$

196. (90)

(90) Energy released by water = $M\Delta TS$

$= 0.3 \times 25 \times 4200 = 31500\, J$

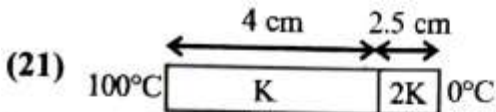Let m kg ice metls = mL

$m \times 3.5 \times 10^5 = 31500$ [∵ Heat lost = Heat absorbed]

$$\Rightarrow m = \frac{31500 \times 10^{-5}}{3.5} = 9000 \times 10^{-5}$$

$m = 0.09\, kg = 90\, gm \Rightarrow x = 90$

197. (21)

(21) 100°C [K] [2K] 0°C   (4 cm, 2.5 cm)

In series, $R_{eq} = R_1 + R_2$

$$\Rightarrow \frac{L}{KA} = \frac{L_1}{K_1 A} + \frac{L_2}{K_2 A} \Rightarrow \frac{L}{K} = \frac{L_1}{K_1} + \frac{L_2}{K_2}$$

$$\Rightarrow \frac{6.5}{K_{eq}} = \frac{4}{K} + \frac{2.5}{2K} \Rightarrow \frac{6.5}{K_{eq}} = \frac{1}{K}\left(\frac{8+2.5}{2}\right)$$

$$\Rightarrow \frac{6.5}{K_{eq}} = \frac{1}{K}\left(\frac{10.5}{2}\right) \therefore K_{eq} = \frac{13K}{10.5} = \frac{26}{21}K = \left(1 + \frac{5}{21}\right)K$$

So, $a = 21$.

198. (42)

(42) Heat absorbed by water per min = $2 \times 4200 \times 40$
$= 336000 \text{J}$

Now, $8 \times 10^3 \text{J}$ of heat is produced by 1 gm.

So, 336000 J of heat is produced by 1 gm

$= \dfrac{1}{8 \times 10^3} \times 336000 \, gm$

So, rate of combustion = 42 gm / min.

199. **(16)**

(16) By Newton's law of cooling

$T(t) = T_s + (T_0 - T_s) e^{-kt}$

$\Rightarrow T(t) = Ts + (T_0 - T_s) e^{-kt} \Rightarrow \Delta T = (T_0 - T_s)e^{-kt}$

Now, from graph

$40 = 60e^{-k.6} \Rightarrow \ln 1.5 = 6k$ ...(i)

$20 = 60e^{-kt_2} \Rightarrow \ln 3 = t_2 k$ ...(ii)

Dividing (ii) by (i), we get

$\dfrac{\ln 3}{\ln 1.5} = \dfrac{t_2}{6} \Rightarrow t_2 = \dfrac{6 \ln 3}{\ln 1.5} \Rightarrow t_2 \approx 16 \sec$

200. **(4)**

(4) For adiabatic process, PV^γ = constant

$\Rightarrow p\left(\dfrac{m}{d}\right)^\gamma = \text{constant} \qquad \left[\because d = \dfrac{m}{V}\right]$

$\Rightarrow \dfrac{p}{d^\gamma} = \text{constant}$

$\Rightarrow \dfrac{p_1}{p_2} = \left(\dfrac{d_1}{d_2}\right)^\gamma = \left(\dfrac{1}{32}\right)^{7/5} = \dfrac{1}{128} \qquad \left[\because \dfrac{d_2}{d_1} = 32\right]$

as $PV = nRT \Rightarrow T \propto PV \Rightarrow \dfrac{T_1}{T_2} = \dfrac{P_1 V_1}{P_2 V_2} = \dfrac{1}{128} 32 = \dfrac{1}{4}$

201. **(1400)**

(1400) Work done = $P\Delta V$

$\Rightarrow 400 = P\Delta V$

$\Rightarrow 400 = nR\Delta T \quad [\because P\Delta V = nR\Delta T \text{ at constant pressure}]$

Now, $Q = nC_P \Delta T$

$= n\dfrac{R\gamma}{\gamma - 1}\Delta T = 400 \times \dfrac{\gamma}{\gamma - 1} = 400 \times \dfrac{1.4}{0.4} = 1400 \text{ J}$

202. (2)

(2) By Ist law of thermodynamics, $\Delta Q = \Delta U + \Delta w$

$\Delta U = \Delta Q - \Delta w = Q - Q/4 = 3Q/4$

Now, $\Delta U = \dfrac{3}{2} nR\Delta T \ [\because \Delta U = \dfrac{f}{2} nR\Delta T]$

$\Rightarrow \dfrac{3Q}{4} = \dfrac{3}{2} Rn\Delta T \Rightarrow n\Delta T = \dfrac{Q}{2R}$

As, $Q = nC\Delta T \Rightarrow Q = \dfrac{Q}{2R} \times C \ [\because n\Delta T = \dfrac{Q}{2R}] \Rightarrow C = 2R$

203. (102)

(102) We have, $\eta = 1 - \dfrac{T_2}{T_1} = 1 - \dfrac{Q_2}{Q_1}$

$\Rightarrow \dfrac{Q_2}{Q_1} = \dfrac{T_2}{T_1} \Rightarrow T_2 = \dfrac{Q_2}{Q_1} \times T_1$

$= \dfrac{225}{300} \times 500 = 375\,k = 102\,°C$

204. (16)

(16) $\eta = 1 - \dfrac{T_{sink}}{T_{source}} = 1 - \dfrac{200}{800} = \dfrac{3}{4}$

Also, $\eta = \dfrac{w}{Q_{abs}} \Rightarrow Q_{abs} = \dfrac{w}{\eta} = \dfrac{12000kJ}{\dfrac{3}{4}}$

$= 16000\,kJ = 16 \times 10^6\,J$

205. (540)

(540) Efficiency $\eta = 1 - \dfrac{Q_L}{Q_H} = 1 - \dfrac{T_L}{T_H}$

$\Rightarrow \dfrac{Q_L}{Q_H} = \dfrac{T_L}{T_H}$

$\Rightarrow T_H = T_L \times \dfrac{Q_H}{Q_L} = 324 \times \dfrac{300}{180} = 540\,K$

206. (750)

(750) $W = nR \, \Delta T = 150 \, J$ $\qquad [\because P\Delta V = nR\Delta T]$

$Q = \Delta U + W = \dfrac{f}{2} nR \, \Delta T + nR \, \Delta T$

$\Rightarrow Q = \left(\dfrac{f}{2} + 1 \right) nR \, \Delta T = \left(\dfrac{8}{2} + 1 \right) 150 = 750J$