MAIN+ADVANCED

TOPIC

HEAT &
THERMODYANICS

SOLUTIONS

HEAT & THERMODYNAMICS

Exercise-1

1. A
From the formula

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

$$\sqrt{\frac{3R\ T_{o_2}}{M_{o_2}}} = \sqrt{\frac{3R\,T_{N_2}}{M_{N_2}}}$$

$$T_{o_2} = \frac{M_{o_2}}{M_{n_2}}.T_{N_2}$$

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

2. C
From the formula

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

$$V_{rms_{o_2}} = \sqrt{\frac{3RT_{o_2}}{M_{o_2}}}$$

$$V_{rmso} = \sqrt{\frac{3RT_{o_2} \times 2}{M_{o_2}/2}} = 2\sqrt{\frac{3RT_{o_2}}{M_{o_2}}} = 2V$$

3. B
The average velocity is given as

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

Independent of other gases. Hence average velocity of oxigen in third container will be V_1 only.
= 7.66 u

4. D

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

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

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

5. A

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

a straight line with positive slope.

7. C
PT = constant

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

P^2V= constant. Therefore the graph C is suitable.

8. A
From the graph shown.

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

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

$\sqrt{V_oP_o} : \sqrt{V_o.4P_o} : \sqrt{4V_oP_o}$

1 : 2 : 2

9. A

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

$PV = nRT$

$$n = \frac{PV}{RT} = \frac{1.3\times10^5 \times \left[7\times\left(10^{-2}\right)^3 \times 10^3\right]}{8.3\times273}$$

So, Number of molecules is

$$= \frac{1.3\times10^5 \times 7\times10^{-3}}{8.3\times273}\times 6.023\times10^{23}$$

$= 2.4\times10^{23}$

12. A

From the graph shown

$$P - 2P_0 = \frac{-P_0V}{V_0} + P_0$$

$$P = \frac{-P_0V}{V_0} + 3P_0$$

$$\frac{-2P_0V}{V_0} + 3P_0 = nR\frac{dT}{dV}$$

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

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

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

$$P = \frac{-P_0V}{2V_0} + \frac{3P_0}{2}$$

Now we know PV = nRT

$$\Rightarrow \left(\frac{3}{2}P_0 - \frac{P_0V}{2V_0}\right)V = nRT$$

For maximum temperature

$$\frac{dT}{dV} = 0 \Rightarrow \frac{3}{2}P_0 - \frac{P_0V}{V_0} = 0$$

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

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

$$= \frac{3}{4}P_0\cdot\frac{3}{2}V_0\cdot\frac{1}{R} = \frac{9P_0V_0}{8R}$$

14. B

Initially

$$PV_1 = \frac{12}{M}RT_1$$

or

$$P\left(4\times10^{-3}\right) = \frac{12}{M}R\left(273+7\right) \quad \text{..... (1)}$$

$$\rho = \frac{m}{V_2} = \frac{12}{V_2} = 6\times10^{-4}\ \text{gm/cc}$$

$$P\left(\frac{12}{6\times10^{-4}}\right)\times\left(10^{-2}\right)^3 = \frac{12}{M}R(T) \quad \text{..... (2)}$$

from $1 \div 2$

$$\frac{4\times10^{-3}}{12\times10^{-6}}\times6\times10^{-4} = \frac{273+7}{T} \Rightarrow T = 1400\,K$$

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

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

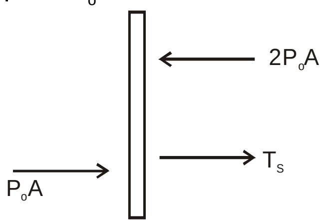
16. C

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

V = const.

T = doubled

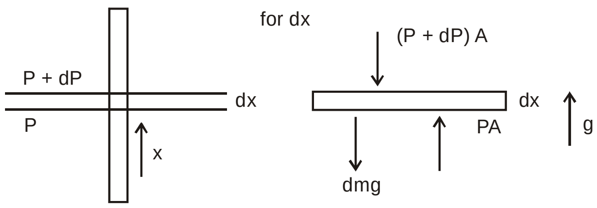
$p = 2P_o$



$$\Rightarrow T_S + P_oA = 2P_oA$$

$$T_S = P_oA$$

17. C



PA – dmg – (P + dP) A = dmg

– AdP = 2dmg

– AdP = 2ρ A dx g

$-\,dP = 2\rho\, g\, dx$. Where $\rho = \dfrac{m}{V}$

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

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

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

$-\,dP = \dfrac{2PM}{RT}.g.dx$

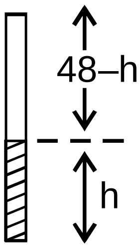
$-\int_{P_o}^{P'_o} dP/P = \dfrac{2Mg}{RT}\int_{o}^{x=H/2} dx$

$\ln\dfrac{P_0}{P_0'} = \dfrac{2Mg}{RT}.\dfrac{H}{2} \Rightarrow \qquad \dfrac{P_0}{P_0'} = e^{MgH/RT}$

18. C

In the final condition.

Let atmospheric pressure is P and ht of liquid column is h.



$P + h = 76$

$P_1V_1 = P_2V_2$

$76 \times 5 = P(43 - h)$

380 = (76 – h) (43 – h)

h = 38 cm

So, 48 - h = 10 cm = 0.1 m.

19. A

P + 50 = 75

P = 25 cm of H_g

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

= 33.3 kPa

20. B

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

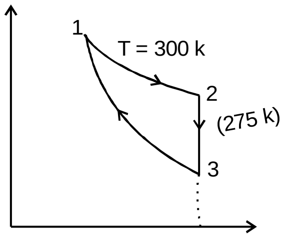
$= a\left[\dfrac{V^3}{3}\right]_{V_1}^{V_2} = \dfrac{a}{3}\left(V_2^3 - V_1^3\right)$

$= \dfrac{1}{3}\left[P_2V_2 - P_1V_1\right]$

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

21. A

22. A



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

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

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

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

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

$\Delta Q_T = \Delta W_T$

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

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

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

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

23. B

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

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

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

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

24. D

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

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

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

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

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

25. D

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

$= 200 - 80 = 120\,J$

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

$= 144 - 120 = 24\,J$

26. B

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

$= -52\,J - 120\,J$

$= 172\,J$

27. D

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

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

28. B

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

$= U_b - U_d$

$= 160 - 88 = 72\,J$

29. B

For AB

$\Delta U = 0 \qquad (T = const.)$

$\Delta W = nRT\ \ell n \frac{V_2}{V_1} = nRT\,\ell n \frac{P_1}{P_2}$

= negative ($\because P_1 < P_2$)

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

(Heat is rejected)

For BC $\because T \downarrow \qquad \therefore U \downarrow$

30. A

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

$= 4\Delta W$

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

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

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

$= \frac{n_1m_1 + n_2m_2}{(n_1 + n_2)} = \frac{(5\times4) + (2\times2)}{(5+2)} = \frac{24}{7}$

33. A

He - monoatomic H_2 - diatomic

f = 3 f = 5

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

$= \frac{3\times5 + 5\times2}{(5+2)} = 3.57$ Ans.

34. C

$\gamma = C_p/C_v = [1 + 2/f]$

$= [1 + 2/3.57] = 1.56$ Ans.

35. A

V/T = const. P - 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^γ = 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

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

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

$\Delta U = 12600$

38. A

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

$= \frac{KV_2^{\,2} - KV_1^{\,2}}{2} = \frac{P_2V_2 - P_1V_1}{2}$

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

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

39. D

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

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

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

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

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

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

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

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

From (1) and (2)

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

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

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

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

$\gamma_B > \gamma_A \Rightarrow$ B is monoatomic
Gas A is diatomic

43. B

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

For Isobaric process $V_1 \to T_1 = \frac{P_1V_1}{nR}$

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

$$\Rightarrow \Delta U_P = \frac{nfR}{2}\left[\frac{T_1}{2}\right] \text{ \_\_\_\_\_\_\_\_(1)}$$

Isothermal $\Delta U_T = 0$ ________(2)

Adiabatic $PV^\gamma = K$

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

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

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

$$\Delta U_{Adiabatic} = n\frac{F}{2}R\left[2^{\gamma-1}\right]\frac{T_1}{2}$$

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

44. A

Free Expansion

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

and $P_1V_1 = P_2(2V_1)$

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

45. D

Ist Process

$$\Delta U_1 = \Delta Q_1 - \Delta W_1$$
$$= 16 - 20 = -4\,KJ$$

IInd Process

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

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

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

46. A

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

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

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

$$= 300\sqrt{2}$$

Exercise-2

1. D

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

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

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

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

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

3. A,B,C

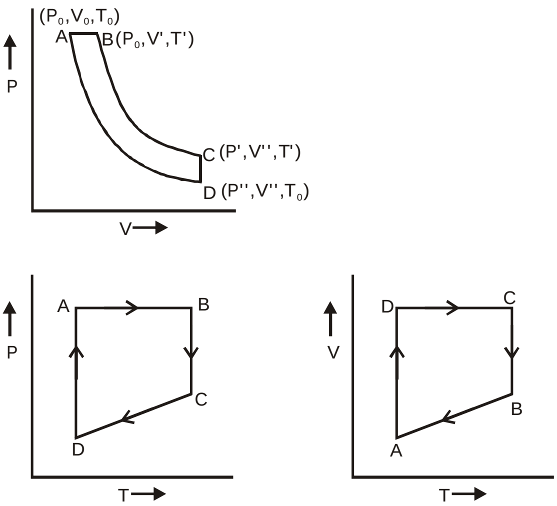
Avg. momentum/mol $\propto \sum V_x^2$

$\sum V_x^2$ is same at NTP

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

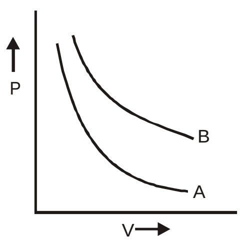
$(K.E.)/vol. \propto T$

4. A,B



5. C

PV = Const
Slope of B > slope of A
$n_B > n_A$
$m_B > m_A$



6. A,D

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

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

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

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

$P_2 = \rho_2 T_2 R/W$

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

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

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

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

9. B,D

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

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

$v_f = \eta v_0 \quad W_{gas} = RT_0 \ell n\eta$
$W_{atm} = pdv = pv(\eta - 1) = RT_0(\eta - 1)$
At constant temperature $\Delta U = 0$

9. B,D

$\Delta W_A = P_1 \Delta V$
$\Delta W_D = P_2\Delta V \ \{P_1 > P_2\}$
$\Delta Q_A = \Delta U_A + \Delta W_A$
$\Delta Q_D = \Delta U_D + \Delta W_D$
$\Delta Q_A - \Delta Q_D = \Delta U_A - \Delta U_D + \Delta W_A - \Delta W_D$
$\Delta Q_A - \Delta Q_D = \Delta W_A - \Delta W_D$
$\{\therefore \Delta U_A = \Delta U_D$
$Q_A > Q_D$

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

$W_C = k\ell n\frac{v_2}{v_1}$

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

10. D

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

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

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

$\Delta Q_1 - \Delta Q_2 = \Delta U_1 - \Delta U_2$
$\Delta U_2 + \Delta W_2 > \Delta U_1 + \Delta W_1$

11. A

PV = nRT Along AB $V\downarrow$ $T\downarrow$

Along BC $P\uparrow$ $T\uparrow$

Along CA $\frac{p}{(1/v)}$ = const U = const

$$w = \int P dv = \int \frac{k dv}{v} = k\,\ell n(v_i / v_f) = -ve$$

12. A,B

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

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

$\Delta T = 1$

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

The gas must be monoatomic.

13. A,D

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

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

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

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

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

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

14. B

Average velocity will be same for same temperature.

15. B

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

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

$\Delta T = 1200 - 300 = 900$ K

$\Delta U = 2 \times 3/2\, R \times 900 = 2700\, R$

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

$\Delta U \neq 0 \qquad \Delta T \neq 0$

PV^γ = constant

18. B,C

Slope of × > slope of y

During expansion

$W_y > W_x$

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

Exercise-3 Level-I

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

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

2. Momentum = mv

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

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

$= 8 \times 10^{-24}$ 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. $$\frac{V_H}{V_N} = \sqrt{\frac{\frac{1}{M_H}}{\frac{1}{M_{N_2}}}} = \sqrt{\frac{\frac{1}{2}}{\frac{1}{28}}} = \sqrt{14}$$

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

$$= [2\times5+4\times3]\frac{RT}{2}$$

$\Delta U = 11\ RT$

6. V = constant $\Rightarrow \Delta W = 0$

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

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

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

$T = 196.22^0\ C$

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

$\therefore$ PV = constant

so U = constant

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

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

$$U_T = \frac{3\times273}{2}R = 3.40\times10^3 J$$

9. VP^2 = constant

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

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

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

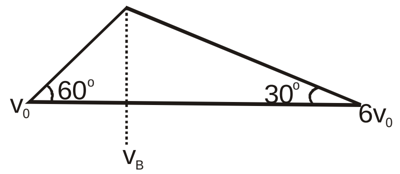
$T_2 = \sqrt{2}T$

10. $\frac{V_{rms1}}{V_{rms2}} = \sqrt{\frac{T_1}{T_2}} = \sqrt{\frac{P_1v_1}{P_2v_2}}$

$\therefore$ n = constant

$$= \sqrt{\frac{10^5\times2}{(2\times10^5)\times2}} = \frac{1}{\sqrt{2}}$$

11. $\frac{T_B}{T_A} = \frac{P_BV_B/nR}{P_AV_A/nR} = \frac{3P_0V_B}{P_0V_0}$



$\Rightarrow (V_B - V_0)\tan 60^0 = (6\ V_0 - V_B)\tan 30°$

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

So $\frac{T_B}{T_A} = \frac{3\times9}{4} = \frac{27}{4}$

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

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

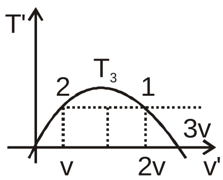
From (1) & (2) $\frac{\rho_B}{\rho_0} = \frac{1}{2/3} \Rightarrow \rho_B = \frac{3}{2}\rho_0$

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

$$P = \frac{3}{4}nR = \frac{3}{4}\times2\times0.0821\ \text{atm}$$

$= 1.23\times10^4$ Pa

14.



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

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

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

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

15. Then $P_{air} + 75 = 76$

$P_{air} = 1$ cm Hg

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

$\because$ (T = Constant)

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

So Actual reading

$P_T = P'_{air} + 74 = \frac{10}{11}[1\,\text{cm of Hg}] + 74\,\text{Hg}$

P_T = (74 + 0.9) cm Hg

16. $W = \int_{v_1}^{v_2} \frac{nR}{\sqrt{Vk}}\,dv = \frac{2nR}{\sqrt{K}} \frac{\left(\sqrt{V_2} - \sqrt{V_1}\right)}{1}$

$= 2nR(T_2 - T_1)$

$$W = \int_{v_1}^{v_2} Pdv$$

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

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

= 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

So work done on gas = $-\Delta W_g$

= 1496.52 J

18. W = $P\Delta V$

= (1×10^5) (1.091–1) × $(10^{-2})^3$

= 9100 × 10^{-6} J = 0.0091 J

19. ΔW = Area

= (2P – P) (2V – V)

= PV

20. ΔW = Area = $-\pi R^2$

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

= – 100 πJ

21. Area under the curve = ΔW

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

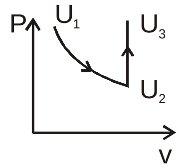
= $3P_1 V_1$

22. ΔW = Area of semi circle

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

$= \frac{\pi}{2}$ atm lt.

23.



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

W = 0 $\quad\therefore$ V = constant

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

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

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

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

ΔU_{acb} = 200 – 80 = 120 J

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

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

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

ΔW_{adb} = (144 – 120) = 24 J

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

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

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

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

= (133600 + 0.02) J

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

= 10 J

2.4 Cal × J = 10 J

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

27. ΔW = (0.05 – 0.02) m^3 × (200 K – 0) Pa

= 6K Pa m^3 = 6000 J

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

2.625 J = (5000 + 6000) J

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

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

$= \Delta Q - 0 \quad \therefore$ (V $\Rightarrow$ Constant)

$\Delta U = \Delta Q$

= 100 J

29. $\Delta W = 0 \quad \therefore$ V = Const.

$$\Delta Q = \Delta U = n_{He}\frac{f_{He}}{2} R\Delta T + n_{N_2}\frac{f_{N_2}}{2} R\Delta T$$

$$\Delta Q = \frac{R\Delta T}{2}\left(n_{He} f_{He} + n_{N_2} f_{N_2}\right) \text{ ...... (i)}$$

Now $v = k\sqrt{T}$

$v \rightarrow 2v$ is $T \rightarrow 4T$

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

So $\Delta Q = \frac{3RT}{2}[1\times3+1\times5]$

= 12 × 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]

$\Rightarrow W_4 = 765$ J

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

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

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

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. $\Delta W = \int Pdv$

$$= \int_{v_1}^{v_2} kvdv$$

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

$$= \frac{p_2v_2 - p_1v_1}{2}$$

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

$$nc_P\Delta T = nc_v\Delta T + nR\frac{\Delta T}{2}$$

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

33. dW = PdV

dQ = dW + du

Molar specific heat capacity is zero.

$\Rightarrow \Delta Q = 0$

So adiabatic

PV^r = Constant

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

$= -b = \gamma$

$\Rightarrow b = -\gamma$

34. $\frac{(n_1+n_2)C'_p\Delta T}{(n_1+n_2)C'_V\Delta T} = \frac{n_1C_{P_1}\Delta T + n_2C_{P_2}\Delta T}{n_1C_{V_1}\Delta T + n_2C_{V_2}\Delta T}$

$$\frac{C'_P}{C'_V} = \frac{n_1\frac{\gamma}{\gamma-1}R + 2n_1\frac{\gamma}{\gamma-1}R}{n_1\frac{\gamma}{\gamma-1}R + 2n_1\frac{\gamma}{\gamma-1}R}$$

$$\frac{C'_P}{C'_V} = \gamma$$

35. $(n_1 + n_2)C_V\Delta T = n_1C_{V_1}\Delta T + n_2C_{V_2}\Delta T$

$$C_V = \frac{n_1C_{V_1} + n_2C_{V_2}}{n_1 + n_2} = 2R$$

Similarly $C_P = 3R$

$$Y = \frac{C_P}{C_V} = \frac{3R}{2R} = 1.5$$

36. $\frac{(n_1+n_2)C_P\Delta T}{(n_1+n_2)C_V\Delta T} = \frac{n_1C_{P_1}\Delta T + n_2C_{P_2}\Delta T}{n_1C_{V_1}\Delta T + n_2C_{V_2}\Delta T}$

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

$$\frac{C_P}{C_V} = \frac{\frac{5}{2} + \frac{7}{2\times8}}{\frac{3}{2} + \frac{1}{8}\times\frac{5}{2}} = \frac{47}{29}$$

$$\frac{C_P}{C_V} = \frac{47}{29}$$

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

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

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

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

$CdT = C_V\, dT + PdV$ ....(1)

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

$dT = T_0\, e^{\alpha v}\, \alpha dv$ ....(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. $V = m\left(\frac{1}{T}\right)$

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

$\Delta Q = \Delta V + \Delta W$

$CdT = C_v dT + PdV$ ....(2)

(1) & (2)

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

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

40. $6300 = nC_v\Delta T$

$6300 = nC_v\, 150$..........(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 $nRT^3 = aP$

$$\frac{nR}{\gamma-1}dT + Pdv \qquad .....(1)$$

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

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

(1), (2) and (3)

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

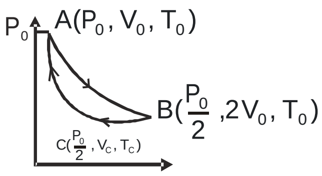
43. $C_P = C_V + R$

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

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

44. Adiabatic Process

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

45. 

For AC

$$P_0V_0^\gamma = \frac{P_0}{2}V_C^\gamma \Rightarrow V_C = 2^{1/\gamma}V_0$$

Now $T_0V_0^{\gamma-1} = T_C(2^{1/\gamma}V_0)^{\gamma-1} \Rightarrow T_C = T_0 2^{\frac{1-\gamma}{\gamma}}$

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

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

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

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

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

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

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

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

$\Rightarrow V^m dP + mv^{m-1}P\,dv = 0$

$$\Rightarrow \frac{dP}{dV} = \frac{-mP}{V} = \tan(180-37^0)$$

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

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

$C = 5R$

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

$VP^n = K$

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

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

From 1 & 2

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

49. Free expansion

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

So $\Delta U = 0$

$\Rightarrow T = 300$ K

Exercise-3 Level-II

1. upper : U Total volume = V

lower : L F = mg/A

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

$= 375\ \frac{R}{V}$ ......(1)

L $P + F = \frac{R \times 300}{\frac{v}{5}}$

$= 1500\ \frac{R}{V}$ ......(2)

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

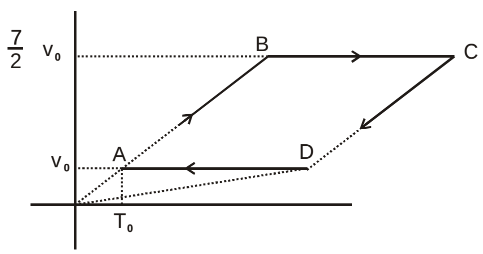
$P' + F = \frac{RT}{\frac{V}{3}} = \frac{3RT}{2V}$ L ......(4)

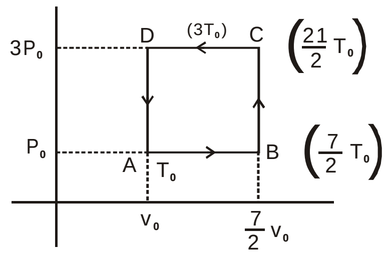
(1) & (2) $F = (1500 - 375)\ \frac{R}{V} = 1125\ \frac{R}{V}$

(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 = $-(3P_0 - P_0)\left(\frac{7}{2}V_0 - V_0\right)$

$= -2\ P_0 \times 2.5\ V_0$ - $= -5\ P_0V_0$

Heat is absorbed in AB & BC

$U_{AB} = nC_p\ \Delta T = n \times \frac{8}{2}\ R\left(\frac{7}{2}T_0 - T_0\right)$

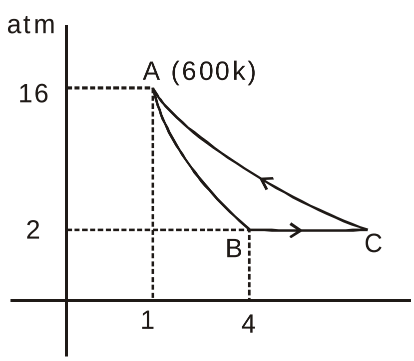
$= 4nR \times \left(\frac{5}{2}T_0\right) = 10\ nRT_0 = 10\ P_0V_0$

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

$= 21\ n\ RT_0 = 21\ P_0V_0$

Total $= Q = 31\ P_0V_0$

3.



$r = 1.5$

$C_v = 2R$

$C_P = 3R$

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

(b) $P_A V_A^r = P_B V_B^r$
$16 \quad 16(1)^{3/2} = P_B (4)^{3/2} = 8 P_8$

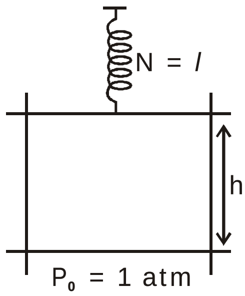
$\boxed{P_B = 2}$

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

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

(d) v_c = 8 litre

4.



$P_{ga} = P_0$
latter resting gas

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

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

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

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

$P_1 v_1^{\gamma} = P_2 v_2^{\gamma}$
$10^5 \times h^{1.5}$ =

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

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

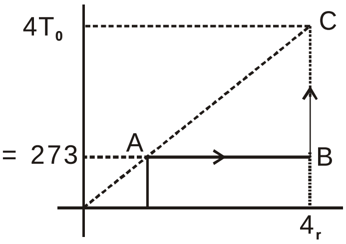
$432 + 370\,h = 432 \times \dfrac{64}{27}$

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

$h_2 = \dfrac{432}{270} = 1.6$ m

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

5. $T_0 = 273$



n = 2

n = ?

u = 27.7 kJ
u = QAB + QBC

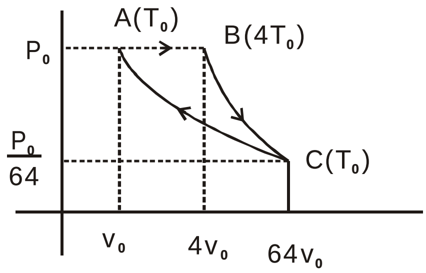
$= nRT_0 ln \left(\dfrac{4v}{v}\right) + nC_v (4T_0 - T_0)$

$= 4RT_0 ln2 + 6C_v T_0$

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

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

6. Let



r = 1.5

$R_p = 3R$

$C_v = 2R$

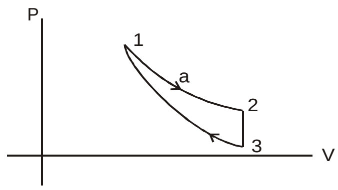
$P_A V_A = P_C V_C \quad \Rightarrow \quad P_0 V_0 = P_C V_C$
$P_B V_B^{\gamma} = P_C V_C^{\gamma} \quad\quad P_0 (4v_0)^{1.5} = P_C V_C^{1.5}$

$\dfrac{(4V_0)^{1.5}}{V_0} = \dfrac{V_c^{1.5}}{V_c} \quad \Rightarrow \quad 8V_0^{1.5} = V_c^{0.5}$

$V_c = 64V_0$
$\Rightarrow P_0 V_0 = P_C V_C \Rightarrow P_C \times 64 V_0 = P_0 V_0$
$P_C = P_0/64$
$Q_{AB} = nC_p \Delta T = n \times 3R \times (3T_0) = 9 P_0 V_0$
$Q_{CA} = nRT_0 ln\,64 = nRTln2 = 6P_0 V_0 ln$

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

7.



1–2 adiabatic
2-3 isochoric
3-1 isothermal
Q = mL = 8000 cal

8. $2mnv^2\cos^2\theta$

9. (a) W = area under AD

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

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

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

(b) $W_{ADC} = W_{AD} + W_{DC}$

$8 > W_{CD} = -3$

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

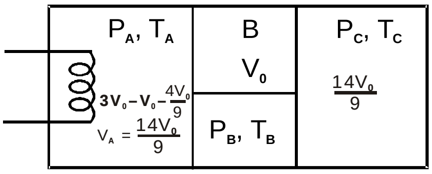
$= \frac{1}{2}\ (0.9 \times 10^5)\ (1.3 - V_C) \times 10^{-3}$

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

$V_c = 1.3 - \frac{80}{90} = 1.3 - \frac{1}{15} = `1.223\ l$

(c) $= -85$

10. In final situation



In section C

$\Delta Q = 0$ (adiabatic)

$\Rightarrow PV^r = C \qquad \Rightarrow \qquad P_t = \frac{27}{8}P_0 = P_C$

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

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

In section A

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

$\frac{\frac{27}{8}P_0 \times \frac{14V_0}{9}}{17} = \frac{P_0V_0}{T_0} \qquad \Rightarrow \qquad T_A = \frac{21}{4}T_0 = T_C$

For T_C

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

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

(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

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

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

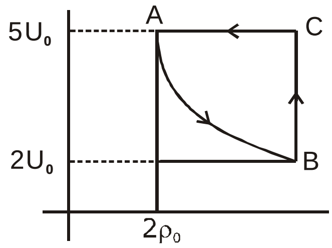
$\frac{10}{9} = 1 + \frac{2}{f}$

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

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

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

12.

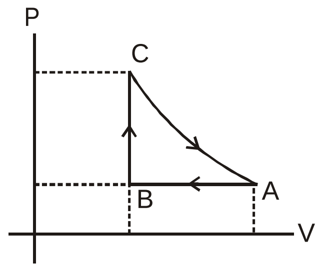


For BA $\quad U\rho_0 =$ constant

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

P = Constant

(a)



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

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

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

$W_{AB} = -\frac{20P_0U_0}{3M} \times \left(\frac{M}{230} - \frac{M}{530}\right) = -2V_0$

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

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

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

when ever $v \propto T^n$

$C = C_v + nR$

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

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

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

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

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

$= 4R\ (T_2 - T_1)$

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

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

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

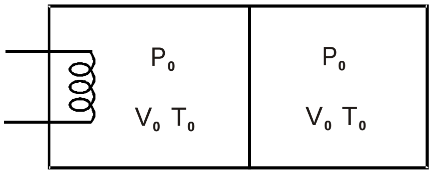
(a) $Q = nC\,\Delta T$

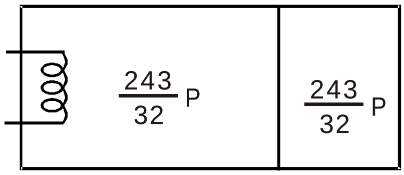
$U = nC_V\,\Delta T$

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

$w = Q - \Delta U = 803$

15.





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

$P_0V_0^{5/3} = \left(\frac{243}{32}P_0\right)V^{5/3}$

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

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

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

$\Rightarrow \frac{P_0V_0}{T_0} = \frac{243}{32}P_0 \times \frac{46}{27}V_0$

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

$W = \frac{P_1V_1 - P_2V_2}{\gamma - 1}$

$= \frac{P_0V_0 - \frac{243}{32}P_0 \times \frac{8}{27}V_0}{\frac{2}{3}} = -\frac{158}{8}$

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_0 and M_H are molecular weights of oxygen and hydrogen and T_0 and T_H the corresponding kelvin temperatures at which C_{rms} is same for both gases.

That is,

$C_{rms(0)} = C_{rms(H)}$

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

Hence,

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

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

M_o 32, $M_H = 2$

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

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% effeciency (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

$T_1 = 627 + 273 = 900K$
$Q_1 = 3\times 10^6$ cal
$T_2 = 27 + 273 = 300K$

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

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

$\Rightarrow \quad Q_2 = \frac{300}{900} \times 3 \times 10^6$

$= 1 \times 10^6$ cal

Work done = $Q_1 - Q_2$
$= 3 \times 10^6 - 1 \times 10^6$
$= 2 \times 10^6$ cal
$= 2 \times 4.2 \times 10^6$ J
$= 8.4 \times 10^6$ J

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

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

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

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 ;

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

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

For a mole of diatomic gas ;

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

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

When these two moles are mixed, then heat required to raise the temperature to 1^0C is

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

Hence, for one mole, heat required

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

$$\therefore \quad C_v = 2R$$

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

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

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

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

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

$$C_V = \frac{n_1 C_{V_1} + n_2 C_{V_2}}{n_1 + n_2}$$

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

$$C_{V_1} = \frac{R}{\gamma_1 - 1} = \frac{R}{\frac{5}{3} - 1} = \frac{3}{2}R$$

$$C_{V_2} = \frac{R}{\gamma_2 - 1} = \frac{R}{\frac{7}{5} - 1} = \frac{5}{2}R$$

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

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

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

$$\Rightarrow \quad \gamma - 1 = \frac{R}{C_V}$$

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

$$\Rightarrow \quad \frac{C_P}{C_V} = \frac{18}{29} + 1 = \frac{18 + 29}{29} = 1.62$$

12. AC

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

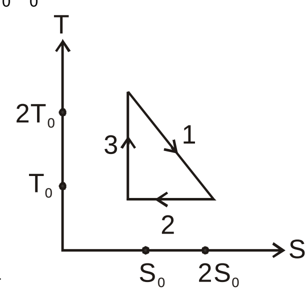
13. C

According to the figure

$Q_1 = T_0S_0 + \frac{1}{2}T_0S_0 = \frac{3}{2}T_0S_0$

$Q_2 = T_0(2S_0 - S_0) = T_0S_0$

$Q_3 = 0$



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

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

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

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.

Box A	Thermal contact	Box B
a mole N_2		a mole He

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

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

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

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

16. A

For adiabatic process,

$dQ = 0$

So, $dU = -\Delta W$

$\Rightarrow \quad nC_V dT = +146 \times 10^3$ J

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

(f $\rightarrow$ Degree of freedom)

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

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, $\eta = \frac{1}{10}$

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

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

So, $\quad Q_2 = 90$ J $\quad$ (as W = 10 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 $\quad U_1 = \frac{fn_1RT_1}{2}$

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

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,

$50 = \Delta U + 20$

$\therefore \ \Delta U = U_f - U_i = 30$ cal

For path ibf

$Q = \Delta U + W$

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

$= 36 - 30 = 6$ cal

21. B

Thermal energy corresponds to internal energy

Mass = 1 kg

density = 4kg m^{-3}

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

Pressure = 8×10^4 Nm^{-2}

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

22. A

$$\frac{F}{2}n_1kT_1 + \frac{F}{2}n_2kT_2 + \frac{F}{2}n_3kT_3$$

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

$$T = \frac{n_1T_1 + n_2T_2 + n_3T_3}{n_1 + n_2 + n_3}$$

23. D

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

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

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

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

On solving Eqs. (i) and (ii)
T_1 = 372 K and T_2 = 310 K

24. C

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

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

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

25. A

Internal energy of the gas remains constant, hence
$T_2 = T$

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

26. C

Heat required to change the temperature of vessel by a small amount dT
$-dQ = mC_PdT$
total heat required

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

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

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

Work done required to maintain the temperature of sink to T_2
$W = Q_1 - Q_2$

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

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

For $\quad T_2$ = 20K

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

For T_2 = 4k

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

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.

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

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

Which is a straight line with negative slope.

28. D

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

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

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

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

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

29. A

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

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

$$\therefore \quad \eta = \frac{P_oV_o}{nC_v\Delta T_1 + nC_P\Delta T_2}$$

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

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

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

30. A

31. A

Exercise-4 Level-II

1. A

$\Delta W_{AB} = P\Delta V = 10\ (2 - 1) = 10$ J

$\Delta W_{BC} = 0$

$\Delta Q = \Delta W + \Delta U \qquad \{\Delta U = 0\}$

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

$\Delta W_{CA} = 5 - (10 + 0) = -5$ J

2. A

$\beta = -\frac{dV/dp}{V}$ = compressibility

$= \frac{1}{\text{coeficietan t}}$

or $\beta = \frac{1}{p}$ isothermal process

3. $V = 1\ m^3 \quad P = 100\ N/m^2$

Let T be the temperature of gas then

(A) Time between two consecutive collision

$= \frac{1}{500}s \qquad \frac{2\ell}{v_{rms}} = \frac{1}{500}$

$\Rightarrow v_{rms} = 1000$ m/s $\qquad \{\ \ell = 1$ m

$\sqrt{\frac{3RT}{m}} = 1000 \Rightarrow T = \frac{(1000)^2(4\times10^{-3})}{3(25/3)} = 160$ K

(B) Avg. Kinetic energy/atom $= \frac{3}{2}kT$

$= 3.312 \times 10^{-21}$ J

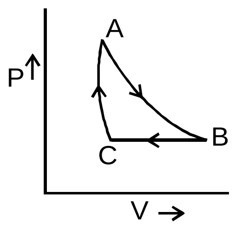
(C) $PV = nRT = \frac{m}{M}RT$

mass of helium gas m

$= \frac{PVm}{RT} \Rightarrow \quad m = \frac{(100)(1)(M)}{(25/3)(160)} = 0.3g$

4. A

AB is isothermal compression and BC is isobaric.

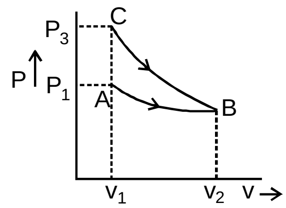


5. The kinetic energy of atoms goes into increasing the temperature.

$\frac{1}{2}mv_0^2 = nC_v\Delta T = \frac{m}{M}\left(\frac{3}{2}R\right)\Delta T$

$\Delta T = \frac{MV_0^2}{3R}$

6. C



$w_{AB} = +ve \quad ; \qquad W_{BC} = -ve$

$|w_{BC}| > |w_{AB}|$

Hence $W_{AB} + W_{BC} = w < 0$

from graph $\qquad P_3 > P_1$

7. At constant Pressure $V \propto T$

$\frac{Ah_2}{Ah_1} = \frac{T_2}{T_1}$

$h_2 = (100)\left(\frac{400}{300}\right) = \frac{4}{3}m$

Adibatic $T_fV_f^{v-1} = T_iV_i^{r-1}$

$T_f = (400)\left(\frac{4}{3}\right)^{1.4-1} \qquad T_f = (400)\left(\frac{4}{3}\right)^{0.4} = 448.8k$

8. C

$\Delta u = 1 \times 1 \times 100 \times 5 \times 60 = 30000$

$\Delta u = \frac{30000}{1000} = 30$ kJ

9. A

$\beta = \frac{\Delta p}{\frac{\Delta v}{v}}$

$= \frac{.155\times10^5}{\frac{.1v}{v}} \qquad = 1.55 \times 10^5$

10. (A) $\Delta T = \frac{\Delta Q}{ms} = \frac{20,000}{1\times400} = 50°C$

$T_f = 20 + 50° = 70°C$

(B) $\Delta V = \gamma\ V\ \Delta T = (9 \times 10^{-5})\left(\frac{1}{9000}\right)(50)$

$= 5 \times 10^{-7}\ m^3$

$w = P\Delta V = (10^5)\ (5 \times 10^{-7}) = 0.05$ J

(C) $\Delta U = \Delta Q - W = (2000 - 0.05)$ J

$= 19999.95$ J

11. Process $J \to K$

(A) V = constant $P \downarrow\ T \downarrow$

$W = 0$, $\Delta U = -$ ve and $Q < 0$

(B) Process $K \to L$

P = const. $V \uparrow\ T \uparrow\ W > 0$

$\Delta U > 0$ and $Q > 0$

(C) In process $L \to M$

$W = \Delta U > 0$ and $Q > 0$

(D) Process $M \to J$

$V \downarrow \quad w < 0$

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

$\Delta U < 0 \qquad Q < 0$

12. A

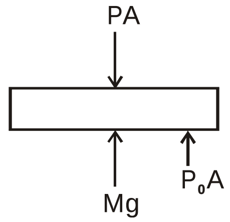
Since it is open from top pressure will be P_0.

13. D

Let P be the pressure in equilibrium

Then $PA = P_0A - Mg$

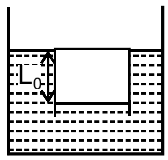
$$P = P_0 - \frac{M_g}{A}$$



$P_0(2AL) = P(AL')$ $\quad$ { 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



$P_1 = P_2$

$P_0 + \rho g\,(L_0 - H) = P \qquad \ldots(i)$

Now apply $P_1V_1 = P_2V_2$

$P_0L_0 = P(L_0 - H) \qquad P = \dfrac{P_0L_0}{L_0 - H}$

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

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

15.B

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

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

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

Statement 1 is correct

Statement 2 is correct but not the correct explanantion 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

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

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

we know $\gamma = \dfrac{dV}{VdT} = \dfrac{3}{T}$ 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 = constant, C = $C_V + \dfrac{R}{1-x}$.

(C) $Q = n\,C\,\Delta T$, for polytropic process, PV^x = constant, $C = C_v + \dfrac{R}{1-x}$.

(D) $T = \dfrac{PV}{nR}$, ΔU = +ve, W = +ve.

A–Q, B–P, R, C – P, S, D– Q,S

18. B, D

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

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

19. B, D

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

$\Delta U < 0$

In ABC, ΔW = Area of semicircular $\neq 0$

For ABCDA, ΔW = 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

$U = \dfrac{f}{2}PV = \dfrac{f}{2}nRT \qquad U_A = U_B$

$W_{AB} = nRT \ln \dfrac{V_f}{V_i} = nRT \ln 4 = P_0V_0 \ln 4$

If in BC $\quad V \propto T$

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

$\Rightarrow T_C = \dfrac{T_0}{4} \qquad PV = nRT$

at A $\quad P_0V_0 = nRT_0$

at C $\quad P_CV_0 = nR\dfrac{T_0}{4} \Rightarrow P_C = \dfrac{P_0}{4}$

23. $PV^\gamma = PV^{\frac{7}{5}}$ = consant

$\dfrac{nRT}{V}.V^{\frac{7}{5}}$ = consant

$TV^{\frac{2}{5}}$ = consant $\quad T_1V^{\frac{2}{5}} = aT_1\left(\frac{V}{32}\right)^{\frac{2}{5}}$

$T_1V^{\frac{2}{5}} = \frac{aT_1V^{\frac{2}{5}}}{4} \qquad \boxed{a = 4}$

24. A

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

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

$T_1V_1^{2/3} = T_2V_2^{2/3}$

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

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

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

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

$= \frac{\frac{1}{4}\times R\times(-3T_1)}{\frac{2}{3}} = \frac{-9}{8}RT_1$

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 = ΔU + W = – ve

Hence heat is lost.

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

W = 0

Q = ΔU + W = + ve

Hence heat is gained.

(C) C → D

P = constant hence Temperature increases

ΔU = + ve

$Q = nC_p\,\Delta T$ = + ve

Hence heat is gained.

(D) D → A

$T_D = T_A$

ΔU = 0

W = – ve

Q = ΔU + W = – ve

Hence heat is lost.

26. D

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

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

27. D

$Q = nC_p\Delta T$

= 2 × 5/2 × R × 5

= 208 J