Thermal Physics

SOLUTIONS

Exercise-I (Conceptual Questions)

1. $\frac{C-0^\circ}{100^\circ}=\frac{F-32^\circ}{180^\circ}$ [As C = F]

$\frac{C}{100^\circ}=\frac{C-32^\circ}{180^\circ}$

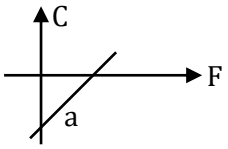
$C = F = -40^\circ$

2. $C=\frac{5}{9}(F-32)$

$\Delta C=\frac{5}{9}\Delta F$

$\Delta F=\frac{9}{5}\times 25=45\,^\circ F$

3. $C=\frac{5}{9}F-\frac{5}{9}\times 32$



$y = mx - C$

4. Slope of line AB

$=\frac{\Delta C}{\Delta F}=\frac{100-0}{212-32}=\frac{100}{180}=\frac{5}{9}$

5. $\frac{C}{5}=\frac{F-32}{9}\Rightarrow\frac{-183}{5}=\frac{F-32}{9}$

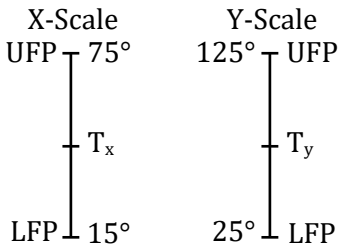
$5[F-32] = -1647$

$F = -329.4 + 32$

$F \approx -297\,^\circ F$

6. Pyrometer is used to measure a temperature of sun by using radiation

7.



$\frac{T_x-15}{75-15}=\frac{T_y-25}{125-25}$

Given $T_x = 60$; $T_y = ?$

$\frac{60-15}{75-15}=\frac{T_y-25}{100}$

$75 = T_y - 25$

$T_y = 100\,^\circ Y$

8. TFFT

9. $\alpha_{Rod} > \alpha_{Frame}$, then rod may touch floor.

10. $\gamma=\frac{\Delta V}{V}\times\frac{1}{\Delta T}$

$\gamma=\frac{0.15}{100}\times\frac{1}{24}\Rightarrow \qquad \alpha=\frac{\gamma}{3}$

$\alpha=\frac{0.15}{100}\times\frac{1}{24}\times\frac{1}{3}$ = 2.0 × 10⁻⁵/°C

11. Always increases (Imagine as a photographic enlargement)

12. $\Delta\ell=\ell\alpha\Delta T\Rightarrow\alpha=\frac{\Delta\ell}{\ell\Delta T}$

$\alpha_1=\frac{1}{1\times100}=10^{-2}$

$\alpha_2=\frac{2}{100}=2\times10^{-2}$

$\alpha_3=\frac{3}{1.5\times50}=4\times10^{-2}$

$\alpha_4=\frac{4\times5}{2.5\times20.5}=8\times10^{-2}$ (maximum)

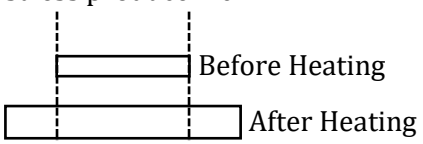
13. $Y=\frac{F\ell}{A\Delta\ell}=\frac{F\ell}{A\ell\Delta T\alpha}=\frac{F}{A\alpha\Delta T}$ $(\Delta L = L\alpha\Delta L)$

$F = YA\,\alpha\,\Delta T$

$F=10^{11}\times10^{-3}\times10^{-6}\times100=10^4\,N$

14. We known that, when rod is freely expand,

stress produce = 0



stress α strain

so strain = 0

15. Heat = $\frac{mgh}{J}=\frac{5\times9.8\times30}{4.2}$ cal = 350 cal

16. $\frac{1}{2}\times\left(\frac{1}{2}mv^2\right)=msd\theta\Rightarrow d\theta=\frac{v^2}{4s}$

17. $Q = ms_{ice}\Delta T + mL_F + ms_{water}\Delta T + mL_V$

$Q = (1)(0.5)(10) + (1)(80) + (1)(1)(100) + (1)(540)$

$Q = 5 + 80 + 100 + 540 = 725$ cal.

or $725 \times 4.18 = 3030$ joule.

18. 2kg ice at – 20°C + 5 kg water at 20°C

$Q_{gain} = Q_{lost}$

$2\times\frac{1}{2}\times20+M\times80=5\times1\times20$

M = 1 kg

Water = 5 + 1 = 6 kg

19. 2 mgh = J msΔT

2 × 5 × 10 × 10 = 2 × 1 × 4.2 × 1000 × ΔT

ΔT = 0.12 °C

20. ms ΔT = m'L

2.5 × 500 × 0.1 = m × 80

m = 1.56 kg

21. at 1kg ice at –10 °C + 4.4 kg of water at 30 °C

Heat gain = Heat loss

$1000\times\frac{1}{2}\times10+1000\times80+1000\ (T-0)$

= 4.4 × 1000 × 1 × (30–T)

$\Rightarrow$ 5.4 T = 4.4 × 30 – 85

$\Rightarrow$ T = 8.7 °C

22. $Q = mL_f + ms\,\Delta\theta + mL_v$

= 1 × 80 + 1 × 1 × 100 + 1 × 536 = 716 cal

23. $536\ \text{cal/g} = \frac{536\times4.2\text{J}}{10^{-3}\text{kg}}$ = 2.25 × 10^6 J/kg

24. Heat given by water 20 °C → 0 °C

Q_1 = 10 × 1 × (20–0) = 200 cal

Heat required to melt 10 g ice

Q_2 = mL = 10 × 80 = 800 cal

$Q_1 < Q_2$ Hence complete ice will not melt

$\therefore$ equilibrium temperature = 0 °C

25. $\Delta Q = msd\theta$

420 J = 10 g × 4.2 × dθ

dθ = 10 °C

26. msΔT = dQ

$\frac{dT}{dQ}=\frac{1}{ms}=\frac{1}{\text{Heat capacity}}$ (For vapour)

27. Heat required for vapourisation = Rate × time

= 42 × (30–20) = mL = 5 × L

$\Rightarrow$ L = 84 kJ/kg

28. $mgh=\frac{mL}{5} \quad\Rightarrow\quad h=\frac{L}{5g}$

29. ΔQ = mL + msΔT + mL + WΔT

= 10 × 80 + 10 × 1 × 100 + 10 × 540 + 10 × 100

= 8200 cal

30. Q_1 = msΔT = 10 × 0.53 × 40 = 212 → (S)

Q_2 = mL = 10 × 80 → (P)

Q_3 = msΔT = 10 × 1 × 100 = 1000 → (Q)

Q_4 = mL = 10 × 540 = 5400 → (R)

31. Thermal capacity of a body is the quantity of heat required to raise its temperature by a unit degree.

32. Heat required is = 2 × 10^3 × 1 × 50 × 4.2 joule

Heat supplied per sec = 1000 – 160 = 840 J/s

So, Heat available for unit time (If total time taken is t)

$P=\frac{Q}{t} \Rightarrow \quad 840=\frac{2\times10^3\times1\times50\times4.2}{t}$

t = 500 sec = 8 min 20 sec

33. $P=\frac{Q}{t}\Rightarrow P=\frac{ms\Delta T}{t}$

P = 2100 J/s ; $\frac{m}{t}$ = 20 g/s

T_1 = 10 °C $\qquad T_2$ = ?

$\left(\frac{2100}{4.2}\right)\frac{\text{cal}}{\text{s}}$ = 20 × 1 (T_2 – 10)

T_2 = 35 °C

34. As $R=\frac{L}{KA}\Rightarrow\frac{L_1}{K_1A}=\frac{L_2}{K_2A}\Rightarrow\frac{L_1}{L_2}=\frac{K_1}{K_2}=\frac{5}{3}$

35. $Q\propto\frac{r^2}{\ell}\Rightarrow\frac{Q_1}{Q_2}=\frac{r^2}{L}\times\frac{2L}{(2r)^2}\Rightarrow Q_2=2Q_1$

36. $\frac{Q}{t}=\frac{KA(\theta_1-\theta_2)}{L}$

$4000=\frac{400\times100\times10^{-4}(\theta_1-\theta_2)}{10\times10^{-2}}$

$\theta_1-\theta_2$ = 100 °C

37. $\frac{(9K)(A)(100-\theta)}{18}=\frac{K(A)(\theta-0)}{6}$

900 – 9θ = 3θ

$\theta=\frac{900}{12}$ = 75 °C

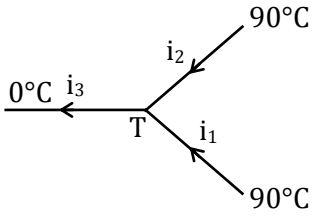
38. $\frac{\Delta Q}{\Delta t}$ = same

So $\frac{KA(20-10)}{\ell}=\frac{2KA(10-\theta)}{\ell}$

$\Rightarrow$ 2θ =10

$\Rightarrow\theta$ = 5 °C

39.



$i_1 + i_2 = i_3$

$$\frac{KA}{\ell}(90-T)+\frac{KA}{\ell}(90-T)=\frac{KA}{\ell}(T-0)$$

$180 - 2T = T$

$3T = 180 \Rightarrow T = 60\ °C$

40 Thermal conductivity (K) depend's on material

41. Heat resistance $R=\frac{\ell}{kA}\Rightarrow R\propto\frac{\ell}{A}$

R is minimum for option IV

So conduction of heat will be more.

42. Gravitation force is required for convection

43. Convection (density difference)

44. $$R=\frac{dQ}{dt}\propto\frac{A}{\ell}\propto\frac{r^2}{\ell}\Rightarrow\frac{R_1}{R_2}=\frac{\left(r_1/r_2\right)^2}{\left(\ell_1/\ell_2\right)}\frac{4/9}{1/2}=\frac{8}{9}$$

45. $L_1 = L_2$, $(\theta_1 - \theta_2)$ is same

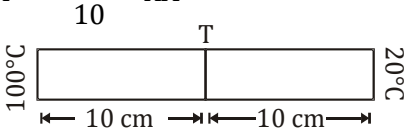
$$\frac{K_1A_1}{L_1}(\theta_1-\theta_2)=\frac{K_2A_2}{L_2}(\theta_1-\theta_2)$$

$K_1A_1 = K_2A_2$

46. $$\frac{(100-T)}{10}KA=\frac{(T-20)}{10}KA$$

$2T = 120$

$T = 60\ °C$



47. $R_{eq} = R_1 + R_2$

$$\frac{2L}{K_{eq}A}=\frac{L}{KA}+\frac{L}{2KA}\Rightarrow K_{eq}=\frac{4}{3}K$$

48. Under steady state, the temperature of a body does not change with time but is different at different point of the body.

49. $$\frac{dQ}{dt}=\frac{KA}{L}(\theta_1-\theta_2)=\frac{(0.2)(10)(40-20)}{2\times10^{-3}}$$

$= 20 \times 10^3 = 2 \times 10^4\ J$

50. Given $\frac{dQ}{Adt}=10$; $K = 0.5$

$$\frac{dQ}{dt}=KA\frac{dT}{dx}\Rightarrow\frac{dT}{dx}=\frac{1}{K}\times\frac{dQ}{Adt}$$

$$\Rightarrow\ \frac{dT}{dx}=\frac{10}{0.5}=20\ °C/cm$$

51. $$R=\frac{\ell}{KA}=R=\frac{\ell}{KA}=\frac{[L]}{\frac{\left[ML^2T^{-2}\times L\right]}{L^2T\theta}\left[L^2\right]}$$

$$R=\left[M^{-1}L^{-2}T^3\theta\right]$$

OR

$$R=\frac{\Delta T}{dQ/dT}$$

$$R=\frac{\theta'}{ML^2T^{-3}}$$

52. Low specific heat means low heat capacity and high conductivity means it will transfer heat to food quickly.

53. Convection (density difference)

54. Metal has high thermal conductivity

55. $$\frac{dQ}{dt}\propto\frac{A}{\ell}\propto\frac{r^2}{\ell},\frac{Q_1}{Q_2}=\left(\frac{2}{1}\right)^2\times\frac{4}{1}=16:1$$

56. $$\frac{KA}{1}(0-\theta)=\frac{(3K)(A)}{2}(\theta-100)$$

$-2\theta = 3\theta - 300 \Rightarrow \theta = 60\ °C$

57. Mud is a bad conductor of heat

58. $$\frac{K_1A(T_1-T)}{d_1}=\frac{K_2A(T-T_2)}{d_2}\ \text{As}\ \left(\frac{dQ_1}{dt}=\frac{dQ_2}{dt}\right)$$

$$T=\frac{K_1T_1d_2+K_2T_2d_1}{K_1d_2+K_2d_1}$$

59. There is a vaccume in the bulb.

60. Convection is due to density difference

61. Convection heat the air molecules which move upward, while high density molecule comes down for low density (pressure)

62. $Q = e_r\sigma AT^4t \Rightarrow \frac{Q}{t}=0.6\sigma AT^4$

63. $r_1 = 1\ m$; $T_1 = 4 \times 10^3\ K$

$r_2 = 4\ m$; $T_2 = 2 \times 10^3\ K$

$$\frac{E_1}{E_2}=\frac{A_1T_1^4}{A_2T_2^4}\ \Rightarrow\ \frac{E_1}{E_2}=\frac{r_1^2T_1^4}{r_2^2T_2^4}$$

$$\Rightarrow\frac{E_1}{E_2}=\frac{(1)^2(4\times10^3)^4}{(4)^2(2\times10^3)^4}=\frac{(1)^2(4)^4}{(4)^2(2)^4}$$

$$\Rightarrow\frac{E_1}{E_2}=\frac{1}{1}$$

64. $R_1 \propto (600)^4 - (200)^4$

$R_2 \propto (400)^4 - (200)^4$

$$\frac{R_2}{R_1} = \frac{(16+4)(16-4)}{(36+4)(36-4)} = \frac{20\times12}{40\times32}$$

$$R_2 = \frac{3}{16}R$$

65. $E = \sigma T^4$

$E' = \sigma (1.1\ T)^4$

$E' = (1.1)^4 \sigma T^4 = (1.1)^4 E$

$E' = 1.21 \times 1.21E = 1.4641E$

$$\%\Delta E = \frac{E'-E}{E'}\times100\% = 0.4641\times100\%$$

$= 46.41\%$

66. $$\frac{E}{E'} = \frac{\sigma(400)^4\times8\times4}{\sigma(600)^4\times4\times2}$$

$$\frac{E}{E'} = \left(\frac{2}{3}\right)^4\times4$$

$$E' = \frac{81}{64}E$$

67. $$\frac{E_1}{E_2} = \frac{E}{E_2} = \left(\frac{546}{273}\right)^4$$

$$E_2 = \frac{E}{16}$$

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

$$\Rightarrow \frac{95-90}{30} = K\left(\frac{95+90}{2}-\theta_0\right) \quad ...(i)$$

$$\Rightarrow \frac{55-50}{70} = K\left(\frac{55+50}{2}-\theta_0\right) \quad ...(ii)$$

By dividing equation (i) by (ii),

$$\frac{7}{3} = \frac{185-2\theta_0}{105-2\theta_0}$$

$\Rightarrow 735 - 14\theta_0 = 555 - 6\theta_0$

$8\theta_0 = 180 \Rightarrow \theta_0 = \frac{180}{8} = 22.5\ °C$

69. $Q = C\Delta T \quad \Rightarrow \quad \frac{dQ}{dt} = C\frac{dT}{dt}$

$$C_1\left(\frac{dT}{dt}\right)_1 = C_2\left(\frac{dT}{dt}\right)_2$$

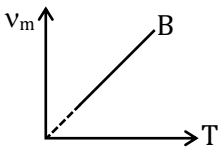
Here C = thermal capacity.

$$\frac{(dT/dt)_1}{(dT/dt)_2} = \frac{C_2}{C_1} = \frac{4}{1}$$

70. Newton's law of cooling is used to calculate the specific heat of liquid .

71. $\lambda_m \propto \frac{1}{T} \Rightarrow \lambda_m = \frac{b}{T}$

$\lambda_m = \frac{c}{\nu_m}$



$\nu_m \propto$ temperature

72. $\lambda_m \uparrow T \downarrow$

wavelength of blue colour is lesser than red so the temperature of blue star is more.

73. $\lambda_{m_1} T_1 = \lambda_{m_2} T_2$

$2597\ K \times 12000Å = 4800Å \times T_2$

$T_2 = 6492.5\ K \simeq 6219.5\ °C$

74. Kirchhoff's Law :- good emitter is a good absorber

75. $\lambda_m = \frac{b}{T}$ weins law

76. Black absorb more, so emit more.

77. $\frac{d\theta}{dt} \propto (\theta - \theta_0)$ (Newton's law)

78. $$\frac{E_1}{E_2} = \frac{\sigma T_1^4}{\sigma T_2^4} \quad \Rightarrow \quad \frac{E}{2E} = \left(\frac{1000}{T}\right)^4$$

$T = 2^{1/4} \times 1000 = \left(\sqrt{2}\right)^{1/2} \times 1000$

$T = 1.19 \times 1000 = 1190\ K$

79. $Q \propto r^2T^4 \Rightarrow \frac{Q_1}{Q_2} = \left(\frac{1}{4}\right)^2 \times \left(\frac{2}{1}\right)^4 = \frac{1}{1}$

80. Good emitter is a good absorber

81. $E \propto T^4 \Rightarrow \frac{E_1}{E_2} = \left(\frac{T_1}{T_2}\right)^4$

$$\Rightarrow \frac{10J}{E_2} = \left(\frac{300}{600}\right)^4 = \frac{1}{16}$$

$E_2 = 160\ J$

82. $$\frac{10^6}{16\times10^6} = \frac{\sigma(400)^4}{\sigma(T)^4} \qquad [E = \sigma T^4]$$

$T^4 = (2 \times 400)^4$

$\Rightarrow T = 800\ K = 527\ °C$

83. Solar constant S

$$S \propto \frac{1}{d^2} \Rightarrow \frac{S'}{S} = \frac{(d)^2}{(d')^2}$$

$$S' = \frac{S.d^2}{(0.4d)^2} \Rightarrow S' = \frac{2}{(0.4)^2} = 12.5\ cal/min\ cm^2$$

84. $T \propto \frac{1}{\lambda}$

$$\frac{Q_1}{Q_2} = \frac{A_1}{A_2}\left(\frac{T_1}{T_2}\right)^4 = \frac{A_1}{A_2}\left(\frac{\lambda_2}{\lambda_1}\right)^4 = \left(\frac{r_1}{r_2}\right)^2\left(\frac{\lambda_2}{\lambda_1}\right)^4$$

$$= \frac{6^2}{18^2} \times \frac{15^4}{5^4} = \frac{1}{3^2} \times 3^4 = 9$$

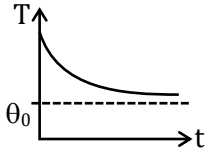
85. $\frac{T_1}{T_2} = \frac{\lambda_2}{\lambda_1} = \frac{560}{420} = \frac{28}{21} = \frac{4}{3}$

86. $\frac{dT}{dt} = -k(T-\theta_0) \Rightarrow \frac{dT}{T-\theta_0} = -kdt$

$\ln(T - \theta_0) = -kt + c$

$T - \theta_0 = e^{-kt+c}$

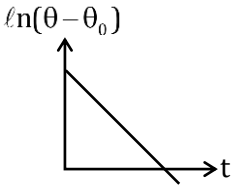
$T = \theta_0 + e^{-kt+c}$



87. $\frac{d\theta}{dt} = -k(\theta-\theta_0)$

$\frac{d\theta}{(\theta-\theta_0)} = -kdt$

$\ell n(\theta-\theta_0) = -kt + c$



88. $-\frac{d\theta}{dt} = k(\theta-\theta_0)$

As difference between body temperature and surrounding temperature decreases. Rate of cooling decreases with time.

89. $\lambda_m \propto \frac{1}{T}$

90. good absorber is good emitter

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

$\Rightarrow 1 = K\,(30)$ ...(i)

$\Rightarrow \frac{50-T}{10} = K\left(\frac{50+T}{2} - 25\right)$

$\Rightarrow \left(\frac{50-T}{10}\right) = K.\frac{T}{2}$ ...(ii)

Solving equation (i) and (ii), we find

T = 42.85 °C

92. good absorber is good emitter

93. Thermal radiation are infrared radiation

94. $\lambda_m \propto \frac{1}{T}$ according to weins law

95. $\frac{R_{C1}}{R_{C2}} = \frac{R_{F1}}{R_{F2}} = \frac{r_2}{r_1} = \frac{2r}{r} = 2:1$

96. $E \propto T^4$ and $E_{max} \propto T^5$ (wein's 5th power law)

97. Kirchhoff's law :-

$\frac{e_\lambda}{a_\lambda} = E_\lambda$

98. Case ...(1) $\frac{80-50}{5} = K\left[\frac{80+50}{2} - 20\right]$

Case ...(2) $\frac{60-30}{t} = K\left[\frac{60+30}{2} - 20\right]$

On solving t = 9 min.

99. $\frac{80-60}{60} = K\left(\frac{80+60}{2} - 30\right)$

$\Rightarrow \frac{1}{3} = K(40)$ ...(i)

$\Rightarrow \frac{60-50}{t} = K\left(\frac{60+50}{2} - 30\right)$

$\Rightarrow \frac{10}{t} = K(25)$ ...(ii)

Solving equation (i) and (ii), we find

t = 48 Sec.

100. Wein's Law $\lambda_m \propto \frac{1}{T}$

101. Amount of radiation emitted and absorbed by it will be equal.

102. Ideal black body, totally absorb heat radiation of all the wavelengths.

103. $\frac{E_1}{E_2} = \frac{r_1^2 T_1^4}{r_2^2 T_2^4} = \left(\frac{8}{2}\right)^2 \cdot \left(\frac{400}{800}\right)^4 \Rightarrow \frac{E_1}{E_2} = 1$

104. Wein's Law $\lambda_m \propto \frac{1}{T}$

105. $R_H \propto \text{Area}(A)$, so same for both

106. $R_F = \frac{d\theta}{dt} \propto \frac{1}{\rho r} \Rightarrow \frac{R_{F_1}}{R_{F_2}} = \frac{\rho_2 r_2}{\rho_1 r_1} = \frac{1\times 2}{2\times 1} = 1:1$

107. $\lambda_m T$ = constant

108. Spectral energy distribution curve is a continuous curve for ideal black body (IBB)

109. $Q = \sigma T^4\, At = 5.6 \times 10^{-8} \times 10^{12} \times 0.1 \times 60$

$Q = \frac{5.67\times 10^4 \times 6}{4.2} = 81000$ cal

110. $E = \sigma T^4 \Rightarrow \frac{E}{E'} = \frac{T}{(T/2)^4} \Rightarrow E' = \frac{E}{16}$

111. Definite absorption takes place in chromosphere

112. $E \propto T^4$

113. For ideal black body (IBB) : $\boxed{a = 1}$

114. $N = \frac{PV}{kT} = \frac{1.3\times10^5\times7\times10^{-3}}{1.38\times10^{-23}\times273}$

$N = 2.41 \times 10^{23}$

115. All real gas behave as an ideal gas at high temperature, low pressure and low density.

116. μ = constant, T = constant, $P_aV_a = P_bV_b$

117. At same temperature pressure and volume ($N_1=N_2=N_3$) Avogadro law

118. All temperature and pressure.

119. $P = \frac{1}{3}\left(\frac{mN}{V}\right)v_{rms}^2$

$P \propto N$ (no of molecule)

$N \rightarrow$ double, so P become double.

120. $PV = \mu RT \Rightarrow P = \frac{\mu RT}{V}$

$PV^{2/3} = C \Rightarrow \frac{\mu RT}{V}\times V^{2/3} = C$

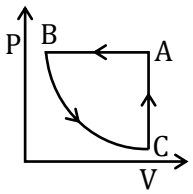
$TV^{-1/3} = C \Rightarrow T \propto V^{1/3}$

$T\uparrow \Rightarrow V\uparrow$

121. $A \rightarrow B \Rightarrow$ P = constant & T↓ So V↓ $\Rightarrow$ IBC

$B \rightarrow C \Rightarrow$ T = constant & P↓ So V↑ $\Rightarrow$ ITE

$C \rightarrow A \Rightarrow$ V = constant & P↑ So T↑ $\Rightarrow$ IC



122. $P = \frac{\mu RT}{V}$

$P^2V = C \Rightarrow \left(\frac{T}{V}\right)^2 \times V = C$

$\frac{T^2}{V} = C \Rightarrow \frac{T_2^2}{T_1^2} = \frac{V_2}{V_1}$ $(\because V_2 = 2V_1)$

$T_2 = \sqrt{2}T$

123. P = constant

$V \propto T \Rightarrow \frac{V_1}{V_2} = \frac{T_1}{T_2}$

$T_2 = T_1 \times \frac{V_2}{V_1} \Rightarrow T_2 = 300 \times \frac{500}{250}$

$T_2 = 600$ K = 327 °C

124. $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \Rightarrow V_2 = \frac{P_1}{P_2}\times\frac{T_2}{T_1}\times V_1$

$V_2 = \frac{1}{0.5}\times\frac{270}{300} \times 500\ m^3 = 900\ m^3$

125. V = constant $\Rightarrow \frac{P_1}{M_1T_1} = \frac{P_2}{M_2T_2}$

Final mass $M_2 = \frac{P_2}{T_2}\times\frac{M_1T_1}{P_1}$

$M_2 = \frac{P/2}{300}\times\frac{6g\times400}{P} = -4\,g$

Leak out mass = $M_1 - M_2 = 6 - 4 = 2$ g

126. High temperature and low density.

Note : All real gas behave as an ideal gas at high temperature, low pressure and low density.

127. T = constant

$P_1V_1 = P_2V_2$

$P_2 = \frac{P_1V_1}{V_2}$

$P_2 = 0.8 \times \frac{5}{8}$

$P_2 = 0.5$ m

128. $PV = \mu RT$

$P = \frac{\rho}{M_w}RT \Rightarrow P \propto \rho$ (At const. temp.)

129. $PV = \mu RT \Rightarrow PV = \frac{M}{M_w}RT \Rightarrow P = \frac{M}{V}\frac{RT}{M_w}$

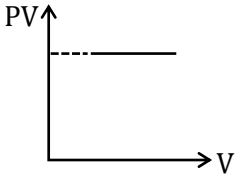
$P = \frac{\rho RT}{M_w} \Rightarrow \rho = \frac{PM_w}{RT} \Rightarrow \rho \propto \frac{P}{T}$

130. Closed container $\Rightarrow$ V = constant

$\frac{\Delta P}{P} = \frac{\Delta T}{T} \Rightarrow T = \frac{P}{\Delta P} = \Delta T$

$T = \frac{100}{0.4} \times 1\ K = 250\ K$

131. PV = constant $\Rightarrow$ T = constant



132. $N = \frac{PV}{kT} = \frac{13.8\,N/m^2 \times 1m^3}{1.38\times10^{-23}\,J/K\times300K}$

$N = 3.3 \times 10^{21}$ molecule

133. Closed contain (V = constant)

Initially,

$M_1 = 10$ kg

$P_1 = 10^7\ N/m^2$

let M′ kg gas leak

Finally $M_2 = (10 - M')$kg

$P_2 = 2.5 \times 10^6\ N/m^2$

given T = constant — for a given gas

$PV = \frac{MRT}{M_w}$ — V = constant

$P \propto M$ — M_w = constant

So $\frac{P_2}{P_1} = \frac{M_2}{M_1}$ — T = Constant

By solving. M′ = 7.5 kg

134. Dalton's law of partial pressure

or $P_{mix} = \frac{P_1V_1 + P_2V_2}{V_{mix}}$ (At const. temp.)

135. $PV = \mu RT \Rightarrow PV = \frac{M}{Mw}RT$

O_2 $M = 5gm$

$M_w = 32$ gm/mole

$PV = \frac{5}{32}RT$

136. Have same mass but negligible volume. (Point mass)

137. $\frac{P}{\rho} = \frac{RT}{M_w}$

$\rho = \frac{PM_w}{RT}$ $\quad M_w = mN_A$

$\rho = \frac{Pm}{kT}$ $\quad \frac{R}{N_A} = k$

138. $\left.\begin{aligned} N_1 &= \frac{P_1V_1}{kT_1} \\ N_2 &= \frac{P_2V_2}{kT_2} \end{aligned}\right\} \Rightarrow \frac{N_1}{N_2} = \frac{P_1V_1}{T_1}\times\frac{T_2}{P_2V_2}$

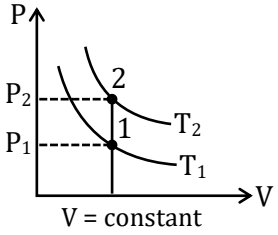
139. At constant temperature

$\therefore P_1V_1 = P_2V_2 \Rightarrow PV = P_2.$

$\frac{V}{4} \Rightarrow P_2 = 4P$

So, $P_2 = 4$ atm

140.



At point 1 and point 2

Let V = constant ($P \propto T$)

so $P_2 > P_1$

$T_2 > T_1$

141. Real gas equation

for μ = 1 mole gas

$\left(P + \frac{a}{V^2}\right)(V - b) = RT$

142. $v_{rms} = \sqrt{\frac{3RT}{M_w}}$

143. $v_{rms} \propto \sqrt{T} \Rightarrow \frac{v_1^2}{v_2^2} = \frac{T_1}{T_2}$

$\left(\frac{v}{v/2}\right)^2 = \frac{600}{T}$

$T = \frac{600}{4} = 150\ K = -123\ °C$

144. $v_{rms} \propto \sqrt{T}$ (Does not depend on pressure)

$\frac{v_{rms_1}}{v_{rms_2}} = \sqrt{\frac{T_1}{T_2}} \Rightarrow \frac{200}{v_{rms_2}} = \sqrt{\frac{300}{400}}$

$v_{rms_2} = \frac{400}{\sqrt{3}}$ m/s

145. average speed $< C > \propto \frac{1}{\sqrt{M_w}}$

$\frac{< C_H >}{< C_{He} >} = \sqrt{\frac{4}{1}}$

$< C_H > = 2 < C_{He} >$

146. $v_{rms} \propto \sqrt{\frac{T}{M_w}}$

$v' \propto \sqrt{\frac{(T/2)}{(2M_w)}} \propto \frac{1}{2}\sqrt{\frac{T}{M_w}}$

Hence v_{rms} become half

147. $v \propto \sqrt{\frac{T}{M_w}}$

$\frac{v_1}{v_2} = \sqrt{\frac{T_1}{T_2} \times \frac{M_{w_2}}{M_{w_1}}}$

$\frac{1930}{v_2} = \sqrt{\frac{300}{1200} \times \frac{32}{2}}$

$\frac{1930}{v_2} = \sqrt{4} \Rightarrow \frac{1930}{V_2} = 2$

$V_2 = \frac{1930}{2} = 965 \text{ m/s}$

148. $v_{r.m.s.} \propto \sqrt{\frac{1}{M_w}} \Rightarrow \frac{(v_{r.m.s.})_{O_2}}{(v_{r.m.s.})_{H_2}} = \sqrt{\frac{2}{32}} = \frac{1}{4}$

149. v_{rms} = same $\Rightarrow$ $T \propto M_w$

$T_{He} = \frac{4}{2} \times 273 = 546 \text{ K} = 273°C$

150. Any speed depends on temperature and molecular weight only so if temperature constant then mean square velocity will also constant.

151. Value of v_{rms} of the molecules of gas is more than escape velocity.

152. $v_{r.m.s} = \sqrt{\frac{v_1^2 + v_2^2 + v_3^2 + v_4^2 + v_5^2}{5}}$

$= \sqrt{\frac{2^2 + 3^2 + 4^2 + 5^2 + 6^2}{5}} = 4.24 \text{ m/s}$

153. Independent of its pressure but directly proportional to the square root of its kelvin temperature.

154. $v_{rms} \propto \frac{1}{\sqrt{M_w}}$

155. $P = \frac{1}{3}\rho v_{rms}^2 = \frac{1}{3} \times 8.99 \times 10^{-2} \times (3180)^2$

$= 3 \times 10^5 \text{ N/m}^2 = 3 \text{ atm}$

156. $P = \frac{1}{3}\left(\frac{M}{V}\right)v_{rms}^2$

P(pressure) $\propto v^2_{rms}$

pressure become four times

157. $v_{rms} = \sqrt{\frac{3RT}{M_w}} = \sqrt{\frac{3kT}{m}}$

$v_{rms} \propto \frac{1}{\sqrt{m}}$ $\quad m \rightarrow$ mass of molecule

158. $v_{rms} = \sqrt{\frac{3P}{\rho}} = \sqrt{3}\sqrt{\frac{P}{\rho}} = 1.71\sqrt{\frac{P}{\rho}}$

$v_{avg} = \sqrt{\frac{8}{\pi}\frac{P}{\rho}} = 1.59\sqrt{\frac{P}{\rho}}$

$v_{mp} = \sqrt{\frac{2P}{\rho}} = 1.41\sqrt{\frac{P}{\rho}}$

for a given gas P and ρ = constant

$v_{rms} > v_{avg} > v_{mp}$

159. $(v_{rms})_{H_2} = (v_{es})_{earth}$

$\Rightarrow \sqrt{\frac{3RT}{M_w}} = 11.2 \times 10^3 \text{ m/s}$

$\Rightarrow \frac{3 \times 8.314 \times T}{2 \times 10^{-3}} = 125 \times 10^6$

$\Rightarrow T \simeq 10^4 \text{ K}$

160. $P = \frac{1}{3}\left(\frac{mN}{V}\right)v_{rms}^2$

$m \rightarrow$ mass of molecule.

161. $v_{rms} \propto \sqrt{\frac{T}{M_w}}$

than $\frac{v'}{v} = \sqrt{\frac{T'}{M_w} \times \frac{M_w}{T}}$

$v' = \sqrt{\frac{2T}{M_w/2} \times \frac{M_w}{T}} \times v$

$v' = 2v$

162. v_{rms} = same $\Rightarrow$ $T \propto M_w$

$\frac{T_{O_2}}{T_{H_2}} = \frac{(M_w)_{O_2}}{(M_w)_{H_2}} \Rightarrow T_{H_2} = \frac{2}{32} \times 320 = 20 \text{ K}$

163. $v_{rms} > v_{mp}$ so different.

$v_{rms} = \sqrt{\frac{3P}{\rho}} = 1.73\sqrt{\frac{P}{\rho}}$

$v_{mp} = \sqrt{\frac{2P}{\rho}} = 1.41\sqrt{\frac{P}{\rho}}$

For given gas P, ρ are constant

164. $v_{rms} > v_{avg} > v_{mp}$

165. We know that total K.E = $\frac{f}{2}kT$

$f \rightarrow$ degree of freedom

for diatomic gas

$f = f_T + f_R$ $\quad f_T=3$

$\quad f_R=2$

$(K.E)_T = \frac{f_T}{2}kT = \frac{3}{2}kT$

$(K.E)_R = \frac{f_R}{2}kT = \frac{2}{2}kT$

$$\frac{(K.E)_T}{(K.E)_R} = \frac{3}{2}$$

166. gram specific heat difference is

$\left(c_p - c_v = r = \frac{R}{M_w}\right)$

for H_2 $\quad c_p - c_v = a = \frac{R}{2}\left(M_w(H_2) = 2\right)$

for O_2 $\quad c_p - c_v = b = \frac{R}{32}\left(M_w(O_2) = 32\right)$

$$a = \frac{R}{2} \; ; \; b = \frac{R}{32}$$

$a = 16b$

167. $U = U_1 + U_2$

$= \mu_1 C_{v_1} T + \mu_2 C_{v_2} T$

$= 2\times\frac{5}{2}RT + 4\times\frac{3}{2}RT$

$= 5RT + 6RT = 11RT$

168. $E \propto T$

$$\frac{E_1}{E_2} = \frac{T_1}{T_2} \Rightarrow \frac{6.21\times10^{-21}}{E_2} = \frac{300}{500}$$

$E_2 = \frac{5}{3} \times 6.21 \times 10^{-21} = 10.35 \times 10^{-21}$ J

169. At same temperature

$$v_{rms} = \sqrt{\frac{3kT}{m}} \quad \text{so} \quad \frac{v_A}{v_B} = \sqrt{\frac{m_B}{m_A}}$$

$$\frac{P_A}{P_B} = \frac{m_A v_A}{m_B v_B} = \frac{m_A}{m_B}\times\sqrt{\frac{m_B}{m_A}}$$

$$\Rightarrow \; P_A = \left(\frac{m_A}{m_B}\right)^{1/2} P_B$$

170. $P = \frac{2}{3}\frac{E_T}{V}$

$P = \frac{2}{3}\times\frac{1.52\times10^5}{200\times10^{-3}} = 5 \times 10^5$ N/m²

171. $M_{mix} = \frac{\mu_1 M_1 + \mu_2 M_2}{\mu_1 + \mu_2} = \frac{5\times4 + 2\times2}{7} = \frac{24}{7}$ g

172. $C_{V_{mix}} = \frac{2\times\frac{5}{2}R + 5\times\frac{3}{2}R}{5+2}$

$C_{P_{mix}} = \frac{2\times\frac{7}{2}R + 5\times\frac{5}{2}R}{5+2}$

$\gamma_{mix} = \frac{C_{P_{mix}}}{C_{V_{mix}}} = \frac{39/7}{25/7} = 1.56$

OR

$\gamma_{mix} = \frac{\mu_1 C_{P_1} + \mu_2 C_{P_2}}{\mu_1 C_{V_1} + \mu_2 C_{V_2}}$

$\gamma_{mix} = \frac{2\times\frac{7}{2}R + 5\times\frac{5}{2}R}{2\times\frac{5}{2}R + 5\times\frac{3}{2}R}$

173. $E_{mix} = E_1 + E_2$

$$\frac{(n_1+n_2)fRT_{mix}}{2} = \frac{n_1 fRT_1}{2} + \frac{n_2 fRT_2}{2}$$

$$T_{mix} = \frac{n_1 T_1 + n_2 T_2}{n_1 + n_2}$$

174. Total K.E = $\frac{5}{2}\mu RT$

for 1 mole = $\frac{5}{2}RT$

$= \frac{5}{2} \times 2 \times 300 = 1500$ cal

175. Mean K.E Per gram molecule = Molar K.E

$$E_{mole} = \frac{3}{2}RT$$

176. $\gamma = \frac{C_P}{C_V} = \frac{C_V + R}{C_V} = \frac{\frac{1}{2}fR + R}{\frac{1}{2}fR} = \frac{f+2}{f}$

$\Rightarrow \gamma f - f = 2 \Rightarrow f = \frac{2}{\gamma - 1}$

177. $E_T = \frac{3}{2}PV$

$\frac{E_T}{V} = \frac{3}{2}P$ $\quad E = \frac{E_T}{V}$ energy density

$P = \frac{2}{3}E$

178. $C_{V_{mix}} = \frac{\mu_1 C_{V_1} + \mu_2 C_{V_2}}{\mu_1 + \mu_2}$

179. Absolute zero temperature is one at which motion of molecules freeze. Hence K.E. of a molecules become zero.

180. $\frac{R}{C_v} = 0.67$

$C_v = \frac{R}{0.67} = \frac{100}{67}R = \frac{3}{2}R$

so, f = 3 (Monoatomic)

181. Total K.E = $\frac{f}{2}NkT$

Total K.E $\propto$ N (no. of gas molecule)

182. KE $\propto$ T

$\frac{E_1}{E_2} = \frac{T_1}{T_2}$

$T_2 = 2 \times 293$

$T_2 = 586$ K = 313°C

183. Avg. Kinetic Energy = $\frac{3}{2}kT$

$\Rightarrow$ Avg. K.E $\propto$ T

184. K.E associated with per degree of freedom of a molecule is $\frac{1}{2}kT$

185. The average of distances travelled between two successive collisions is mean free path.

186. The molecules are transferring their momentum to the wall.

187. $\Delta U = \mu C_v \Delta T$ (always) = $\frac{1}{2}$ = $\mu R \Delta T$, ΔT = same

$\Rightarrow \frac{U_1}{U_2} = \frac{1}{1}$

188. specific heat of an ideal gas is independent on temperature

189. Can have any value between 0 to ∞ because it depends on temperature and process.

190. Use $T_{mix} = \frac{\mu_1 f_1 T_1 + \mu_2 f_2 T_2}{\mu_1 f_1 + \mu_2 f_2}$

191. E $\propto$ T

192. K.E $\propto$ T $\Rightarrow$ T = absolute temperature

193. $(K.E)_{avg} = \frac{f}{2}kT$ [for monoatomic gas f = 3]

$(K.E)_{avg} = \frac{3}{2}kT$

194. A diatomic molecule has 5 degree of freedom.

195. $\gamma_{mix} = \frac{C_{Pmix}}{C_{Vmix}} = \frac{\mu_1 C_{P_1} + \mu_2 C_{P_2}}{\mu_1 C_{V_1} + \mu_2 C_{V_2}}$

$\gamma_{mix} = 1.55$

196. 1st law of thermodynamics is based on law of conservation of energy.

197. Q = 500 cal = 500 × 4.18 = 2093 J

W = –100 J

$\Delta U = Q - W$

$\simeq$ 2193 J

198. Given Q = – 20 J, W = – 8 J

$\Delta U = U_f - U_i$ So, $Q = \Delta U + W$

$-20 = U_f - U_i - 8$

$-20 = U_f - 30 - 8 \Rightarrow U_f = 18$ joule

199. $Q_1 = \Delta U_1 + W_1$

$Q_1 = 16 - 20 = -4$ kJ

$Q_2 = \Delta U_2 + W_2$

$W_2 = Q_2 - \Delta U_2$ $\quad (\because \Delta U_1 = \Delta U_2)$

= 9 – (–4) = 13 kJ

200. $Q_{ABC} = 90$ J and $W_{ABC} = 30$ J

$\therefore$ $\Delta U = 90 - 30 = 60$ J

if $W_{ADC} = 20$ J

$Q_{ADC} = \Delta U_{ADC} + W_{ADC} = 60$ J + 20 J = 80 J

201. W = Area of ellipse

$W = \pi\left(\frac{P_2 - P_1}{2}\right)\left(\frac{V_2 - V_1}{2}\right)$

202. W = Area of LMNOL = PV

203. $\Delta U = \mu C_V \Delta T = 2 \times 4.96 \times 2 = 19.84$ cal

204. Work done always depends on path.

205. Change in internal energy is same and $W_A > W_B$ So, $Q_A > Q_B$

206. FLOT $Q = W + \Delta U$

Q = +110 J

ΔU = +40 J

110 = 40 + W

W = + 70 J

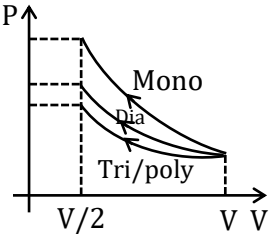
207. According to FLOT :-
$Q = W + \Delta U$ $\Delta U = mC_V\Delta T$
$Q = W + mC_v\Delta T$

208. $W = \frac{1}{2} \times 4P_0 \times 3V_0 = 6P_0V_0$

209. For cyclic process
$\Delta U = U_f - U_i = 0$
Zero in all the four cases.

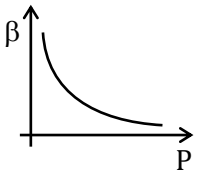
210. Heat capacity = $\frac{Q}{\Delta T}$
At constant volume W = 0
$Q = \Delta U = 80$ J
Heat capacity = $\frac{80}{20}$ = 4 J/K

211.



$P_2 = P_1\left(\frac{V_1}{V_2}\right)^{\gamma}$ $V_1 = V$ and $V_2 = V/2$
Hence $P_2 = P_1(2)^{\gamma}$
$\gamma\uparrow$ $P_2\uparrow$
As $\gamma_{Mono} > \gamma_{Dia} > \gamma_{Tri}$
then $P_{Mono} > P_{Dia} > P_{Tri}$

212. At constant temperature
PV = constant
On differentiation
$VdP + PdV = 0$
$\frac{dP}{dV} = -\frac{P}{V} \Rightarrow \frac{dV}{dP} = -\frac{V}{P}$



$\beta = \frac{-\left(\frac{dV}{dP}\right)}{V} = \frac{1}{P}$
$\beta = \frac{1}{P}$ Hence $\beta \propto \frac{1}{P}$

213. $\beta = \gamma P = \frac{7}{5} \times 10^5$ N/m^2 = 1.4 × 10^5 N/m^2

214. β = P (for isothermal)

215. $Slope_{adiabatic} \propto \gamma$
Slope of 1 < Slope of 2
$\gamma_1 < \gamma_2$ and $\gamma_{mono} > \gamma_{dia}$
So, 2 is monoatomic & 1 is diatomic

216. For adiabatic
$\frac{\Delta P}{\Delta V} = -\gamma\frac{P}{V} \Rightarrow \frac{\Delta P}{P} = -\gamma\frac{\Delta V}{V}$

217. $TV^{\gamma-1}$ = constant
$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1}$
$\frac{T_2}{300} = \left(\frac{27}{8}\right)^{\frac{5}{3}-1} = \left(\frac{27}{8}\right)^{2/3} = \frac{3^2}{2^2} = \frac{9}{4}$
$T_2 = 300 \times \frac{9}{4} = 675$ K
$\Delta T = T_2 - T_1 = 675 - 300 = 375$ K

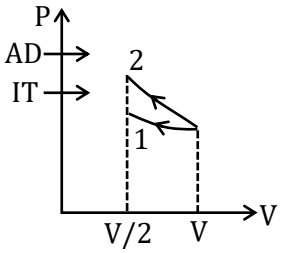
218. For adiabatic process
$P^{1-\gamma}T^{\gamma}$ = constant
$P \propto T^{\left(\frac{-\gamma}{1-\gamma}\right)} \propto T^{\left(\frac{\gamma}{\gamma-1}\right)}$
as per question $P \propto T^C$
on comparing
$C = \frac{\gamma}{\gamma-1} = \frac{5/3}{5/3-1} = \frac{5}{2}$

219. $\frac{W}{Q} = \frac{\mu R\Delta T}{\mu C_p\Delta T} = \frac{R}{C_p} = \frac{R}{\frac{5}{2}R} = \frac{2}{5} \times 100\% = 40\%$

220. $B \rightarrow$ Adiabatic $\rightarrow P \propto \frac{1}{V^{\gamma}}$ V↑P↓ (more steep)
$A \rightarrow$ Isothermal $\rightarrow P \propto \frac{1}{V}$ V↑P↓ (less steep)
(C, D) $\rightarrow$ positive slope

221. Slope of adiabatic = γ (Slope of isothermal)
Isothermal for A and C while adiabatic for B and D

222.



In isothermal process T = constant, ΔT=0
But V↓, P↑
In adiabatic process (P, V, T) are variable,
V↓, W = –ve, ΔU = +ve (Temp↑)
V↓, P↑
Option (3) is correct

223. $\frac{W}{Q}=\frac{\mu R\Delta T}{\mu C_P\Delta T}=\frac{R}{C_P}=\frac{R}{\frac{5}{2}R}=\frac{2}{5}$

$W=\frac{2}{5}Q$

224. For polytropic process

$W=\frac{\mu R\Delta T}{1-x}$

Here $x=-2$

$W=\frac{\mu R(T_2-T_1)}{1-(-2)}$

$W==\frac{1}{3}R(T_2-T_1)$

225. $\frac{dU}{\Delta Q_P}=\frac{\mu C_V dT}{\mu C_P dT}=\frac{C_V}{C_P}=\frac{1}{\gamma}=\frac{5}{7}$

$\left(\because\ \gamma=\frac{7}{5}\right)$ for diatomic gas

226. Adiabatic relation between pressure and temperature.

$P^{(1-\gamma)}T^{\gamma}$ = constant

227. PV^{γ} = constant $\Rightarrow$ $\frac{\mu RT}{V}V^{\gamma}$ = constant

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

If $V\uparrow \Rightarrow T\downarrow\ U\downarrow$ or $V\downarrow \Rightarrow T\uparrow U\uparrow$

May decrease and may also increase

228. $\Delta U=\mu C_V\Delta T=1\times\frac{3}{2}R\times 100$

$\Delta U=1\times\frac{3}{2}\times 8.31\times 100=12.48\times 10^2$ J

229. V = constant

$W=0$

$(Q)_V=(\Delta U)_V+0$

P = constant

$W\neq 0$

$(Q)_P=(\Delta U)_P+(W)_P$

So $(Q)_P>(Q)_V$

$\mu Cp\Delta T>\mu C_v\Delta T$

$C_P>C_V$

Work is done in the expansion of the gas at constant pressure.

So option (1) is correct

230. In adiabatic process $\Delta Q=0$

$\Delta U+\Delta W=0$

$\Delta U=-\Delta W$

When gas adiabaticaly compressed, then V↓

ΔV = –ve, So ΔW = –ve

ΔU = +ve $\Rightarrow$ U↑

$\mu C_v(T_f-T_i)>0$

$T_f>T_i$ hence temperature ↑

231. $\frac{T_1^{\gamma}}{P_1^{\gamma-1}}=\frac{T_2^{\gamma}}{P_2^{\gamma-1}}$

$T_2=\left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}\times T_1$

$T_2=\left(\frac{1}{2}\right)^{0.5/1.5}\times 300=\frac{1}{2^{1/3}}\times 300$

T_2= 240 K = –33°C

232. $C=\frac{\Delta Q}{\mu\Delta T}$

for adiabatic $\Delta Q=0$

$C_{AD}=0$

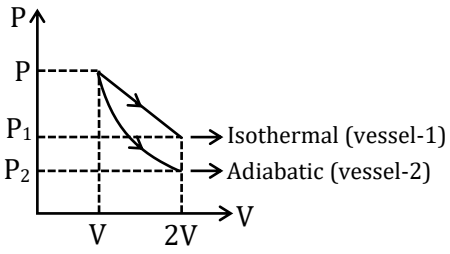
233. Gas suddenly compressed (V↓)

so

W = – ve and Q = 0 (for adiabatic)

ΔU = +ve (temperature increase)

234.



$P_1>P_2$, final pressure in vessel (1) is more than vessel (2)

$W_1>W_2$ $\quad$ $W\propto$ Area

so, In first vessel, both pressure and work done are more.

235. Heat is rejected by gas

Q = W (for isothermal process $\Delta U=0$)

when gas compressed V↓, ΔV = –ve

W = –ve

Q = –ve (heat rejected)

236. $(\text{slope})_{AD}=-\gamma\frac{P}{V}$

$(\text{slope})_{AD}=\gamma\left(-\frac{P}{V}\right)$

$(\text{slope})_{AD}=\gamma(\text{slope})_{IT}$

237. Work done in cyclic process is area enclosed.

$\text{Area}=W=\frac{1}{2}BH$

$W_{ABCD}=\frac{1}{2}(3V_1-V_1)(4P_1-P_1)$

$W_{ABCD}=3P_1V_1$

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

$W = -\frac{(1)(8.3)(102-27)}{1.5-1} = -1245$ J

239. According to FLOT

$\delta Q = \delta W + dU$

Isometric V = Constant $\Delta V = 0$

$\delta Q = dU$

240. $W = P\Delta V = 10^3 \times 0.25$

$W = 250$ J

241. Q = W, when $\Delta U = 0$, T = constant (isothermal process)

242. $P_1V_1^{\gamma} = P_2V_2^{\gamma} \Rightarrow P_2 = \left(\frac{V_1}{V_2}\right)^{\gamma} \times P_1$

$P_2 = \left(\frac{V}{V/8}\right)^{4/3} \times P_0 = 16\,P_0$

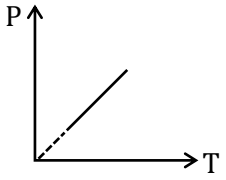
243. Work equals to area under the P-V graph or curve and V-axis.

244. In adiabatic process Q = 0

Total heat content of the system remain constant.

245. Isometric V = constant

$P \propto T$



246. Adiabatic equation in terms of P, V

PV^{γ} = constant

247. $\Delta U = Q - W = 300 - 0$; V = constant ; W = 0

Change in internal energy per gram

$= \Delta U/M = \frac{300}{50} = 6$ cal/g

248. $T_B > T_A = T_C > T_D \Rightarrow U = \mu C_V T$

$U_B > U_A = U_C > U_D \Rightarrow U \propto T$

249. Free expansion as $P_{ext} = 0 \Rightarrow W = 0$

250. Heat cannot be converted in 100% work, but reverse is true.

251. Heat can't flow from the body at lower temperature to body at higher temperature is a consequences of second law of thermodynamics.

252. $\eta = 1 - \frac{T_2}{T_1} = \frac{W}{Q}$

$1 - \frac{300}{900} = \frac{W}{3\times10^6}$

$\frac{2}{3} = \frac{W}{3\times10^6}$

$W = 2 \times 10^6$ cal $= 2 \times 4.2 \times 10^6$ J $= 8.4 \times 10^6$ J

253. $COP = \frac{T_C}{T_H - T_C}$

254. $(\text{slope})_{\text{adiabatic}} = \gamma\,(\text{slope})_{\text{isothermal}}$

BC, DA $\rightarrow$ adiabatic

AB, CD $\rightarrow$ isothermal

255. Exchange of heat take place in isothermal process

A $\rightarrow$ B	$\Delta U = 0$	(T=constant)
	W = +ve	(V$\uparrow$)
	Q = W =+ve	(Heat absorbed)
C $\rightarrow$ D	$\Delta U = 0$	(T = constant)
	W = –ve	(V$\downarrow$)
	Q = –ve	(Heat rejected)

256. $\eta = 1 - \frac{T_2}{T_1}$

257. $\eta = 1 - \frac{Q_2}{Q_1} = 1 - \frac{T_2}{T_1}$

$\Rightarrow \frac{T_2}{T_1} = \frac{Q_2}{Q_1}$

$\Rightarrow \frac{T_2}{400} = \frac{80}{100}$

$\Rightarrow T_2 = 320$ K $= 47$ °C

258. $\frac{\text{Work done}}{\text{Heat supplied}} = \frac{W}{Q_1} = \frac{T_1 - T_2}{T_1}$

$\Rightarrow \frac{800}{Q_1} = \frac{600-300}{600}$

$\Rightarrow Q_1 = 1600$ J

259. $\frac{W}{Q_1} = \frac{T_1 - T_2}{T_1}$

$\frac{W}{6\times10^4} = \frac{500-400}{500} \Rightarrow W = 1.2 \times 10^4$ cal

260. $COP = \frac{T_2}{T_1 - T_2}$

$T_1 = 300$ K , $T_2 = 263$ K

$COP = \frac{263}{300-263} = 7.1$

Exercise-II (Previous Year Questions)

1. $m_1L_v + m_1s\Delta\theta = m_2s\Delta\theta$
$m \times 540 + m \times 1 \times 20 = 20 \times 1 \times 70$
$m_1 \times 560 = 1400$
$m_1 \approx 2.5$ g
$\therefore$ Total mass of water = 20 + 2.5 = 22.5 g

2. $\frac{T_1 - T_2}{t} = K\left(\frac{T_1 + T_2}{2} - T_0\right)$
$T_0 \rightarrow$ surrounding temperature.

3. Mean free path $\lambda_m = \frac{1}{\sqrt{2}\pi d^2 n}$
where d = diameter of molecule
n = molecular density
$\Rightarrow \lambda_m \propto \frac{1}{r^2}$

4. In isothermal process : $P_1V_1 = P_2V_2$
$PV = P_2(2V) \Rightarrow P_2 = \frac{P}{2}$
In adiabatic process
$\left(\frac{P}{2}\right)(2V)^{\gamma} = P'(16V)^{\gamma}$
$P' = \frac{P}{2} \times \frac{1}{32} = \frac{P}{64}$

5. $W_{cyclic} = \frac{1}{2}[3P_0 + P_0] \times V_0 - 3P_0V_0$
$+\frac{1}{2}[3P_0 + P_0]V_0 - P_0V_0 = 0$

6. $\Delta U = \mu C_V \Delta T$ & $T = \frac{PV}{\mu R}$
so $\Delta T = T_2 - T_1 = \frac{P_2V_2 - P_1V_1}{\mu R}$
so $\Delta U = \frac{\mu R}{\gamma - 1}\left(\frac{P_2V_2 - P_1V_1}{\mu R}\right) = \frac{P_2V_2 - P_1V_1}{\gamma - 1}$
$\Rightarrow \Delta U = \frac{-8 \times 10^3}{2/5} = -20$ kJ

7. From Wein's displacement law
$\lambda_m \propto \frac{1}{T}$
Now from sequence 'VIBGYOR'
$(\lambda_m)_P < (\lambda_m)_R < (\lambda_m)_Q$
So $T_P > T_R > T_Q$

8. For Engine & refrigerators operating between two same temperatures
$\eta = \frac{1}{1+\beta} \Rightarrow \frac{1}{10} = \frac{1}{1+\beta} \Rightarrow \beta = 9$
$\beta = \frac{Q_2}{W}$ (From the principle of refrigerator)
$9 = \frac{Q_2}{10} \Rightarrow Q_2 = 90$ J

9. $\gamma = 1 + \frac{2}{n}$ (Here degree of freedom $\rightarrow$ n)

10. In cyclic process ABCA,
$\Delta U_{cyclic} = 0$
$Q_{cyclic} = W_{cyclic}$
$Q_{AB} + Q_{BC} + Q_{CA}$ = closed loop area.
$400 + 100 + Q_{CA} = \frac{1}{2} \times (2 \times 10^{-3}) \times 4 \times 10^4$
$400 + 100 - Q_{AC} = 40$
$Q_{AC} = 460$ J

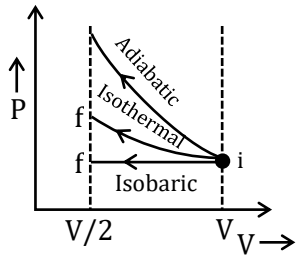
11. Rate of heat flow $\propto$ temperature difference between two ends
$\Rightarrow \frac{dQ}{dt} \propto (T_1 - T_2) \qquad T_1 > T_2$
Here temperature difference in both case is same (i.e. 10 °C)
So, rate of heat flow will also be same
So, $\frac{dQ}{dt}$ = 4 J/s

12. According to ideal gas equation
$P = \frac{\rho RT}{M_w} \Rightarrow M_w = \frac{\rho RT}{P}$
so $\frac{M_A}{M_B} = \frac{\rho_A}{\rho_B} \cdot \frac{T_A}{T_B} \cdot \frac{P_B}{P_A} = (1.5)\ (1)\left(\frac{1}{2}\right)$
$\Rightarrow \frac{M_A}{M_B} = \frac{3}{4}$

13. Molecular mass M_w = 4.0 g
$v_{sound} = \sqrt{\frac{\gamma RT}{M_w}} \Rightarrow \gamma = \frac{M_w v_s^2}{RT} = 1.6$
So, $C_p = \gamma C_v = 1.6 \times 5.0 = 8.0$ J K^{-1} mol^{-1}

14. Coefficient of performance of refrigerator
$COP = \frac{T_L}{T_H - T_L}$
Where $T_L \rightarrow$ lower Temperature
and $T_H \rightarrow$ Higher Temperature
So, $5 = \frac{253}{T_H - 253} \Rightarrow T_H = 303.6K \simeq 31°C$

15.



work done on the gas

$W_{isochoric} = 0$

and $W_{adiabatic} > W_{Isothermal} > W_{Isobaric}$

16. $d_f = \dfrac{d_i}{(1 + \gamma\Delta T)}$

fractional change

$= \dfrac{d_i - d_f}{d_i} = 1 - \dfrac{d_f}{d_i}$

$= 1 - (1 + \gamma\Delta T)^{-1}$

$= 1 - (1 - \gamma\Delta T)$

$\because (1+x)^n \; 1 + nx$

$= \gamma\Delta T$

$= 5 \times 10^{-4} \times 40$

$= 0.020$

17. $\beta = \dfrac{Q_2}{W} = \dfrac{T_2}{T_1 - T_2}$ (Where Q_2 is heat removed)

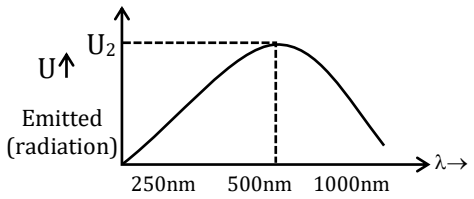
$\Rightarrow \quad \dfrac{600 \times 4.2}{W} = \dfrac{277}{303 - 277}$

$\Rightarrow$ W = 236.5 joule

$\Rightarrow$ Power $= \dfrac{W}{t} = \dfrac{236.5 \text{ joule}}{1 \text{ sec}}$ = 236.5 watt.

18. Maximum amount of emitted radiation corresponding to $\lambda_m = \dfrac{b}{T}$

$\lambda_m = \dfrac{2.88 \times 10^6 \text{ nmK}}{5760\text{K}} = 500$ nm



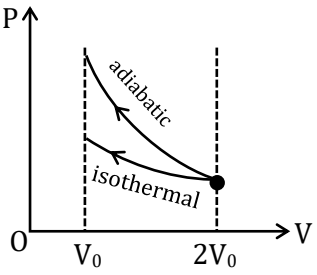
From the graph $U_1 < U_2 > U_3$

19. Change in length for both rods should be same

$\Delta\ell_1 = \Delta\ell_2 \Rightarrow \ell_1\alpha_1\Delta T = \ell_2\alpha_2\Delta T \Rightarrow \ell_1\alpha_1 = \ell_2\alpha_2$

20. $v \propto \sqrt{T} \Rightarrow \dfrac{v}{200} = \sqrt{\dfrac{400}{300}} \Rightarrow v = \dfrac{400}{\sqrt{3}}$ m/s

21.



W_{ext} = negative of area with volume-axis

W(adiabatic) > W(isothermal)

22. $\dfrac{mgh}{4} = mL \Rightarrow h = \dfrac{4L}{g} = \dfrac{4 \times 3.4 \times 10^5}{10} = 136$ km.

23. Let θ be the final common temperature. Further, let s_c and s_h be the average heat capacities of the cold and hot (initially) bodies respectively (where $s_c < s_h$ given)

From, principle of calorimetry,

heat lost = heat gained

$s_h(100°C - \theta) = s_c\theta$

$\therefore \quad \theta = \dfrac{s_h}{(s_h + s_c)} \times 100°C = \dfrac{100°C}{\left(1 + \dfrac{s_c}{s_h}\right)}$

$\because \quad s_c / s_h < 1 \qquad \therefore \; 1 + s_c / s_h < 2$

$\therefore \quad \theta > \dfrac{100°C}{2}$ or $\theta > 50°C$

OR

Body at 100°C has more heat capacity then body at 0°C so final temperature must be greater than 50°C.

24. Newton's laws of cooling

$\dfrac{T_1 - T_2}{t} = k\left(\dfrac{T_1 + T_2}{2} - T\right)$

$\dfrac{3T - 2T}{10} = k\left(\dfrac{5T - 2T}{2}\right) \Rightarrow \dfrac{T}{10} = k\left(\dfrac{3T}{2}\right)$ ...(i)

$\dfrac{2T - T'}{10} = k\left(\dfrac{2T + T'}{2} - T\right)$

$\Rightarrow \dfrac{2T - T'}{10} = k\left(\dfrac{T'}{2}\right)$ ...(ii)

By solving (i) and (ii) $T' = \dfrac{3}{2}T$

25. PV^x = constant (Polytropic process)

Heat capacity in polytropic process is given by $\left[C = C_V + \frac{R}{1-x}\right]$

Given that PV^3 = constant $\Rightarrow x = 3$ ...(1)

also gas is monoatomic so $C_V = \frac{3}{2}R$ ...(2)

by formula

$$C = \frac{3}{2}R + \frac{R}{1-3} = \frac{3}{2}R - \frac{R}{2} = R$$

26. Heat delivered = Q_1

$$COP(\beta) = \frac{Q_2}{W} = \frac{Q_1 - W}{W} = \frac{Q_1}{W} - 1 = \frac{T_2}{T_1 - T_2}$$

$$\Rightarrow \quad \frac{Q_1}{W} = 1 + \frac{t_2 + 273}{t_1 - t_2} = \frac{t_1 + 273}{t_1 - t_2}$$

27. $\frac{P}{\rho} = \frac{RT}{M_w}$ (Ideal gas equation)

$$\Rightarrow \quad \rho = \frac{PM_w}{RT} = \frac{P \times (mN_A)}{kN_A T} = \frac{Pm}{kT}$$

28. In parallel $\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$

$$\frac{K_{eq}(2A)}{\ell} = \frac{K_1 A}{\ell} + \frac{K_2 A}{\ell}$$

$$K_{eq} = \frac{K_1 + K_2}{2}$$

29. Process (1) $\rightarrow$ volume constant $\rightarrow$ Isochroic

Process (2) $\rightarrow V\uparrow \Rightarrow V\downarrow \rightarrow$ adiabatic

Process (3) $\rightarrow$ Temperature constant $\rightarrow$ Isothermal

Process (4) $\rightarrow$ Pressure constant $\rightarrow$ Isobaric

30. $P \propto r^2 T^4 \Rightarrow \frac{P_1}{P_2} = \left(\frac{r_1}{r_2}\right)^2 \left(\frac{T_1}{T_2}\right)^4$

P_2 = 1800 watt

31. $\eta = \frac{1}{1+\beta}$

$$\frac{1}{10} = \frac{1}{1+\beta} \Rightarrow \beta = 9$$

$$\beta = \frac{Q_2}{W} \Rightarrow 9 = \frac{Q_2}{10} \Rightarrow Q_2 = 90 \text{ J}$$

32. $U = \frac{f}{2}nRT$

$$U_{total} = \frac{5}{2}(2)RT + \frac{3}{2}(4)RT$$

U_{total} = 11RT

33. Q = 54 cal = 54 × 4.18 joule = 225.72 joule

$W = P[V_{steam} - V_{water}]$ [For water 0.1 gram=0.1 cc]

$= 1.013 \times 10^5[167.1 \times 10^{-6} - 0.1 \times 10^{-6}]$ joule

$= 1.013 \times 167 \times 10^{-1} = 16.917$ joule

By FLOT

$\Rightarrow \quad \Delta U = Q - W = 225.72 - 16.917 = 208.8$ joule

34. $P = \sigma AT^4 \Rightarrow P \propto T^4$

According to Wein's law $T \propto \frac{1}{\lambda_m}$

$$\Rightarrow \quad P \propto \left(\frac{1}{\lambda_m}\right)^4 \Rightarrow \frac{P_2}{P_1} = \left(\frac{\lambda_{m_1}}{\lambda_{m_2}}\right)^4$$

$$\Rightarrow \quad \frac{P_2}{P_1} = \left(\frac{\lambda_0}{\frac{3}{4}\lambda_0}\right)^4 \Rightarrow \frac{nP}{P} = \frac{256}{81} \Rightarrow n = \frac{256}{81}$$

35. $V \propto T \Rightarrow W = P\Delta V = \mu R \Delta T$

$Q = \mu C_P \Delta T$

for mono atomic gas f = 3

$$C_P = \left(\frac{f}{2}R + R\right) = \frac{5}{2}R \text{ So } \frac{W}{Q} = \frac{\mu R \Delta T}{\mu C_P \Delta T} = \frac{2}{5}$$

36. $\eta = \left(\frac{T_1 - T_2}{T_1}\right) \times 100$

where T_1 = 373, T_2 = 273

$$\Rightarrow \quad \eta = \frac{100}{373} \times 100 = 26.8\%$$

37. $v_{es} = v_{rms} \quad \Rightarrow \quad 11.2 \times 10^3 = \sqrt{\frac{3kT}{m}}$

$$\Rightarrow T = \frac{\left(11.2 \times 10^3\right)^2 m}{3k}$$

Putting value of m and k

T = 8.360 × 10^4 K

38. Adiabatic process

$\Delta Q = 0$

39. KE $\propto$ Temperature

As temperature increases KE also increases

40. At any temperature

$(\Delta\ell)_{Cu} = (\Delta\ell)_{Al}$

$\ell_1\alpha_1\Delta T = \ell_2\alpha_2\Delta T$

$88 \times 1.7 \times 10^{-5} = \ell_2 \times 2.2 \times 10^{-5}$

ℓ_2 = 68 cm

41. $\frac{dQ}{dt} = -(K)A\frac{dT}{dx}$

$\frac{J}{s} = (K)m^2\frac{kelvin}{m}$

(K) = watt m^{-1} K^{-1}

42. $\frac{T_1 - T_2}{t} = K\left(\frac{T_1 + T_2}{2} - Ts\right)$

$\frac{80-70}{12} = K\left(\frac{80+70}{2} - 25\right)$ ...(1)

$\frac{70-60}{t} = K\left(\frac{70+60}{2} - 25\right)$ ...(2)

on solving : t = 15 min

43. $KA\frac{[0-(-26)]}{x}dt = A(dx)\rho L$

$\Rightarrow \frac{dx}{dt} = \frac{26K}{\rho L x}$

44. Hydrogen $\rightarrow$ 7/5 (diatomic),
Helium $\rightarrow$ 5/3 (monoatomic), X $\rightarrow$ 9/7

45. $Q = \Delta U + W \Rightarrow mL = \Delta U + P(V_2 - V_1)$
$\Rightarrow 1(2256) = \Delta U + 1 \times 10^5 (1670 \times 10^{-6})$
$\Rightarrow \Delta U = 2089$ J

46. Average thermal energy = $\frac{3}{2}K_B T$

where 3 is translational degree of freedom
For monoatomic gas total degree of freedom f = 3 (translational degree of freedom)

47. Mean free path for a gas sample

$\lambda_m = \frac{1}{\sqrt{2}\pi d^2 n}$

where d is diameter of a gas molecule and n is molecular density

48. Heat supplied $\Delta Q = MS\Delta T$
For same material 'S' same.

$\Delta Q \propto M$ and $M = \frac{4}{3}\pi r^3\rho \Rightarrow \Delta Q \propto r^3$

$\frac{\Delta Q_1}{\Delta Q_2} = \left(\frac{r_1}{r_2}\right)^3 = \left(\frac{1.5}{1}\right)^3 = \frac{27}{8}$

49. For an ideal gas sample

$\frac{P}{\rho} = \frac{RT}{M_w}$

$\rho = \frac{PM_w}{RT} = \frac{249\times10^3\times2\times10^{-3}}{8.314\times300} = 0.199$

$\rho \simeq 0.2$ kg/m^3

50. Free expansion i.e. expansion against vacuum is adiabatic in nature for all type of gases. It should be noted that final temperature is equal to initial temperature for ideal gases.

51. Efficiency of cannot engine

$\eta = 1 - \frac{T_2}{T_1}$

T_1 = temperature of source
T_2 = temperature of sink

52. $\lambda = \frac{1}{\sqrt{2}\pi d^2 n} \propto \frac{1}{d^2}$

λ = mean free path
d = effective diameter of molecule
n = number density of molecules

53. PV = nRT

$\Rightarrow P = \frac{1}{V}.\left(\frac{m}{M_0}\right)RT = \left(\frac{m}{V}\right)\left(\frac{RT}{M_0}\right)$

$\Rightarrow P = \frac{\rho RT}{M_0}$

$\rho = \frac{m}{v}$ = mass density

& M_0 = molar mass

54. P = constant $\Rightarrow$ Isobaric process

55. By using Wien's law $\lambda_m T$ = constant,

we have $T \propto \frac{1}{\lambda_m}$

As $\lambda_B < \lambda_Y < \lambda_R$ (VIBGYOR)
$\Rightarrow T_A > T_C > T_B$

56. According to Newton's law of cooling

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

For 1st cup of coffee,

$\Rightarrow \frac{90-80}{t} = K\left[\frac{90+80}{2} - 20\right]$ ...(1)

For 2nd cup of coffee,

$\Rightarrow \frac{80-60}{t'} = K\left[\frac{80+60}{2} - 20\right]$ ...(2)

Divide (1) by (2)

$\frac{t'}{2t} = \frac{65}{50} \Rightarrow t' = \frac{13}{5}t$

57. Root mean square speed of gas molecules

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

Pressure exerted by ideal Gas

$$P = \frac{1}{3}\rho\upsilon_{rms}^2$$

$$P = \frac{1}{3}mn\upsilon^2$$

$\rho = mn$, $\upsilon_{rms}^2 = \vec{\upsilon}^2$

Average kinetic energy of a molecule

$$KE = \frac{3}{2}KT$$

Total internal energy of 1 mole of a diatomic gas

$$U = \frac{5}{2}\mu RT$$

or $U = \frac{5}{2}RT$ (For 1 mole diatomic gas)

63. $v_{rms} \propto \sqrt{T}$

$$\frac{v_1}{v_2} = \sqrt{\frac{T_1}{T_2}}$$

= let initial speed is v

As speed is increased by 3 times so final speed become 4v

$$\Rightarrow \frac{v}{4v} = \sqrt{\frac{223}{T}}$$

T = 3568 K

So temp. in °C = 3568 – 273 = 3295°C

64. Efficiency of carnot engine

$$\%\eta = \left(1 - \frac{T_{sink}}{T_{source}}\right) \times 100$$

T_{source} = 327°C = 600 K

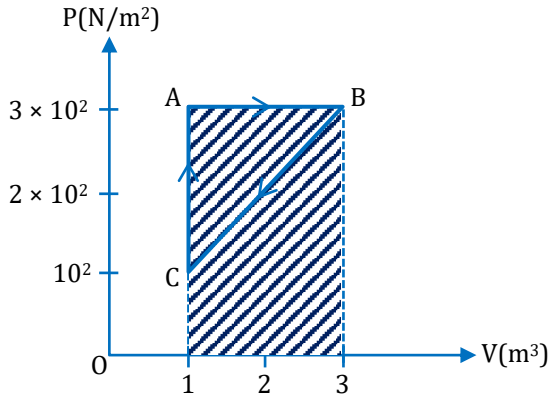
$$50 = \left(1 - \frac{T_{sink}}{600}\right) \times 100$$

$$\frac{1}{2} = 1 - \frac{T_{sink}}{600}$$

$$T_{Sink} = 300K$$

So temp. of sink is °C = 300 – 2763 = 27°C

65.



AB is isobaric process

$W_{AB} = P(V_2 - V_1)$

$W_{AB} = 3 \times 10^2 (3-1)$

$W_{AB} = 3 \times 100 \times 2$

W_{AB} = 600 J

66. $$P_{mix} = \frac{(\mu_1 + \mu_2)RT_{mix}}{V_{mix}}$$

$$= \frac{(0.2+0.3)\times 8.3\times 200}{200\times 10^{-6}}$$

$$= \frac{0.5\times 8.3\times 200}{200\times 10^{-6}}$$

$P_{mix} = 4.15 \times 10^6\ P_a$

67. For path bc volume is constant

so work done is zero

$\Rightarrow W = 0$

68. PV = nRT

$$\Rightarrow T = \frac{P}{nR}.V$$

comparing with y = mx

$$m = \text{slope} = \frac{P}{nR} \propto P$$

$\Rightarrow P_1 > P_2 > P_3$

69. Houses made of concrete roofs overlaid with foam keep the room colder during summer.

70. Water is a good coolant because of it's high specific heat capacity.

71. Equilibrium state of a thermodynamic system is described by thermodynamic variables such as pressure, temperature, volume etc.

72. Let vibrational degrees of freedom be f_{vib}
Translatory degrees of freedom = 3
Rotatory degrees of freedom = 3
Total degree of freedom = f + 6

$$\gamma = 1 + \frac{2}{f_{total}} \Rightarrow \gamma = 1 + \frac{2}{f_{vib} + 6}$$

$$\Rightarrow f_{vib} = \frac{2(4-3\gamma)}{\gamma - 1}$$

$$\Rightarrow \text{Vibrational modes} = \frac{(4-3\gamma)}{\gamma - 1}$$

Exercise-III (Analytical Questions)

1. Celsius scale ranges from 0°C to 100°C Fahrenheit scale ranges from 32°F to 212°F Kelvin scale ranges from 273.15 K to 373.15 K unknown scale ranges from x to y.

2. When a bimetallic strip is heated it bends in the from of an arc with material having greater temperature expansion co-efficient going on outer side. It is used in thermostate.

3. Since the coefficient of linear expansion for brass is greater than steel so system should be cooled to take out the disc from the plate.

4. When heat is supplied to the solid its temperature may increase (phase heating) or it may remains constant (state change).

5. A good cooking utensil should have low specific heat, low thermal capacity and high coefficient of thermal conductivity.

6. In BC temperature remains constant
ice $\rightarrow$ water
As density of ice is less than water so after melting volume decreases.

7. During melting temperature of substance remains constant.

8. Heat $\rightarrow$ Energy in transit
Internal energy $\rightarrow$ It is sum of energy due to attractive force and due to random motion.
Temperature $\rightarrow$ Degree of hotness or coldness of a substance.
Specific heat $\rightarrow$ Amount of heat required to raise temperature of unit mass by 1°C.

9. If t = 0
$\Rightarrow a(\uparrow), r\downarrow, e(\uparrow)$ {Here, a + r = 1 and $a \propto e$}
$\Rightarrow a(\downarrow), r\uparrow, e(\downarrow)$

11. $P = \frac{dQ}{dt} = \sigma A T^4 \propto r^2$

$$R = \frac{d\theta}{dt} = \frac{\sigma A T^4}{ms} \propto \frac{A}{v} \propto \frac{r^2}{r^3} \propto \frac{1}{r}$$

13. $\lambda_m \propto \frac{1}{T}$

(As temperature increases λ_m decreases)

14. $V_{RMS} \propto \sqrt{\frac{T}{M_w}}$

V_{RMS} also depends on nature of gas.

15. $V \propto \sqrt{\frac{T}{M_w}}$

$\Rightarrow T \rightarrow \text{const.} \Rightarrow V \propto \frac{1}{\sqrt{M_w}}$

$\Rightarrow (M_w)_{N_2} > (M_w)_{He}$

$\Rightarrow V_{He} > V_{N_2}$

and $KE = \frac{f}{2} kT$; $KE \propto f$

for N_2 gas ; f↑ KE↑

16. As $\frac{p}{\rho} = \frac{RT}{M_w} \Rightarrow p = \left(\frac{M}{V}\right)\left(\frac{RT}{M_w}\right)$

at constant temperature $\Rightarrow p \propto \frac{1}{V}$

V↑ and P↓

18. Remember

$$V_s = \sqrt{\frac{\gamma RT}{M_w}} ; V_{Avg} = \sqrt{\frac{8}{\pi}\frac{RT}{M_w}}$$

$$V_{RMS} = \sqrt{\frac{3RT}{M_w}} ; V_{mp} = \sqrt{\frac{2RT}{M_w}}$$

19. (A) Adiabatic bulk modulus

$$= -\left(\frac{dP}{dV}\right) \times V = -\left(-\gamma \frac{P}{V}\right) \times V = +\gamma P$$

(B) Slope of isothermal curve PV = K

$PdV + VdP = 0$

$$(\text{slope})_{IT} = \frac{dP}{dV} = -\frac{P}{V}$$

(C) $C_V = \frac{f}{2}R$, $C_P = \left(\frac{f}{2}+1\right)r$, $\gamma = \frac{C_P}{C_V}$

Therefore $\gamma = 1+\frac{2}{f}$

So, $f = \frac{2}{\gamma-1}$

(D) $C_P = \frac{\gamma R}{\gamma-1}$

$\frac{C_P}{R} = \frac{\gamma}{\gamma-1}$

20. $Q = W + \Delta U$
$Q = 0$
$\Delta U = -W$

21. Process ab $\rightarrow$ (Isothermal process)
T = constant $\Rightarrow U$ = constant $\Rightarrow \Delta U = 0$
and ρ increasing
Process bc $\Rightarrow$ ρ = constant
then isochoric process
Process cd $\Rightarrow$ (Isothermal process)
T = constant $\Rightarrow U$ = constant $\Rightarrow \Delta U = 0$
and ρ decreasing.
Process da $\Rightarrow$ (Isothermal process)
ρ = constant then isochoric process

22. (i) $dU = nC_v dT$ is valid for all types of process.
(ii) Temperature of the system can change in adiabatic process, polytropic process.
(iii) $dQ = dU + dW$ (First law) is valid for all types of process.
(iv) The process in which heat exchange does not occurs is adiabatic process and free expansion.

23. $C_P - C_V = R$
$C_P \Rightarrow Q = W + \Delta U$
$C_V \Rightarrow Q = \Delta U$
(in isobaric process)

24. In a cyclic process $dU = 0 \Rightarrow U \rightarrow$ constant
In an isothermal process $dU = 0$
$\Rightarrow U \rightarrow$ constant
If $\Delta Q = \Delta W$ means $dU = 0 \Rightarrow U \rightarrow$ constant

25. $Q = 0$ for adiabatic
(i) $nCdT = 0 \Rightarrow C = 0$

(ii) $C = \frac{\Delta Q}{mdT}$ for IT ; $dT = 0$

$c = \infty$

(iii) $C_V = \frac{f}{2}R$; $C_P = \left(\frac{f+2}{2}\right)R$

f dependents on nature of gas

(iv) $Q = mS\Delta T$ ...(1)
$Q = nC\Delta T$ ...(2)

$n = \frac{m}{M_w}$

$mS = nC$

$mS = \frac{m}{M_w}C \Rightarrow C = M_wS$

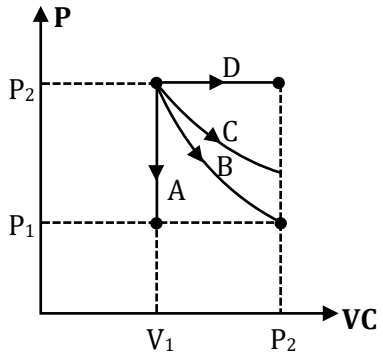
26. (A) Adiabatic expansion – Temperature decrease so decrease in internal energy

(B) Isobaric expansion – Volume increases and hence temperature increases since P $\rightarrow$ constant ($V \propto T$)
So internal energy increases

(C) Isothermal expansion – $T \rightarrow$ constant
So, constant internal energy

(D) Isochoric process – $V \rightarrow$ constant
So, No work done
As $\omega = P\Delta V = 0$

27.



For (i) : $W = 0$ & $\Delta T < 0 \Rightarrow Q < 0$ & $\Delta U < 0$
For (ii) : $Q = 0$, $W > 0 \Rightarrow \Delta U < 0$
For (iii) : $\Delta T = 0$, $\Rightarrow \Delta U = 0 \Rightarrow Q = W > 0$
For (iv) : $V \propto T \Rightarrow W > 0$ & $\Delta U > 0 \Rightarrow Q > 0$