

MAIN+ADVANCED

TOPIC

HEAT &
THERMODYNAMICS

SOLUTIONS

HEAT & THERMODYNAMICS

Exercise-1

1. **A**

From the formula

$$V_{rms} = \sqrt{\frac{3RT}{M_0}}$$

$$\sqrt{\frac{3R T_{O_2}}{M_{O_2}}} = \sqrt{\frac{3R T_{N_2}}{M_{N_2}}}$$

$$T_{O_2} = \frac{M_{O_2}}{M_{N_2}} \cdot T_{N_2}$$

$$= \frac{16}{14} \times 373 = 426.3K$$

2. **C**

From the formula

$$V_{rms} = \sqrt{\frac{3RT}{M_0}}$$

$$V_{rms_{O_2}} = \sqrt{\frac{3RT_{O_2}}{M_{O_2}}}$$

$$V_{rms_{O}} = \sqrt{\frac{3RT_{O_2} \times 2}{M_{O_2}/2}} = 2 \sqrt{\frac{3RT_{O_2}}{M_{O_2}}} = 2V$$

3. **B**

The average velocity is given as

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

Independent of other gases. Hence average velocity of oxygen in third container will be V_1 only.

$$= 7.66 u$$

4. **D**

$$V_{avg} = \frac{1+2+3+\dots+N}{N} = \frac{N(N+1)}{2N} = \frac{(N+1)}{2}$$

$$V_{rms} = \sqrt{\frac{1^2 + 2^2 + \dots + N^2}{N}} = \sqrt{\frac{2N+1}{6}}$$

$$\frac{V_{rms}}{V_{avg}} = \frac{2}{(N+1)} \sqrt{\frac{2N+1}{3}}$$

5. **A**

$$\text{Average rotational K. E.} = \frac{1}{2}KT \times 2 = KT$$

So it will be same for both the gases.

6. **B**

For $L \rightarrow M$

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

a straight line with positive slope.

7. **C**

$PT = \text{constant}$

$$P \left(\frac{PV}{nR} \right) = \text{constant}$$

$P^2V = \text{constant}$. Therefore the graph C is suitable.

8. **A**

From the graph shown.

$$V_{av} \propto \sqrt{T} \propto \sqrt{PV}$$

$$V_{av_1} : V_{av_2} : V_{av_3}$$

$$\sqrt{V_0 P_0} : \sqrt{V_0 \cdot 4P_0} : \sqrt{4V_0 P_0}$$

$$1 : 2 : 2$$

9. **A**

$$\text{We are given } P = \frac{2E}{3V}$$

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

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

Here E is the Translational K.E. for all the particles.

10. **C**

The number of molecules in 1 mole is always same for all the ideal gases.

11. **A**

We know that

$$PV = nRT$$

$$n = \frac{PV}{RT} = \frac{1.3 \times 10^5 \times [7 \times (10^{-2})^3 \times 10^3]}{8.3 \times 273}$$

So, Number of molecules is

$$= \frac{1.3 \times 10^5 \times 7 \times 10^{-3}}{8.3 \times 273} \times 6.023 \times 10^{23}$$

$$= 2.4 \times 10^{23}$$

12. A

From the graph shown

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

$$P = \frac{-P_0 V}{V_0} + 3P_0$$

$$\frac{-2P_0 V}{V_0} + 3P_0 = nR \frac{dT}{dV}$$

Till $V = \frac{3}{2} V_0$ the change in temperature is positive

hence temperature increases. After that $\frac{dT}{dV} < 0$

so temperature decreases.

13. C

From the graph shown the equation of line is

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

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

$$P = \frac{-P_0 V}{2V_0} + \frac{3P_0}{2}$$

Now we know $PV = nRT$

$$\Rightarrow \left(\frac{3}{2} P_0 - \frac{P_0 V}{2V_0} \right) V = nRT$$

For maximum temperature

$$\frac{dT}{dV} = 0 \Rightarrow \frac{3}{2} P_0 - \frac{P_0 V}{V_0} = 0$$

$$V = \frac{3}{2} V_0$$

$$T_{\max} = \left(\frac{3}{2} P_0 - \frac{P_0}{2V_0} \cdot \frac{3}{2} V_0 \right) \frac{3}{2} V_0 \cdot \frac{1}{nR}$$

$$= \frac{3}{4} P_0 \cdot \frac{3}{2} V_0 \cdot \frac{1}{R} = \frac{9P_0 V_0}{8R}$$

14. B

Initially

$$PV_1 = \frac{12}{M} R T_1$$

or

$$P(4 \times 10^{-3}) = \frac{12}{M} R (273 + 7) \dots (1)$$

$$\rho = \frac{m}{V_2} = \frac{12}{V_2} = 6 \times 10^{-4} \text{ gm/cc}$$

$$P \left(\frac{12}{6 \times 10^{-4}} \right) \times (10^{-2})^3 = \frac{12}{M} R (T) \dots (2)$$

from 1 ÷ 2

$$\frac{4 \times 10^{-3}}{12 \times 10^{-6}} \times 6 \times 10^{-4} = \frac{273 + 7}{T} \Rightarrow T = 1400 \text{ K}$$

15. B

From ideal gas equation

$$PV = nRT$$

$$PV = \frac{m}{M} RT \Rightarrow \frac{V}{T} = \frac{mR}{MP} = C_B$$

In second case

$$\frac{V}{T} = \frac{2mR}{M}$$

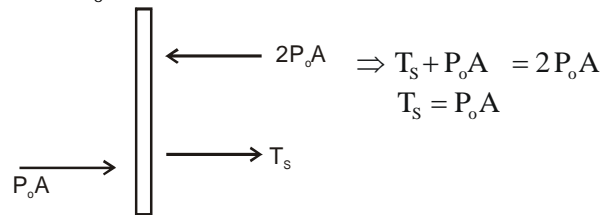
16. C

As the volume remains constant on increasing temperature pressure becomes double.

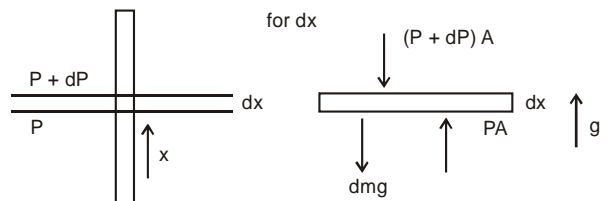
$V = \text{const.}$

$T = \text{doubled}$

$p = 2P_0$



17. C



$$PA - dm g - (P + dP) A = dm g$$

$$- AdP = 2dm g$$

$$- AdP = 2\rho A dx g$$

$$-dP = 2\rho g dx. \text{ Where } \rho = \frac{m}{V}$$

$$PV = \frac{m}{M}RT$$

$$\frac{PM}{RT} = \frac{m}{V}$$

$$\rho = \frac{PM}{RT}$$

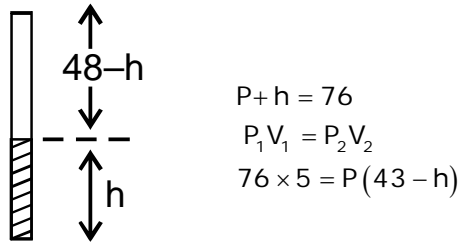
$$-dP = \frac{2PM}{RT} \cdot g \cdot dx$$

$$-\int_{P_0}^{P_1} \frac{dP}{P} = \frac{2Mg}{RT} \int_0^{x=H/2} dx$$

$$\ln \frac{P_0}{P_1} = \frac{2Mg}{RT} \cdot \frac{H}{2} \Rightarrow \frac{P_0}{P_1} = e^{MgH/RT}$$

18. C

In the final condition.
Let atmospheric pressure is P and ht of liquid column is h.



$$380 = (76 - h)(43 - h)$$

$$h = 38 \text{ cm}$$

$$\text{So, } 48 - h = 10 \text{ cm} = 0.1 \text{ m.}$$

19. A

$$P + 50 = 75$$

$$P = 25 \text{ cm of } H_g$$

$$\frac{10^5}{75} \times 25$$

$$= 33.3 \text{ kPa}$$

20. B

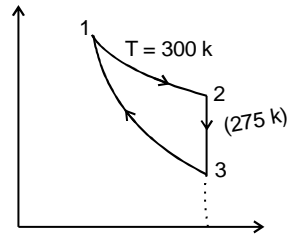
$$W = \int_{V_1}^{V_2} PdV = \int_{V_1}^{V_2} aV^2dV$$

$$= a \left[\frac{V^3}{3} \right]_{V_1}^{V_2} = \frac{a}{3} (V_2^3 - V_1^3)$$

$$= \frac{1}{3} [P_2 V_2 - P_1 V_1]$$

$$= \frac{1}{3} [nR\Delta T] = \frac{1}{3} R (T_2 - T_1)$$

21. A
22. A



$$\Delta Q_{1-2} = \Delta W_{1-2}$$

$$\Delta Q_{2-3} = \Delta U_{2-3} = -40 \text{ J}$$

$$\Rightarrow \Delta W_{2-3} = 0$$

$$\Delta Q_{3-1} = 0$$

$$\Delta u_{3-1} = n c_v (300 - 275)$$

$$\Delta Q_T = \Delta W_T$$

$$\Delta Q_{3-1} + \Delta Q_{2-3} + \Delta Q_{1-2}$$

$$= \Delta W_{1-2} + \Delta W_{2-3} + \Delta W_{3-1}$$

$$\Delta Q_{2-3} - \Delta W_{2-3} = \Delta W_{3-1}$$

$$\Delta W_{3-1} = -40 \text{ J}$$

23. B

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

$$\Delta U = \Delta Q - \Delta W$$

$$\Delta U = Q - P_0 \Delta V$$

$$\Delta U = Q - P_0 \left(\frac{1}{\rho_2} - \frac{1}{\rho_1} \right)$$

24. D

$$W_{\text{net}} = W_{1-2} + W_{2-3} + W_{3-1}$$

$$10 = W_{1-2} + 0 - 20$$

$$W_{1-2} = 30 \text{ J}$$

$$\Delta U_{1-2} = 0$$

$$\therefore \Delta Q_{1-2} = \Delta W_{1-2} + \Delta U_{1-2} = 30 \text{ J}$$

25. D

$$\Delta U_{ab} = \Delta Q_{acp} - \Delta W_{acb}$$

$$= 200 - 80 = 120 \text{ J}$$

$$\Delta W_{adb} = \Delta Q_{adb} - \Delta U_{ab}$$

$$= 144 - 120 = 24 \text{ J}$$

26. B

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

$$= -52 \text{ J} - 120 \text{ J}$$

= 172J

27. D

$$\Delta U_{ab} = U_b - U_a$$

$$U_b = 120 + 40 = 160J$$

28. B

$$\Delta Q_{db} = \Delta U_{db} + \Delta W_{db} \quad (v = \text{const.})$$

$$= U_b - U_d$$

$$= 160 - 88 = 72J$$

29. B

For AB

$$\Delta U = 0 \quad (T = \text{const.})$$

$$\Delta W = nRT \ln \frac{V_2}{V_1} = nRT \ln \frac{P_1}{P_2}$$

= negative ($\because P_1 < P_2$)

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

(Heat is rejected)

For BC $\therefore T \downarrow \quad \therefore U \downarrow$

30. A

$$\Delta Q = \Delta W + 3\Delta W$$

$$= 4\Delta W$$

$$\therefore n = \frac{\Delta W}{\Delta Q} = \frac{\Delta W}{4\Delta W} = 0.25$$

31. A

$$\frac{1}{2}mv^2 = nC_v dT$$

$$\frac{1}{2}mv^2 = \frac{m}{.03} \left(\frac{5}{2}R \right) \Delta T$$

$$\Delta T = \frac{.03 \times 100^4}{5R} = \frac{6 \times 10^{-3} \times 10^4}{R} = \frac{60}{R}$$

32. D

$$\frac{\text{Total Mass}}{\text{Total No. of moles}} = \text{Equivalent molar mass}$$

$$= \frac{n_1 m_1 + n_2 m_2}{(n_1 + n_2)} = \frac{(5 \times 4) + (2 \times 2)}{(5 + 2)} = \frac{24}{7}$$

33. A

He - monoatomic H_2 - diatomic
 $f = 3 \quad \quad \quad f = 5$

$$f = \frac{3n_{He} + 5n_{H_2}}{n_{He} + n_{H_2}}$$

$$= \frac{3 \times 5 + 5 \times 2}{(5 + 2)} = 3.57 \text{ Ans.}$$

34. C

$$\gamma = \frac{C_p}{C_v} = \left[1 + \frac{2}{f} \right]$$

$$= \left[1 + \frac{2}{3.57} \right] = 1.56 \text{ Ans.}$$

35. A

$V/T = \text{const.} \quad P = \text{const.}$

$$\Delta Q = nC_p \Delta T = n \frac{\gamma R}{\gamma - 1} \Delta T$$

$$\Delta W = nR \Delta T$$

$$\frac{\Delta Q}{\Delta W} = \frac{\gamma}{\gamma - 1}$$

36. C

$PV^\gamma = \text{constant}$

$$V^\gamma \frac{dP}{dV} = \gamma PV^{\gamma-1} \frac{dV}{dV} = 0$$

$$\frac{dP}{dV} = \frac{-\gamma PV^{\gamma-1}}{V^\gamma} = \frac{-\gamma P}{V}$$

$$= -1.4 \times \frac{0.7 \times 10^5}{0.0049}$$

$$= -2 \times 10^7$$

37. B

$$\Delta U = nC_v \Delta T$$

Given

$$6300 = \Delta U_i = nC_v (150)$$

$$\text{So,} \quad \Delta U = \frac{6300}{150} \times 300$$

$$\Delta U = 12600$$

38. A

$$\Delta W = \int_{V_1}^{V_2} PdV = \int_{V_1}^{V_2} KVdV \quad \therefore \frac{P}{V} = K$$

$$= \frac{KV_2^2 - KV_1^2}{2} = \frac{P_2 V_2 - P_1 V_1}{2}$$

$$\Rightarrow \Delta U = \frac{3}{2}R(2T_0 - T_0) = \frac{3}{2}RT_0$$

$$\Delta Q = \Delta U + \Delta W = 2RT_0$$

39. D

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

$$2C \Delta T = n \frac{f}{2} R \Delta T + PdV$$

$$2C\Delta T = 2 \times \frac{5}{2} R\Delta T + PdV \quad \text{---(1)}$$

$$\frac{PT^2}{V} = K$$

$$\text{or } \frac{T^3}{V^2} = \frac{K}{nR} \Rightarrow T^3 = \frac{K}{nR} V^2$$

$$\Rightarrow 3T^2 dT = \frac{K}{nR} 2V dV$$

$$\text{or } \frac{3T^2}{2V} dT = \frac{K}{nR} dV$$

$$\frac{3}{2} dT = \frac{P}{nR} dV \quad \text{---(2)}$$

From (1) and (2)

$$2C\Delta T = 5R\Delta T + nR \frac{3}{2} \Delta T$$

$$2C = 5R + 3R$$

$$2C = 8R$$

So, molar heat capacity $C = 4R$

40. C

$$PV^\gamma = \text{Constant}$$

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

$$\frac{V_B}{V_C} = \left(\frac{T_1}{T_2}\right)^{\gamma-1} = \frac{V_A}{V_D}$$

41. C

Slope of adiabatic > isothermal

(A) (B)

42. D

$$PV^\gamma = K$$

$$\ln P + \gamma \ln V = \ln K$$

Differentiate both sides

$$d(\ln P) + \gamma d(\ln V) = 0$$

$$\frac{d(\ln P)}{d(\ln V)} = -\gamma$$

$$\gamma_B > \gamma_A \Rightarrow \text{B is monoatomic}$$

Gas A is diatomic

43. B

$$\Delta U = n \frac{f}{2} R \Delta T$$

$$\text{For Isobaric process } V_1 \rightarrow T_1 = \frac{P_1 V_1}{nR}$$

$$\text{At } V_2 \rightarrow T_2 = \frac{P_1 (V_1/2)}{nR} = \frac{T_1}{2}$$

$$\Rightarrow \Delta U_p = \frac{nfR}{2} \left[\frac{T_1}{2} \right] \quad \text{---(1)}$$

$$\text{Isothermal } \Delta U_T = 0 \quad \text{---(2)}$$

$$\text{Adiabatic } PV^\gamma = K$$

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

$$\frac{T_1}{T_2} = \frac{V_2^{\gamma-1}}{V_1^{\gamma-1}} = \frac{1}{2^{\gamma-1}}$$

$$T_2 = 2^{\gamma-1} T_1 > \frac{T_1}{2}$$

$$\Delta U_{\text{Adiabatic}} = n \frac{f}{2} R [2^{\gamma-1}] \frac{T_1}{2}$$

$$\Delta U_{\text{adiabatic}} = \Delta U_p (2^{\gamma-1}) \quad \text{---(3)}$$

44. A

Free Expansion

$$\text{So, } \left. \begin{array}{l} \Delta W = 0 \\ \Delta Q = 0 \end{array} \right\} \Rightarrow \Delta U = 0 \Rightarrow \Delta T = 0$$

$$\text{and } P_1 V_1 = P_2 (2V_1)$$

$$P_2 = \frac{P_1}{2}$$

45. D

Ist Process

$$\Delta U_1 = \Delta Q_1 - \Delta W_1$$

$$= 16 - 20 = -4 \text{ KJ}$$

IInd Process

$$\Delta W_2 = \Delta Q_2 - \Delta U_2$$

$$\Delta U_1 = \Delta U_2 \quad (\because \Delta T = \text{same})$$

$$\text{So, } \Delta W_2 = [9 - (-4)] = 13 \text{ KJ}$$

46. A

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

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

$$= 300 \left(\frac{1}{4} \right)^{\frac{1-\frac{4}{3}}{3}}$$

$$= 300\sqrt{2}$$

Exercise-2

1. D

(A) $K.E. = \frac{f}{2}KT$

(B) $V_{\text{mean}} = 1.59\sqrt{\frac{KT}{m}}$

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

($\Delta U \rightarrow 0$) for isothermal

$\Delta W \rightarrow +ve$ so $K.E. \uparrow$

3. A,B,C

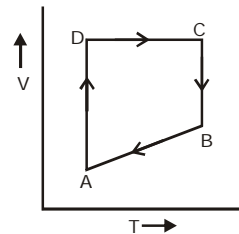
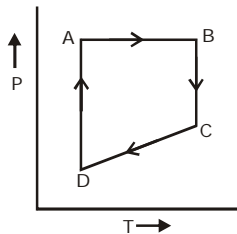
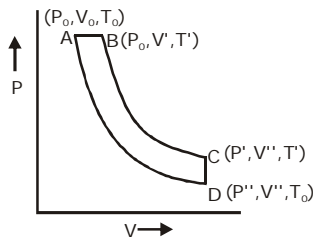
Avg. momentum/mol $\propto \sum V_x^2$

$\sum V_x^2$ is same at NTP

$(K.E.)_{\text{avg}} \propto T$

$(K.E.)/\text{vol.} \propto T$

4. A,B



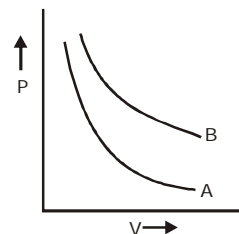
5. C

$PV = \text{Const}$

Slope of B > slope of A

$n_B > n_A$

$m_B > m_A$



6. A,D

$\frac{P^2}{\rho} = C \Rightarrow \frac{P_1^2}{\rho_1} = \frac{P_2^2}{\rho_2}$

$\Rightarrow P_2^2 = P_1^2 \times \frac{1}{2} \Rightarrow P_2 = \frac{P_1}{\sqrt{2}}$

$PV = \frac{m}{W} \times RT = \frac{\rho V}{W} RT$

$P = \rho T \frac{R}{W} \Rightarrow P_1 = \rho_1 T_1 R/W$

$P_2 = \rho_2 T_2 R/W$

$\frac{P_1}{P_2} = \frac{\rho_1 T_1}{\rho_2 T_2} \Rightarrow \sqrt{2} = 2 \frac{T_1}{T_2}$

$\Rightarrow T_2 = \sqrt{2}T_1$

$\Rightarrow P = \rho \frac{TR}{W} \Rightarrow \frac{P^2}{\rho} = \frac{PTR}{W} = C$

$\Rightarrow P \propto \frac{1}{T}$

9. B,D

$v_{\text{rms}} = 1.73 \sqrt{\frac{KT}{m}}$

so v_{rms} does not change

$\frac{P_1}{n_1} = \frac{P_2}{n_2} \Rightarrow \frac{n_1}{n_2} = \frac{1}{2}$

8. D

$v_f = \eta v_0 \quad W_{\text{gas}} = RT_0 \ln \eta$

$W_{\text{atm}} = p dv = pv (\eta - 1) = RT_0 (\eta - 1)$

At constant temperature $\Delta U = 0$

9. B,D

$\Delta W_A = P_1 \Delta V$

$\Delta W_D = P_2 \Delta V \{P_1 > P_2\}$

$\Delta Q_A = \Delta U_A + \Delta W_A$

$\Delta Q_D = \Delta U_D + \Delta W_D$

$\Delta Q_A - \Delta Q_D = \Delta U_A - \Delta U_D + \Delta W_A - \Delta W_D$

$\Delta Q_A - \Delta Q_D = \Delta W_A - \Delta W_D$

$\{ \therefore \Delta U_A = \Delta U_D$

$Q_A > Q_D$

$W_B = PdV = \int_{v_1}^{v_2} \frac{k}{v} dv = k \ln \frac{v_2}{v_1}$

$W_C = k \ln \frac{v_2}{v_1}$

hence $W_B - W_C = 0 \Rightarrow Q_B > Q_C$

$Q_A > Q_B > Q_C > Q_D$

10. D

$(p_0, v_0) \rightarrow (p_0, 2v_0)$

$\Delta U_1 = \frac{3}{2} nR\Delta T ; \Delta U_2 = \frac{5}{2} nR\Delta T$

$\Delta U_2 > \Delta U_1 ; \Delta W_1 = \Delta W_2$

$$\Delta Q_1 - \Delta Q_2 = \Delta U_1 - \Delta U_2$$

$$\Delta U_2 + \Delta W_2 > \Delta U_1 + \Delta W_1$$

11. A

$$PV = nRT \text{ Along AB } \quad V \downarrow \quad T \downarrow$$

$$\text{Along BC } \quad P \uparrow \quad T \uparrow$$

$$\text{Along CA } \quad \frac{P}{(1/v)} = \text{const } U = \text{const}$$

$$w = \int Pdv = \int \frac{kdv}{v} = k \ln(v_i / v_f) = -ve$$

12. A,B

$$\Delta Q = \frac{f}{2} nR\Delta T$$

$$f = \frac{2 \times 3 \times 4.2}{1 \times 8.3 \times 1} \quad \begin{cases} n = 1 \\ R = 8.3 \end{cases}$$

$$\Delta T = 1$$

$$= \frac{6 \times 4.2}{8.3} \cong 3$$

The gas must be monoatomic.

13. A,D

$$n_1 = \frac{7}{28}; \quad n_2 = \frac{11}{44}$$

$$\text{So } n_1 + n_2 = \frac{1}{4} + \frac{1}{4} = \frac{1}{2}$$

$$m_0 = \frac{18\text{kg}}{(1/2)} = 36\text{kg}$$

$$C_{V\text{mix}} = \frac{\frac{1}{4} \times \frac{5}{2} R + \frac{1}{4} \times 3R}{\frac{1}{4} + \frac{1}{4}} = \frac{11}{4} R$$

$$C_{P\text{mix}} = \frac{11}{4} R + R = \frac{15}{4} R$$

$$r = \frac{C_P}{C_V} = \frac{15}{11} = \frac{45}{33} \cong \frac{47}{35}$$

14. B

Average velocity will be same for same temperature.

15. B

$$\frac{P}{V} = \frac{nRT}{V^2}$$

$$\text{so } \frac{T_1}{T_2} = \frac{kv_1^2}{kv_2^2} = \frac{1}{4} \Rightarrow T_2 = 1200\text{K}$$

$$\Delta T = 1200 - 300 = 900\text{K}$$

$$\Delta U = 2 \times \frac{3}{2} R \times 900 = 2700 R$$

16. C,D

As the process is carried out suddenly it may be adiabatic and as the conductivity is good enough then may be isothermal.

17. C,D

In adiabatic process

$$\Delta U \neq 0 \quad \Delta T \neq 0$$

$$PV^\gamma = \text{constant}$$

18. B,C

Slope of $x >$ slope of y

During expansion

$$W_y > W_x$$

$$U_y > U_x \Rightarrow C_{v_2} > C_{v_1} \quad f_2 > f_1$$

Exercise-3

Level-I

1. $t = \frac{d}{v_{\text{avg}}} = \frac{d}{\sqrt{\frac{8RT}{\pi m_0}}}$

$$= \frac{12800 \times 10^3}{\frac{8}{\pi} \times \frac{8.314 \times 300}{32 \times 10^{-3}}} = 28.7236 \times 10^3 \text{sec}$$

2. Momentum = mv

$$mv_{\text{avg}} = m \sqrt{\frac{8RT}{\pi M_0}}$$

$$= 664 \times 10^{-27} \sqrt{\frac{8 \times 8.314 \times 273}{\pi \times (4 \times 10^{-3})}}$$

$$= 8 \times 10^{-24} \text{kgm/sec}$$

3. As average velocity is same.

$$\sqrt{\frac{8RT_H}{\pi M_H}} = \sqrt{\frac{8RT_{He}}{\pi M_{He}}}$$

$$\frac{T_H}{T_{He}} = \frac{M_H}{M_{He}} = \frac{2}{4} = \frac{1}{2}$$

4. $\frac{V_H}{V_N} = \sqrt{\frac{\frac{1}{M_H}}{\frac{1}{M_{N_2}}}} = \sqrt{\frac{1}{\frac{2}{28}}} = \sqrt{14}$

5. $\Delta U = n_0 \frac{f_0}{2} RT + n_{Ar} \frac{f_{Ar}}{2} RT$

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

$$\Delta U = 11 RT$$

6. $V = \text{constant} \Rightarrow \Delta W = 0$

$$\Rightarrow \Delta Q = \Delta U = 12 = \frac{nf}{2} R(\Delta T)$$

$$\Rightarrow 24 = \left(\frac{0.04}{4}\right) 3R(T-100)$$

$$\Rightarrow \frac{800}{R} + 100 = T$$

$$T = 196.22^\circ \text{C}$$

7. $U = n \frac{f}{2} RT = \frac{f}{2} PV$

$\therefore PV = \text{constant}$
so $U = \text{constant}$

8. $U_T = n \frac{f}{2} RT, f = 3, n = 1$

$$U_T = 1 \times \frac{3}{2} R(0 + 273)$$

$$U_T = \frac{3 \times 273}{2} R = 3.40 \times 10^3 \text{ J}$$

9. $VP^2 = \text{constant}$

$$\frac{VT^2}{V^2} = \text{constant}$$

$$\frac{T^2}{V} = \text{constant}$$

$$\frac{T_1^2}{V_1} = \frac{T_2^2}{V_2} \Rightarrow \frac{T^2}{V} = \frac{T_2^2}{2V}$$

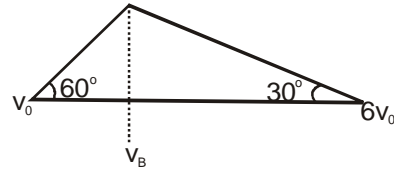
$$T_2 = \sqrt{2} T$$

10. $\frac{V_{\text{rms1}}}{V_{\text{rms2}}} = \sqrt{\frac{T_1}{T_2}} = \sqrt{\frac{P_1 V_1}{P_2 V_2}}$

$\therefore n = \text{constant}$

$$= \sqrt{\frac{10^5 \times 2}{(2 \times 10^5) \times 2}} = \frac{1}{\sqrt{2}}$$

11. $\frac{T_B}{T_A} = \frac{P_B V_B / nR}{P_A V_A / nR} = \frac{3P_0 V_B}{P_0 V_0}$



$$\Rightarrow (V_B - V_0) \tan 60^\circ = (6V_0 - V_B) \tan 30^\circ$$

$$\Rightarrow V_B = \frac{9}{4} V_0$$

So $\frac{T_B}{T_A} = \frac{3 \times 9}{4} = \frac{27}{4}$

12. $\rho_0 = \frac{m}{V_A} = \frac{m}{\left(\frac{nRT_0}{P}\right)} \dots\dots\dots(1)$

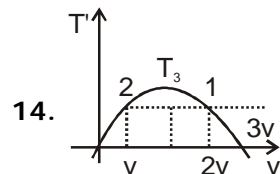
Now $\rho_B = \frac{m}{V_B} = \frac{m}{\left(\frac{nR(2T_0)}{3P}\right)} \dots\dots(2)$

From (1) & (2) $\frac{\rho_B}{\rho_0} = \frac{1}{2/3} \Rightarrow \rho_B = \frac{3}{2} \rho_0$

13. $\frac{V}{T} = \frac{nR}{P} \tan 53^\circ = 4/3$

$$P = \frac{3}{4} nR = \frac{3}{4} \times 2 \times 0.0821 \text{ atm}$$

$$= 1.23 \times 10^4 \text{ Pa}$$



14.

(i) $P_1 < P_2 \quad T_2 > T_1$ for same v

(ii) $P' = \left(\frac{2P - P}{V - 2V}\right) V' + 3P$

$$\Rightarrow \frac{nRT'}{V'} = \frac{-P}{V} V' + 3P$$

$$T' = V' \left(3P - \frac{P}{V} V'\right)$$

15. Then $P_{\text{air}} + 75 = 76$
 $P_{\text{air}} = 1 \text{ cm Hg}$

Now $P_{\text{air}} \times [10 \text{ A}] = P'_{\text{air}} [(10 + 1) \text{ A}]$

$\therefore (T = \text{Constant})$

$$\Rightarrow P'_{\text{air}} = \frac{10}{11} P_{\text{air}}$$

So Actual reading

$$P_T = P_{\text{air}} + 74 = \frac{10}{11} [1 \text{ cm of Hg}] + 74 \text{ Hg}$$

$$P_T = (74 + 0.9) \text{ cm Hg}$$

$$16. W = \int_{V_1}^{V_2} \frac{nR}{\sqrt{V_k}} dv = \frac{2nR}{\sqrt{k}} \frac{(\sqrt{V_2} - \sqrt{V_1})}{1}$$

$$= 2nR(T_2 - T_1)$$

$$W = \int_{V_1}^{V_2} P dv$$

$$\because v = KT^2, v = K \left(\frac{Pv}{nR} \right)^2$$

$$P = \frac{nR}{\sqrt{vk}}$$

$$= 2nR(60) = 120(1) R = 120 R$$

$$17. \Delta W_g = P\Delta V$$

$$= 10^5 \left(\frac{V}{2} - V \right)$$

$$= -10^5 \frac{V}{2} = -\frac{10^5}{2} \times \left(\frac{nRT}{P} \right)$$

$$= -\frac{10^5}{2} \times \frac{1 \times 8.314 \times 360}{105}$$

$$= -180R J$$

$$= -1496.52 J$$

$$\text{So work done on gas} = -\Delta W_g = 1496.52 J$$

$$18. W = P\Delta V$$

$$= (1 \times 10^5) (1.091 - 1) \times (10^{-2})^3$$

$$= 9100 \times 10^{-6} J = 0.0091 J$$

$$19. \Delta W = \text{Area}$$

$$= (2P - P) (2V - V)$$

$$= PV$$

$$20. \Delta W = \text{Area} = -\pi R^2$$

$$= -\pi \left(\frac{30 - 10^2}{2} \right)^2 (K P_a) (U_r)$$

$$= -100 \pi J$$

$$21. \text{Area under the curve} = \Delta W$$

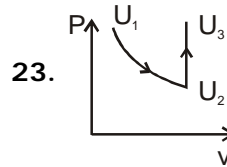
$$\Delta W = \frac{1}{2} [4P_1 - P_1] \times [3V_1 - V_1]$$

$$= 3P_1 V_1$$

$$22. \Delta W = \text{Area of semi circle}$$

$$\frac{1}{2} \pi R^2 = \frac{1}{2} \pi (2 - 1) \left(\frac{3 - 1}{2} \right)$$

$$= \frac{\pi}{2} \text{ atm.lit.}$$



23.

$$U_2 - U_1 = -W \quad \therefore \Delta Q = 0$$

$$W = 0 \quad \therefore V = \text{constant}$$

$$\Delta Q = \Delta U = U_3 - U_2$$

$$\Rightarrow \Delta U = U_3 - U_2 = Q$$

$$\text{Now } (U_3 - U_2) + (U_2 - U_1) = U_3 - U_1$$

$$\Rightarrow Q + (-W) = U_3 - U_1$$

$$\Rightarrow U_3 = Q + U_1 - W$$

$$U_3 - U_1 = Q - W$$

$$24. \Delta U_{acb} = \Delta U_{adb}$$

$$\text{Now } \Delta U_{acb} = \Delta Q_{acb} - \Delta W_{acb}$$

$$\Delta U_{acb} = 200 - 80 = 120 J$$

$$\text{Now } \Delta U_{adb} + \Delta W_{adb} = \Delta Q_{adb}$$

$$\Delta W_{adb} = \Delta Q_{adb} - \Delta U_{adb}$$

$$= \Delta Q_{adb} - \Delta U_{acb}$$

$$\Delta W_{adb} = (144 - 120) = 24 J$$

$$25. \Delta Q = ms\Delta T = 2 \times 4200 \times 4 = 33600 J$$

$$\Delta W = P_a \Delta V = 10^5 \left(\frac{2}{1000} - \frac{2}{999.9} \right)$$

$$= -\frac{200}{9999} \cong -0.02$$

$$\Delta U = \Delta Q - \Delta W$$

$$= (33600 + 0.02) J$$

$$26. \Delta W = \frac{1}{2} \times 100 \times 10^3 \times 200 \times 10^{-6}$$

$$= 10 J$$

$$2.4 \text{ Cal} \times J = 10 J$$

$$J = \frac{10 \text{ J}}{2.4 \text{ Cal}} = \frac{25}{6} \text{ J/Cal}$$

$$27. \Delta W = (0.05 - 0.02) \text{ m}^3 \times (200 \text{ K} - 0)$$

$$= 6 \text{ K Pa m}^3 = 6000 J$$

$$\text{Now } \Delta Q = \Delta U + \Delta W$$

$$2.625 J = (5000 + 6000) J$$

$$J = \frac{11000}{2625} = \frac{88}{21} \text{ J/Cal}$$

28. $\Delta U = \Delta Q - \Delta W$
 $= \Delta Q - 0 \therefore (V \Rightarrow \text{Constant})$

$$\Delta U = \Delta Q$$

$$= 100 \text{ J}$$

29. $\Delta W = 0 \therefore V = \text{Const.}$

$$\Delta Q = \Delta U = n_{\text{He}} \frac{f_{\text{He}}}{2} R\Delta T + n_{\text{N}_2} \frac{f_{\text{N}_2}}{2} R\Delta T$$

$$\Delta Q = \frac{R\Delta T}{2} (n_{\text{He}} f_{\text{He}} + n_{\text{N}_2} f_{\text{N}_2}) \dots\dots (i)$$

Now $v = k\sqrt{T}$

$$v \rightarrow 2v \text{ is } T \rightarrow 4T$$

$$\Rightarrow \Delta T = 4T - T = 3T$$

$$\text{So } \Delta Q = \frac{3RT}{2} [1 \times 3 + 1 \times 5]$$

$$= 12 \times 300 R$$

$$\Rightarrow \Delta Q = 3600 R$$

30. (i) $\Delta Q_T = \Delta W_T$ in cyclic process
 $[5960 + (-5585) + (-2980) + 3645]$
 $= [2200 - 825 - 1100 + W_4]$
 $\Rightarrow W_4 = 765 \text{ J}$

31. (ii) $\eta = \frac{\Delta W_r}{\Delta Q(\text{only the})} \times 100$

$$\left[\frac{2200 - 825 - 1100 + 765}{5960 + 3645} \right] \times 100$$

$$\eta = \frac{104000}{9605} = \frac{208}{1921} \times 100$$

31. $Q = \frac{Q}{2} + \Delta U$

$$\Rightarrow \Delta U = \frac{Q}{2} = \frac{3}{2} \eta R\Delta T$$

$$\Rightarrow Q = 3\eta R\Delta T$$

$$\Rightarrow nC_p \Delta T = 3\eta R\Delta T$$

$$C_p = 3R$$

32. $\Delta W = \int Pdv$

$$= \int_{v_1}^{v_2} kv dv$$

$$= \frac{kv_2^2 - kv_1^2}{2}$$

$$= \frac{p_2 v_2 - p_1 v_1}{2}$$

$$= \frac{nR\Delta T}{2}$$

$$nC_p \Delta T = nC_v \Delta T + nR \frac{\Delta T}{2}$$

$$\Rightarrow C_p = C_v + \frac{R}{2}$$

33. $dW = PdV$

$$dQ = dW + du$$

Molar specific heat capacity is zero.

$$\Rightarrow \Delta Q = 0$$

So adiabatic

$$PV^\gamma = \text{Constant}$$

$$\text{Now } PV^{-\gamma} = a$$

$$= -b = \gamma$$

$$\Rightarrow b = -\gamma$$

34. $\frac{(n_1 + n_2)C'_p \Delta T}{(n_1 + n_2)C'_v \Delta T} = \frac{n_1 C_{p_1} \Delta T + n_2 C_{p_2} \Delta T}{n_1 C_{v_1} \Delta T + n_2 C_{v_2} \Delta T}$

$$\frac{C'_p}{C'_v} = \frac{n_1 \frac{\gamma}{\gamma-1} R + 2n_1 \frac{\gamma}{\gamma-1} R}{n_1 \frac{\gamma}{\gamma-1} R + 2n_1 \frac{\gamma}{\gamma-1} R}$$

$$\frac{C'_p}{C'_v} = \gamma$$

35. $(n_1 + n_2) C_v \Delta T = n_1 C_{v_1} \Delta T + n_2 C_{v_2} \Delta T$

$$C_v = \frac{n_1 C_{v_1} + n_2 C_{v_2}}{n_1 + n_2} = 2R$$

Similarly $C_p = 3R$

$$Y = \frac{C_p}{C_v} = \frac{3R}{2R} = 1.5$$

36. $\frac{(n_1 + n_2)C_p \Delta T}{(n_1 + n_2)C_v \Delta T} = \frac{n_1 C_{p_1} \Delta T + n_2 C_{p_2} \Delta T}{n_1 C_{v_1} \Delta T + n_2 C_{v_2} \Delta T}$

$$\frac{C_p}{C_v} = \frac{\left(\frac{16}{4}\right)\left(\frac{3}{2} + 1\right) + \frac{16}{32}\left(\frac{5}{2} + 1\right)}{\frac{16}{4}\left(\frac{3}{2}\right) + \frac{16}{32}\left(\frac{5}{2}\right)}$$

$$\frac{C_p}{C_v} = \frac{\frac{5}{2} + \frac{7}{2 \times 8}}{\frac{3}{2} + \frac{1}{8} \times \frac{5}{2}} = \frac{47}{29}$$

$$\frac{C_p}{C_v} = \frac{47}{29}$$

37. $\Delta Q = \Delta u + \Delta W = \frac{f}{2}nR\Delta T + nR\Delta T$

$$\Delta Q = \left(1 + \frac{f}{2}\right)nR\Delta T \Rightarrow \frac{2500}{100} = \left(\frac{1+f}{2}\right)R \Rightarrow f = 4$$

$$r = 1 + \frac{2}{f} = \frac{3}{2}$$

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

$$CdT = C_v dT + PdV \dots (1)$$

$$\text{Now } T = T_0 e^{\alpha v}$$

$$dT = T_0 e^{\alpha v} \alpha dv \dots (2)$$

(1) & (2)

$$C = C_v + \frac{P}{T_0 \alpha e^{\alpha v}} = C_v + \frac{P}{\alpha T} \Rightarrow C = C_v + \frac{1}{\alpha} \frac{R}{V}$$

39. $v = m \left(\frac{1}{T}\right)$

$$\Rightarrow VT = \text{Constant.} \Rightarrow TdV + VdT = 0 \dots (1)$$

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

$$CdT = C_v dT + PdV \dots (2)$$

(1) & (2)

$$CdT = C_v dT - \frac{P}{T} VdT$$

$$C = C_v - R = \frac{3}{2}R - R \Rightarrow C = \frac{R}{2}$$

40. $6300 = nC_v \Delta T$

$$6300 = nC_v 150 \dots (1)$$

So $nC_v 300 = \Delta U_f = 2 \times 6300$

$$\Rightarrow \Delta U_f = 12600J$$

41. Given

$$70 = n \left(\frac{f}{2} + 1\right) R \Delta T$$

$$70 = n \frac{f}{2} R \Delta T + nR \Delta T$$

$$\Delta Q_v = n \frac{f}{2} R \Delta T = 70 - 2R(45 - 40)$$

$$= 70 - 10 \left(\frac{8.314}{4.2}\right)$$

$$\approx 50 \text{ cal}$$

42. $\Delta Q = \Delta U + \Delta W$ and $nRT^3 = aP$

$$\frac{nR}{\gamma - 1} dT + PdV \dots (1)$$

$$Pv = nRT \Rightarrow PdV + VdP = nRdT \dots (2)$$

$$v = \frac{a}{T^2} \Rightarrow dv = \frac{-2a}{T^3} dT \dots (3)$$

(1), (2) and (3)

$$dQ = \left(\frac{nR}{\gamma - 1} - \frac{2aP}{T^3}\right) dT = R \Delta T \frac{(3 - 2\gamma)}{\gamma - 1}$$

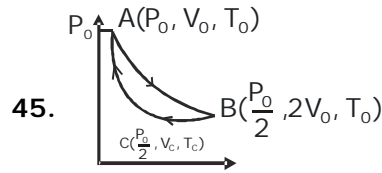
43. $C_p = C_v + R$

$$(0.2M) = (0.15M) + R \text{ \{for per mole\}}$$

$$m = \frac{R}{0.05} = \frac{2}{0.05} = 40 \text{ gm}$$

44. Adiabatic Process

$$P_{\text{atm}} V^\gamma = P_{\text{new}} \left(\frac{V}{4}\right)^\gamma \Rightarrow P_{\text{new}} = P_{\text{atm}} 4^{3/2} = 8P_{\text{atm}}$$



For AC

$$P_0 V_0^\gamma = \frac{P_0}{2} V_c^\gamma \Rightarrow V_c = 2^{1/\gamma} V_0$$

$$\text{Now } T_0 V_0^{\gamma-1} = T_c (2^{1/\gamma} V_0)^{\gamma-1} \Rightarrow T_c = T_0 2^{1-\gamma}$$

$$\Delta W = \left(nRT_0 \ln \frac{2V_0}{V_0}\right) + \frac{P_0}{2} \left(2^{1/\gamma} V_0 - 2V_0\right)_{BC}$$

$$- \frac{nR}{\gamma - 1} (T_0 - T_c)$$

$$\Rightarrow \Delta W = nRT_0 \ln 2 + \frac{nRT_0}{2} \left(2^{1/\gamma} - 2\right)$$

$$- \frac{nRT_0}{\gamma - 1} \left(1 - 2^{-(\gamma-1)/\gamma}\right)$$

$$= nRT_0 \left[\ln 2 + \left(2^{1/\gamma} - 1\right) \frac{-1 - 2^{-\gamma/(\gamma-1)}}{\gamma - 1} \right]$$

$$\text{Now } \Delta Q_{AB} = \Delta W_{AB} \{ \because \Delta U_{AB} = 0 \} = nRT_0 \ln 2$$

$$\text{So } n = \frac{\Delta W}{\Delta Q_{AB}} = 1 - \frac{3\left(1 - \frac{1}{2^{1/\gamma}}\right)}{\ln 2}$$

46. $PV^m = \text{const.}$

$$\Rightarrow V^m dP + mV^{m-1} PdV = 0$$

$$\Rightarrow \frac{dP}{dV} = \frac{-mP}{V} = \tan(180 - 37^\circ)$$

$$\Rightarrow \frac{3}{4} = m \frac{2 \times 10^5}{4 \times 10^5} \Rightarrow m = \frac{3}{2}$$

47. $C\Delta T = \Delta Q \leq 2\Delta U = \frac{2f}{2} R\Delta T$

$C = 5R$

48. $\beta = -\frac{\Delta P}{\Delta V/V} = -V \frac{dP}{dV} \dots\dots(1)$

$VP^n = K$

$\Rightarrow dV \cdot P^n + nP^{n-1}VdP = 0$

$$\Rightarrow \frac{dP}{dV} = \frac{-P}{nV} \dots\dots(2)$$

From 1 & 2

$$\beta = -V \left(\frac{-P}{nV} \right) \Rightarrow \beta = \frac{P}{V}$$

49. Free expansion

So $\Delta W = 0$ and $\Delta Q = 0$

So $\Delta U = 0$

$\Rightarrow T = 300 \text{ K}$

Exercise-3

Level-II

1. upper : U Total volume = V
lower : L F = mg/A

$$U \quad P = \frac{R \times 300}{\frac{4}{5}V} = \frac{1500}{4} \left(\frac{R}{V} \right) = 375 \frac{R}{V} \dots\dots(1)$$

$$L \quad P + F = \frac{R \times 300}{\frac{V}{5}} = 1500 \frac{R}{V} \dots\dots(2)$$

latter $P' = \frac{RT}{\frac{2}{3}V} = \frac{3RT}{2V} \quad U \dots\dots(3)$

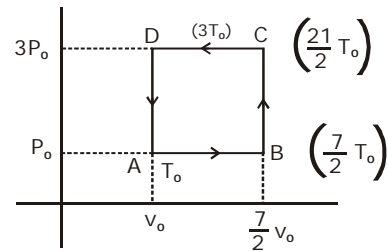
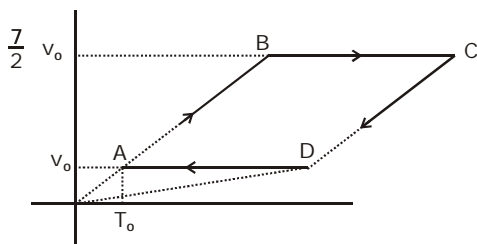
$$P' + F = \frac{RT}{\frac{V}{3}} = \frac{3RT}{2V} \quad L \dots\dots(4)$$

(1) & (2) $F = (1500 - 375) \frac{R}{V} = 1125 \frac{R}{V}$

(4) give $\frac{3RT}{2V} + 1125 \frac{R}{V} = \frac{3RT}{V}$

$1125 + \frac{3T}{2} \Rightarrow T = \frac{1125 \times 2}{3} = 750$

2. $f = 6$ & $C_v = 3R$ & $C_p = 4R$ & $r = \frac{4}{3}$



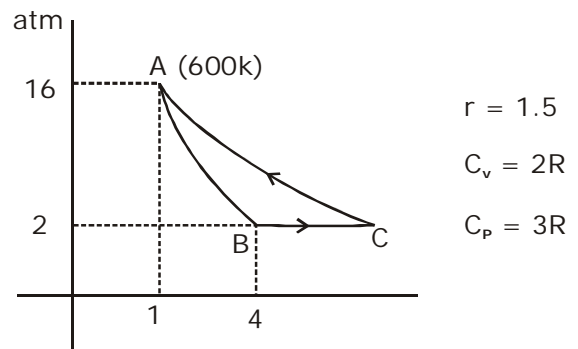
work done = Area = $-(3P_0 - P_0) \left(\frac{7}{2}V_0 - V_0 \right) = -2 P_0 \times 2.5 V_0 = -5 P_0 V_0$
Heat is absorbed in AB & BC

$$U_{AB} = nC_p \Delta T = n \times \frac{8}{2} R \left(\frac{7}{2}T_0 - T_0 \right) = 4nR \times \left(\frac{5}{2}T_0 \right) = 10 nRT_0 = 10 P_0 V_0$$

$$U_{BC} = nC_v \Delta T = n \times 3R \left(\frac{21}{2}T_0 - \frac{7}{2}T_0 \right) = 21 nRT_0 = 21 P_0 V_0$$

Total = Q = $31 P_0 V_0$

3.



(a) AB & adia, more - more negative slope

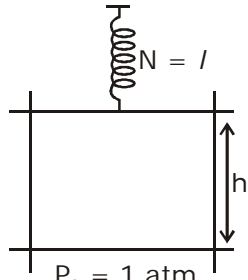
(b) $P_A V_A^\gamma = P_B V_B^\gamma$
 $16 \cdot 16(1)^{3/2} = P_B (4)^{3/2} = 8 P_B$

$P_B = 2$

(c) $T_C = 600 \text{ K}$ and $P_A V_A = P_C V_C$
 $16 \times 1 = 2 \times v_c \Rightarrow v_c = 8$

$T_B = \frac{T_A}{2} = 300 \text{ K}$

(d) $v_c = 8 \text{ litre}$



4.

$P_{ga} = P_0$
 latter resting gas

$= \frac{h}{2} + \frac{h}{16} = \frac{h}{2} + \frac{h}{16} = \frac{9}{16} h$

$F_{sp} = Kx = 3700 \times \frac{h}{16}$

$P_{sp} = \frac{Kx}{A} = \frac{3700 \times h}{16 \times 27 \times 10^{-4}}$

$\Rightarrow P_{sp} = \frac{370}{432} \times 10^5 h$

$P_1 V_1^\gamma = P_2 V_2^\gamma$
 $10^5 \times h^{1.5} =$

$\left[(10^5 + \left(\frac{370}{432} h \times 10^5 \right)) \right] \left(\frac{9}{16} h \right)^{1.5}$

$1 = \frac{432 + 3700h}{432} \times \frac{27}{64}$

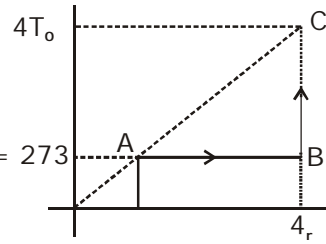
$432 + 370 h = 432 \times \frac{64}{27}$

$370 h = 432 \left(\frac{64}{27} - 1 \right) = 432 \times \frac{37}{27}$

$h_2 = \frac{432}{270} = 1.6 \text{ m}$

& $T_2 = \left(\frac{P_2 V_2}{P_1 V_1} \right) T_1 = 364 \text{ K}$

5.



$n = 2$
 $n = ?$

$u = 27.7 \text{ kJ}$

$u = Q_{AB} + Q_{BC}$

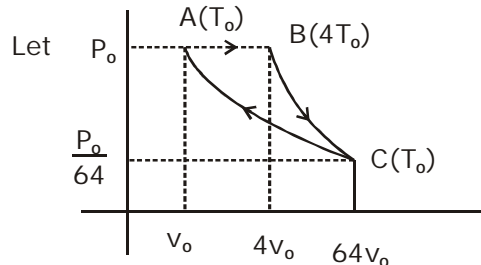
$= nRT_0 \ln \left(\frac{4v}{v} \right) + nC_v (4T_0 - T_0)$

$= 4RT_0 \ln 2 + 6C_v T_0$

$= 4RT_0 \ln 2 + 3fRT_0 = 27700$

$= f = 3.14 \quad \& \quad r = \frac{f+2}{f} = 1.63$

6.



$r = 1.5$
 $R_p = 3R$
 $C_v = 2R$

$P_A V_A = P_C V_C \Rightarrow P_0 V_0 = P_C V_C$
 $P_B V_B^\gamma = P_C V_C^\gamma \Rightarrow P_0 (4V_0)^{1.5} = P_C V_C^{1.5}$

$\frac{(4V_0)^{1.5}}{V_0} = \frac{V_C^{1.5}}{V_C} \Rightarrow 8V_0^{1.5} = V_C^{0.5}$

$V_C = 64V_0$

$\Rightarrow P_0 V_0 = P_C V_C \Rightarrow P_C \times 64 V_0 = P_0 V_0$

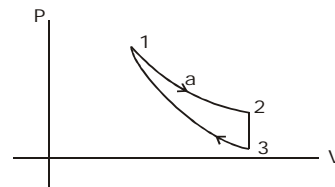
$P_C = P_0 / 64$

$Q_{AB} = nC_p \Delta T = n \times 3R \times (3T_0) = 9 P_0 V_0$

$Q_{CA} = nRT_0 \ln 64 = nRT_0 \ln 2 = 6 P_0 V_0 \ln 2$

$\eta = 1 - \frac{2}{3} \ln 2 = \frac{3 - 2 \ln 2}{3}$

7.



1-2 adiabatic

2-3 isochoric

3-1 isothermal

$Q = mL = 8000 \text{ cal}$

8.

$2mnv^2 \cos^2 \theta$

9.

(a) $W = \text{area under AD}$

$W = \frac{1}{2} (P_A + P_0) (V_0 - V_A)$

$$= \frac{1}{2} (1.6 \times 10^5) (1.1 \times 10^{-3})$$

$$= 0.8 \times 1.1 \times 10^2 = 88$$

(b) $W_{ADC} = W_{AD} + W_{DC}$
 $8 > W_{CD} = -3$

$$3 = \frac{1}{2} (P_B + P_D) (V_D - V_C)$$

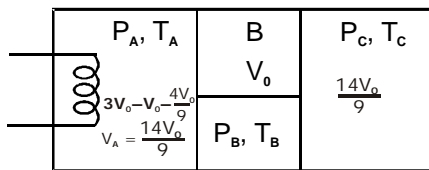
$$= \frac{1}{2} (0.9 \times 10^5) (1.3 - V_C) \times 10^{-3}$$

$$6 = 90 \times (1.3 - V_C)$$

$$V_C = 1.3 - \frac{80}{90} = 1.3 - \frac{1}{15} = 1.223 \text{ l}$$

(c) = -85

10. In final situation



In section C
 $\Delta Q = 0$ (adiabatic)

$$\Rightarrow PV^\gamma = C \quad \Rightarrow \quad P_t = \frac{27}{8} P_0 = P_C$$

Section B is at rest and there is tension in the rod.

$$\Rightarrow P_A = \frac{27}{8} P_0$$

In section A

$$\Rightarrow PV = nRT \quad \Rightarrow \quad \frac{PV}{T} = C$$

$$\frac{27}{8} P_0 \times \frac{14V_0}{9} = \frac{P_0 V_0}{T_0} \quad \Rightarrow \quad T_A = \frac{21}{4} T_0 = T_C$$

For T_C

$$PV = nRT \quad \Rightarrow \quad \frac{PV}{T} = \text{const}$$

$$T_C = \frac{9}{2} T_0$$

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

$\Delta W = (\Delta U)$ in C

(D) Work done by gas in B is zero.

11. When vibration is removed

$$\gamma = 1 + \frac{2}{f} = 1 + \frac{2}{6} = \frac{4}{3}$$

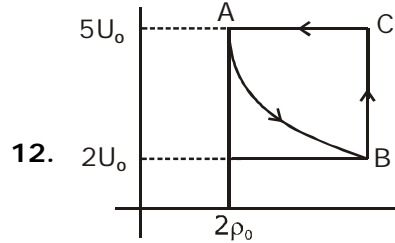
$$\text{and } \gamma' = \frac{\gamma}{1.2} = \frac{4}{3} \times \frac{10}{12} = \frac{10}{9}$$

$$\frac{10}{9} = 1 + \frac{2}{f}$$

$$\frac{2}{f'} = \frac{10}{9} - 1 = \frac{1}{9}$$

$$f' = 18 = 6 + (3n - 6)$$

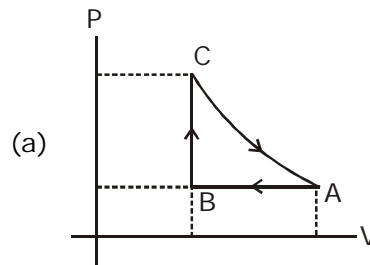
$$3n = 18 \Rightarrow n = 6$$



For BA $UP_0 = \text{constant}$

$$\frac{f}{2} nRT \left(\frac{m}{v} \right) = \text{constant} > \frac{T}{v} = \text{constant}$$

$P = \text{Constant}$



(b) $Q = W(\text{cyclic})$

$$= W_{AB} + W_{BC} + W_{CA}$$

$$= W_{AB} + W_{CA}$$

$$W_{AB} = - \frac{20P_0 U_0}{3M} \times \left(\frac{M}{230} - \frac{M}{530} \right) = -2V_0$$

$$W_{CA} = nRT \ln \frac{V_A}{V_C} = P_A V_A \ln \frac{5}{2} = \frac{10}{3} \ln \frac{5}{2}$$

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

$$\frac{nRT}{V} \times \frac{1}{T} = v \propto T^2$$

when ever $v \propto T^n$

$$C = C_v + nR$$

$$C = C_v + 2R = \frac{3}{2} R + 2R = \frac{7}{2} R$$

(ii) $W = Q - \Delta U$

$$= nC \Delta T - nC_v \Delta T$$

$$= n\Delta T (C - C_v)$$

$$= 2 \times (T_2 - T_1) (2R)$$

$$= 4R (T_2 - T_1)$$

14. $U = a\sqrt{V}$

$$\frac{f}{2} nRT = a\sqrt{V} = T^2 \propto V$$

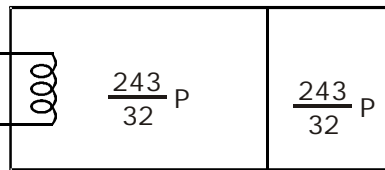
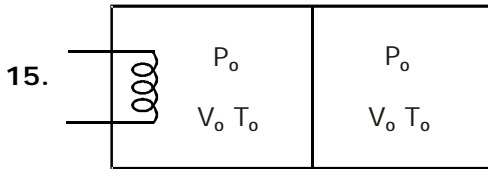
$$C = C_v + nR = \frac{5}{2} R + 2R = \frac{a}{2} R$$

(a) $Q = nC \Delta T$

$$U = nC_v \Delta T$$

$$\frac{Q}{U} = \frac{C}{C_v} = \frac{a/2}{5/2} = \frac{a}{5} \quad U = 180$$

$$w = Q - \Delta U = 803$$



$$P^{1-\gamma} T^\gamma = \text{cons}$$

$$P_0^{-2/3} T_0^{5/3} \left(\frac{243}{32} P_0 \right)^{-2/3} T^{5/3}$$

$$\Rightarrow T = \frac{9}{4} T_0$$

and $PV^\gamma = \text{cons}$

$$P_0 V_0^{5/3} = \left(\frac{243}{32} P_0 \right) V^{5/3}$$

$$\Rightarrow V = \frac{8}{27} V_0$$

$$V_1 = 2V_0 - \frac{8V_0}{27} = \frac{46}{27} V_0$$

$$\left(\frac{PV}{T} \right)_r = \left(\frac{PV}{T} \right)_f$$

$$\Rightarrow \frac{P_0 V_0}{T_0} = \frac{243}{32} P_0 \times \frac{46}{27} V_0$$

$$\Rightarrow T = \frac{207}{16} T_0$$

$$W = \frac{P_1 V_1 - P_2 V_2}{\gamma - 1}$$

$$= \frac{P_0 V_0 - \frac{243}{32} P_0 \times \frac{8}{27} V_0}{\frac{2}{3}} = -\frac{158}{8}$$

Exercise-4

Level-I

1. D

The rms velocity of the molecule of a gas of molecular weight M at temperature T is given by,

$$C_{rms} = \sqrt{\left(\frac{3RT}{M} \right)}$$

Let M_o and M_H are molecular weights of oxygen and hydrogen and T_o and T_H the corresponding kelvin temperatures at which C_{rms} is same for both gases.

That is,

$$C_{rms(o)} = C_{rms(H)}$$

$$\sqrt{\left(\frac{3RT_o}{M_o} \right)} = \sqrt{\left(\frac{3RT_H}{M_H} \right)}$$

Hence,

$$\frac{T_o}{M_o} = \frac{T_H}{M_H}$$

Given, $T_o = 273 + 47 = 320K$

$$M_o 32, \quad M_H = 2$$

$$\therefore T_H = \frac{2}{32} \times 320 = 20K$$

2. C

Using the relation

$$\frac{n_1 + n_2}{\gamma - 1} = \frac{n_1}{\gamma_1 - 1} + \frac{n_2}{\gamma_2 - 1}$$

$$\Rightarrow \frac{1+1}{\gamma - 1} = \frac{1}{(5/3 - 1)} + \frac{1}{(7/5 - 1)}$$

or $\frac{2}{\gamma - 1} = \frac{3}{2} + \frac{5}{2} = 4$

$$\Rightarrow \gamma = \frac{3}{2} = \frac{24}{16}$$

3. A

Efficiency of all reversible cycles depends upon temperature of source and sink which will be different.

4. C

the efficiency of carnot engine is,

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

where, T_1 is the temperature of the source and T_2 that of sink.

Since, $\frac{T_2}{T_1} = \frac{Q_2}{Q_1}$

So, $\eta = 1 - \frac{Q_2}{Q_1}$

To obtain 100% efficiency (ie, $\eta = 1$), Q_2 must be zero that is, if a sink at absolute zero would be available, all the heat taken from the source would have been converted into work.

The temperature on sink means a negative temperature on the absolute scale at which the efficiency of engine is greater than unity. This would be a violation of the 2nd law of thermodynamics. Hence, a negative temperature on the absolute scale is impossible. Hence we cannot reach absolute zero temperature.

5. B

$$T_1 = 627 + 273 = 900\text{K}$$

$$Q_1 = 3 \times 10^6 \text{ cal}$$

$$T_2 = 27 + 273 = 300\text{K}$$

Now, $\frac{Q_1}{T_1} = \frac{Q_2}{T_2}$

or $Q_2 = \frac{T_2}{T_1} \times Q_1$

$$\Rightarrow Q_2 = \frac{300}{900} \times 3 \times 10^6 = 1 \times 10^6 \text{ cal}$$

$$\begin{aligned} \text{Work done} &= Q_1 - Q_2 \\ &= 3 \times 10^6 - 1 \times 10^6 \\ &= 2 \times 10^6 \text{ cal} \\ &= 2 \times 4.2 \times 10^6 \text{ J} \\ &= 8.4 \times 10^6 \text{ J} \end{aligned}$$

6. C

Work does not characterise the thermodynamic state of matter, it is a path function giving only relationship between two quantities.

7. D

Given, $P \propto T^3$... (i)

In an adiabatic process

$$T^\gamma p^{1-\gamma} = \text{constant}$$

$$T \propto \frac{1}{p^{(1-\gamma)/\gamma}}$$

$$T^{\gamma/(1-\gamma)} \propto p \quad \dots \text{(ii)}$$

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

$$\frac{\gamma}{\gamma - 1} = 3$$

or $3\gamma - 3 = \gamma$

or $2\gamma = 3$

or $\frac{C_p}{C_v} = \gamma = \frac{3}{2}$

8. A

Heat cannot flow itself from a body at lower temperature to a body at higher temperature. This corresponds to second law of thermodynamics.

9. A

Mayer's Formula is

$$C_p - C_v = R$$

and $\gamma = \frac{C_p}{C_v}$

Therefore, using above two relations, we find

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

For a mole of monoatomic gas ;

$$\gamma = \frac{5}{3}$$

$$\therefore C_v = \frac{R}{\left(\frac{5}{3}\right) - 1} = \frac{3}{2}R$$

For a mole of diatomic gas ;

$$\gamma = \frac{7}{5}$$

$$\therefore C_v = \frac{R}{\left(\frac{7}{5}\right) - 1} = \frac{5}{2}R$$

When these two moles are mixed, then heat required to raise the temperature to 1°C is

$$C_v = \frac{3}{2}R + \frac{5}{2}R = 4R$$

Hence, for one mole, heat required

$$= \frac{4R}{2} = 2R$$

$$\therefore C_v = 2R$$

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

or $\gamma = \frac{3}{2}$

Alternative

$$\frac{n_1 + n_2}{\gamma - 1} = \frac{n_1}{\gamma_1 - 1} + \frac{n_2}{\gamma_2 - 1}$$

Here, $n_1 = 1, n_2 = 1, \gamma_1 = \frac{5}{3}, \gamma_2 = \frac{7}{5}$

$$\therefore \frac{1+1}{\gamma-1} = \frac{1}{\left(\frac{5}{3}\right)-1} + \frac{1}{\left(\frac{7}{5}\right)-1}$$

$$\Rightarrow \frac{2}{\gamma-1} = \frac{3}{2} + \frac{5}{2}$$

or $\frac{2}{\gamma-1} = \frac{8}{2}$

or $\frac{2}{\gamma-1} = 4$

$$\Rightarrow \gamma = \frac{2}{4} + 1$$

Hence, $\gamma = \frac{3}{2}$

10. B

Internal energy does not change in isothermal process. ΔS can be zero for adiabatic process. Work done in adiabatic process may be non-zero.

11. B

$$C_v = \frac{n_1 C_{v1} + n_2 C_{v2}}{n_1 + n_2}$$

For helium,

$$n_1 = \frac{16}{4} = 4$$

and $\gamma_1 = \frac{5}{3}$

For oxygen,

$$n_2 = \frac{16}{32} = \frac{1}{2}$$

and $\gamma_2 = \frac{7}{5}$

$$C_{v1} = \frac{R}{\gamma_1 - 1} = \frac{R}{\frac{5}{3} - 1} = \frac{3}{2}R$$

$$C_{v2} = \frac{R}{\gamma_2 - 1} = \frac{R}{\frac{7}{5} - 1} = \frac{5}{2}R$$

$$\therefore C_v = \frac{4 \times \frac{3}{2}R + \frac{1}{2} \times \frac{5}{2}R}{4 + \frac{1}{2}}$$

$$= \frac{6R + \frac{5}{4}R}{\frac{9}{2}} = \frac{29R \times 2}{9 \times 4} = \frac{29R}{18}$$

Now, $C_v = \frac{R}{\gamma - 1}$

$$\Rightarrow \gamma - 1 = \frac{R}{C_v}$$

or $\gamma = \frac{R}{C_v} + 1 = \frac{R}{\frac{29}{18}R} + 1$

$$\Rightarrow \frac{C_p}{C_v} = \frac{18}{29} + 1 = \frac{18 + 29}{29} = 1.62$$

12. AC

Statements (a) and (d) are wrong. Concept of entropy is associated with second law of thermodynamics.

13. C

According to the figure

$$Q_1 = T_0 S_0 + \frac{1}{2} T_0 S_0 = \frac{3}{2} T_0 S_0$$

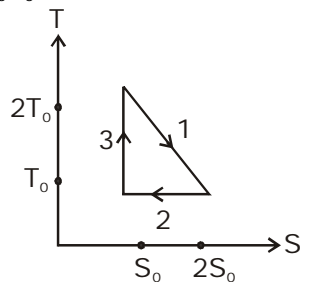
$$Q_2 = T_0 (2S_0 - S_0) = T_0 S_0$$

$$Q_3 = 0$$

$$\therefore \eta = \frac{W}{Q_1}$$

$$= \frac{Q_1 - Q_2}{Q_1}$$

$$= 1 - \frac{Q_2}{Q_1} = 1 - \frac{2}{3} = \frac{1}{3}$$



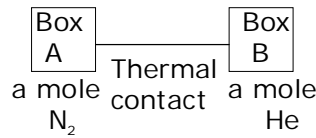
14. A

The change in internal energy does not depend upon path followed by the process. It only depends on initial and final states.

Hence, $\Delta U_1 = \Delta U_2$

15. C

Here, change in internal energy of the system is zero, ie, increase in internal energy of one is equal to decrease in internal energy of other.



$$\Delta U_A = 1 \times \frac{5R}{2} (T_f - T_0)$$

$$\Delta U_B = 1 \times \frac{3R}{2} (T_f - \frac{7}{3} T_0)$$

Now $\Delta U_A + \Delta U_B = 0$

$$T_f = \frac{3}{2} T_0$$

16. A

For adiabatic process,

$$dQ = 0$$

So, $dU = - \Delta W$

$$\Rightarrow nC_v dT = +146 \times 10^3 \text{ J}$$

$$\Rightarrow \frac{nfR}{2} \times 7 = 146 \times 10^3$$

(f → Degree of freedom)

$$\Rightarrow \frac{10^3 \times f \times 8.3 \times 7}{2} = 146 \times 10^3$$

$$f = 5.02 = 5$$

So, it is a diatomic gas.

17. A

According to Mayer's relation

$$C_p - C_v = \frac{R}{m} = \frac{R}{28}$$

18. B

For carnot engine using as refrigerator

$$W = Q_2 \left(\frac{T_1}{T_2} - 1 \right)$$

It is given that, $\eta = \frac{1}{10}$

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

$$\text{or } \frac{T_2}{T_1} = \frac{9}{10}$$

So, $Q_2 = 90 \text{ J}$ (as $W = 10 \text{ J}$)

19. A

As no work is done and system is thermally insulated from surrounding, it means sum of internal energy of gas in two partitions is constant ie, $U = U_1 + U_2$.

Assuming, both gases have same degree of freedom, then

$$U = \frac{f(n_1 + n_2)RT}{2}$$

and $U_1 = \frac{fn_1RT_1}{2}$

$$U_2 = \frac{fn_2RT_2}{2}$$

Solving we get,

$$T = \frac{(p_1V_1 + p_2V_2)T_1T_2}{p_1V_1T_1 + p_2V_2T_2}$$

20. A

From first law of thermodynamics,

$$Q = \Delta U + W$$

For path iaf,

$$50 = \Delta U + 20$$

$$\therefore \Delta U = U_f - U_i = 30 \text{ cal}$$

For path ibf

$$Q = \Delta U + W$$

or $W = Q - \Delta U$

$$= 36 - 30 = 6 \text{ cal}$$

21. B

Thermal energy corresponds to internal energy

Mass = 1 kg

density = 4kg m⁻³

$$\Rightarrow \text{Volume} = \frac{\text{mass}}{\text{density}} = \frac{1}{4} \text{ m}^3$$

Pressure = 8 × 10⁴ Nm⁻²

$$\therefore \text{Internal energy} = \frac{5}{2} P \times V = 5 \times 10^4 \text{ J}$$

22. A

$$\frac{F}{2} n_1 k T_1 + \frac{F}{2} n_2 k T_2 + \frac{F}{2} n_3 k T_3$$

$$= \frac{F}{2} (n_1 + n_2 + n_3) k T$$

$$T = \frac{n_1 T_1 + n_2 T_2 + n_3 T_3}{n_1 + n_2 + n_3}$$

23. D

$$\eta_1 = 1 - \frac{T_2}{T_1} \Rightarrow \frac{1}{6} = 1 - \frac{T_2}{T_1}$$

$$\Rightarrow \frac{T_2}{T_1} = \frac{5}{6} \quad \dots(i)$$

$$\eta_2 = 1 - \frac{T_2 - 62}{T_1}$$

$$\Rightarrow \frac{1}{3} = 1 - \frac{T_2 - 62}{T_1} \quad \dots(ii)$$

On solving Eqs. (i) and (ii)
 $T_1 = 372 \text{ K}$ and $T_2 = 310 \text{ K}$

24. C

As no heat is lost,
 Loss of kinetic energy = gain of internal energy of gas

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

$$\Rightarrow \Delta T = \frac{Mv^2(\gamma - 1)}{2R} \text{ K}$$

25. A

Internal energy of the gas remains constant, hence

$$T_2 = T$$

Using $p_1V_1 = p_2V_2$, $p_2 = \frac{P}{2}$

26. C

Heat required to change the temperature of vessel by a small amount dT

$$-dQ = mC_p dT$$

total heat required

$$-Q = m \int_{20}^4 32 \left(\frac{T}{400} \right)^3 dT$$

$$= \frac{100 \times 10^{-3} \times 32}{(400)^3} \left[\frac{T^4}{4} \right]_{20}^4$$

$$\Rightarrow Q = 0.001996 \text{ kJ}$$

Work done required to maintain the temperature of sink to T_2

$$W = Q_1 - Q_2$$

$$= \frac{Q_1 - Q_2}{Q_2} Q_2$$

$$W = \left(\frac{T_1}{T_2} - 1 \right) Q_2 \Rightarrow W = \left(\frac{T_1 - T_2}{T_2} \right) Q_2$$

For $T_2 = 20 \text{ K}$

$$W_1 = \frac{300 - 20}{20} \times 0.001996 = 0.028 \text{ kJ}$$

For $T_2 = 4 \text{ K}$

$$W_2 = \frac{300 - 4}{4} \times 0.001996 = 0.148 \text{ kJ}$$

As temperature is changing from 20 K to 4 K, work done required will be more than W_1 but less than W_2 .

27. D

According to Newton's law of cooling, rate of fall in temperature is proportional to the difference in temperature of the body with surrounding i.e.

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

$$\Rightarrow \int \frac{d\theta}{\theta - \theta_0} = \int -k dt; \quad \ln(\theta - \theta_0) = kt + C$$

Which is a straight line with negative slope.

28. D

Efficiency, $\eta = 1 - \frac{T_{\text{sink}}}{T_{\text{source}}}$

Now, $0.4 = 1 - \frac{T_{\text{sink}}}{500 \text{ K}}$

$$\Rightarrow T_{\text{sink}} = 0.6 \times 500 \text{ K} = 300 \text{ K}$$

Thus, $0.6 = 1 - \frac{300 \text{ K}}{T'_{\text{source}}}$

$$T'_{\text{source}} = \frac{300 \text{ K}}{0.4} = 750 \text{ K}$$

29. A

Efficiency of a process is defined as the ratio of work done to energy supplied. Here,

$$\eta = \frac{\Delta W}{\Delta Q} = \frac{\text{Area under } p - V \text{ diagram}}{\Delta Q_{AB} + \Delta Q_{BC}}$$

$$\therefore \eta = \frac{P_0 V_0}{nC_V \Delta T_1 + nC_P \Delta T_2}$$

$$= \frac{P_0 V_0}{\frac{3}{2} nR(T_B - T_A) + \frac{5}{2} nR(T_C - T_D)}$$

$$= \frac{P_0 V_0}{\frac{3}{2} (2P_0 V_0 - P_0 V_0) + \frac{5}{4} (4P_0 V_0 - 2P_0 V_0)}$$

$$= \frac{1}{6.5} = 15.4 \%$$

30. A

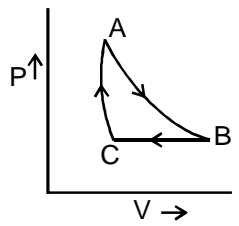
31. A

Exercise-4

Level-II

1. **A**
 $\Delta W_{AB} = P\Delta V = 10(2 - 1) = 10 \text{ J}$
 $\Delta W_{BC} = 0$
 $\Delta Q = \Delta W + \Delta U \quad \{ \Delta U = 0 \}$
 $= \Delta W_{AB} + \Delta W_{BC} + \Delta W_{CA}$
 $\Delta W_{CA} = 5 - (10 + 0) = -5 \text{ J}$
2. **A**
 $\beta = -\frac{dV/dp}{V} = \text{compressibility}$
 $= \frac{1}{\text{coefficient of } p}$
 or $\beta = \frac{1}{p}$ isothermal process
3. $V = 1 \text{ m}^3$ $P = 100 \text{ N/m}^2$
 Let T be the temperature of gas then
 (A) Time between two consecutive collision
 $= \frac{1}{500} \text{ s} \quad \frac{2\ell}{v_{rms}} = \frac{1}{500}$
 $\Rightarrow v_{rms} = 1000 \text{ m/s} \quad \{ \ell = 1 \text{ m} \}$
 $\sqrt{\frac{3RT}{m}} = 1000 \Rightarrow T = \frac{(1000)^2(4 \times 10^{-3})}{3(25/3)} = 160 \text{ K}$
 (B) Avg. Kinetic energy/atom = $\frac{3}{2}kT$
 $= 3.312 \times 10^{-21} \text{ J}$
 (C) $PV = nRT = \frac{m}{M}RT$
 mass of helium gas m
 $= \frac{PVm}{RT} \Rightarrow m = \frac{(100)(1)(M)}{(25/3)(160)} = 0.3 \text{ g}$

4. **A**
 AB is isothermal compression and BC is isobaric.



5. The kinetic energy of atoms goes into increasing the temperature.
 $\frac{1}{2}mv_0^2 = nC_v\Delta T = \frac{m}{M}\left(\frac{3}{2}R\right)\Delta T$
 $\Delta T = \frac{MV_0^2}{3R}$

6. **C**
-
- $w_{AB} = +ve ; \quad W_{BC} = -ve$

$|w_{BC}| > |w_{AB}|$
 Hence $W_{AB} + W_{BC} = w < 0$
 from graph $P_3 > P_1$

7. At constant Pressure $V \propto T$
 $\frac{Ah_2}{Ah_1} = \frac{T_2}{T_1}$
 $h_2 = (100)\left(\frac{400}{300}\right) = \frac{4}{3} \text{ m}$
 Adiabatic $T_f V_f^{v-1} = T_i V_i^{v-1}$
 $T_f = (400)\left(\frac{4}{3}\right)^{1.4-1} \quad T_f = (400)\left(\frac{4}{3}\right)^{0.4} = 448.8 \text{ k}$

8. **C**
 $\Delta u = 1 \times 1 \times 100 \times 5 \times 60 = 30000$
 $\Delta u = \frac{30000}{1000} = 30 \text{ kJ}$

9. **A**
 $\beta = \frac{\Delta p}{\frac{\Delta v}{v}}$
 $= \frac{.155 \times 10^5}{\frac{.1v}{v}} = 1.55 \times 10^5$

10. (A) $\Delta T = \frac{\Delta Q}{ms} = \frac{20,000}{1 \times 400} = 50^\circ \text{C}$
 $T_f = 20 + 50^\circ = 70^\circ \text{C}$
 (B) $\Delta V = \gamma V \Delta T = (9 \times 10^{-5}) \left(\frac{1}{9000}\right)(50)$
 $= 5 \times 10^{-7} \text{ m}^3$
 $w = P\Delta V = (10^5)(5 \times 10^{-7}) = 0.05 \text{ J}$
 (C) $\Delta U = \Delta Q - W = (2000 - 0.05) \text{ J} = 1999.95 \text{ J}$

11. Process $J \rightarrow K$
 (A) $V = \text{constant}$ $P \downarrow$ $T \downarrow$
 $W = 0$, $\Delta U = -ve$ and $Q < 0$
 (B) Process $K \rightarrow L$
 $P = \text{const.}$ $V \uparrow$ $T \uparrow$ $W > 0$
 $\Delta U > 0$ and $Q > 0$
 (C) In process $L \rightarrow M$
 $W = \Delta U > 0$ and $Q > 0$
 (D) Process $M \rightarrow J$

$$V \downarrow \quad w < 0$$

$$(PV)_J < (PV)_M \Rightarrow T_J < T_M$$

$$\Delta U < 0 \quad Q < 0$$

12. A

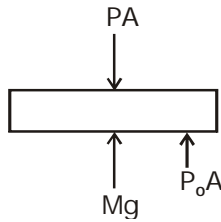
Since it is open from top pressure will be P_0 .

13. D

Let P be the pressure in equilibrium

Then $PA = P_0A - Mg$

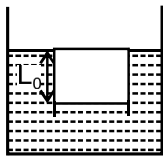
$$P = P_0 - \frac{Mg}{A}$$



$$P_0(2AL) = P(AL') \quad \{ \text{using } P_1V_1 = P_2V_2 \}$$

$$L' = \frac{2P_0L}{P} = \left[\frac{P_0}{P_0 - \frac{mg}{\pi R^2}} \right] (2L)$$

14. C



$$P_1 = P_2$$

$$P_0 + \rho g (L_0 - H) = P \quad \dots (i)$$

$$\text{Now apply } P_1V_1 = P_2V_2$$

$$P_0L_0 = P(L_0 - H) \quad P = \frac{P_0L_0}{L_0 - H}$$

$$P_0 + \rho g (L_0 - H) = \frac{P_0L_0}{L_0 - H}$$

$$\Rightarrow \rho g (L_0 - H)^2 + P_0 (L_0 - H) - P_0L_0 = 0$$

15. B

$$PV = \frac{1}{3} mN\bar{v}^2$$

$$PV = \frac{2}{3} \{N(1/2 m\bar{v}^2)\} = \frac{2}{3} \{ \text{total K.E.} \}$$

$$\Rightarrow \text{K.E.} = \left(\frac{3}{2} \right) PV$$

Statement 1 is correct

Statement 2 is correct but not the correct explanation of statement - 1.

16. C

$$PT^2 = \text{constant} \Rightarrow \frac{nRT}{V} T^2 = \text{constant}$$

$T^3 V^{-1} = \text{constant}$
on differentiating

$$\frac{3T^2}{V} dT - \frac{T^3}{V^2} dV = 0$$

$$3T dT = \frac{T^2}{V} dV$$

$$\text{we know } \gamma = \frac{dV}{VdT} = \frac{3}{T} \text{ ans. C}$$

17. (A) Free expansion $W = 0, \Delta U = 0$.
(B) $PV^2 = c, PV = nRT, Q = n C \Delta T$, for polytropic process, $PV^x = \text{constant}, C =$

$$C_v + \frac{R}{1-x}$$

(C) $Q = n C \Delta T$, for polytropic process, $PV^x =$

$$\text{constant}, C = C_v + \frac{R}{1-x}$$

(D) $T = \frac{PV}{nR}, \Delta U = +ve, W = +ve$.

A-Q, B-P, R, C-P, S, D-Q, S

18. B, D

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

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

19. B, D

In BCD $\Delta W < 0 \Rightarrow \Delta Q_1 < 0$

$\Delta U < 0$

In ABC, $\Delta W = \text{Area of semicircular} \neq 0$

For ABCDA, $\Delta W = \text{Area within curve} > 0$

20. **A-P, Q, S, T, B-Q, C-S, D-S**

21. D

Pressure is low and temperature is high

22. A, B

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

$$W_{AB} = nRT \ln \frac{V_f}{V_i} = nRT \ln 4 = P_0 V_0 \ln 4$$

If in BC $V \propto T$

$$\text{so } \frac{T_B}{T_C} = \frac{V_B}{V_C} \Rightarrow \frac{T_0}{T_C} = \frac{4V_0}{V_0}$$

$$\Rightarrow T_C = \frac{T_0}{4} \quad PV = nRT$$

$$\text{at A } P_0 V_0 = nRT_0$$

$$\text{at C } P_C V_0 = nR \frac{T_0}{4} \Rightarrow P_C = \frac{P_0}{4}$$

23. $PV^\gamma = PV^{5/7} = \text{constant}$

$$\frac{nRT}{V} \cdot V^{7/5} = \text{constant}$$

$$TV^{\frac{2}{5}} = \text{constant} \quad T_1 V_1^{\frac{2}{5}} = a T_1 \left(\frac{V}{32}\right)^{\frac{2}{5}}$$

$$T_1 V_1^{\frac{2}{5}} = \frac{a T_1 V^{\frac{2}{5}}}{4} \quad \boxed{a = 4}$$

24. A

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

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

$$T_1 V_1^{2/3} = T_2 V_2^{2/3}$$

$$T_1 (5.6)^{\frac{2}{3}} = T_2 (0.7)^{\frac{2}{3}}$$

$$T_2 = T_1 (8)^{\frac{2}{3}} = 4T_1$$

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

$$= \frac{5.6}{22.4} \times R(T_1 - 4T_1) = \frac{2}{3}$$

$$= \frac{1}{4} \times R \times (-3T_1) = \frac{-9}{8} RT_1$$

25. A → p, t, r ; B → p, r ; C → q, s ; D → r, t

(A) A → B

Volume and temperature both decrease so internal energy decreases and work is done

on gas and
 $Q = \Delta U + W = -ve$
 Hence heat is lost.

(B) $W = 0$; Temperature decreases so internal energy of the system decreases.

$W = 0$
 $Q = \Delta U + W = +ve$
 Hence heat is gained.

(C) C → D
 $P = \text{constant}$ hence Temperature increases

$\Delta U = +ve$
 $Q = nC_p \Delta T = +ve$
 Hence heat is gained.

(D) D → A

$T_D = T_A$
 $\Delta U = 0$
 $W = -ve$
 $Q = \Delta U + W = -ve$
 Hence heat is lost.

26. D

$$v_{\text{rms}} = \sqrt{\frac{3RT}{M}}$$

$$\frac{v_{\text{He}}}{v_{\text{Ar}}} = \sqrt{\frac{M_{\text{Ar}}}{M_{\text{He}}}} = \sqrt{\frac{40}{4}} = \sqrt{10} = 3.16$$

27. D

$$Q = nC_p \Delta T = 2 \times \frac{5}{2} \times R \times 5 = 208 \text{ J}$$