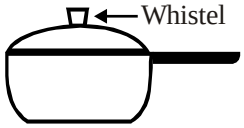
# EXERCISE # (S-1)

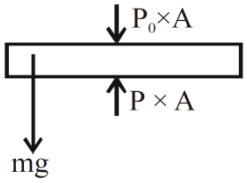
***HCV Worked out Examples(Chapter No.24 - {2,4,7,11,13,14,16,19,21})***

**1.** An empty pressure cooker of volume 10 litres contains air at atmospheric pressure $10^5$ Pa and temperature of 27°C. It contains a whistle which has area of 0.1 $cm^2$ and weight of 100 gm. What should be the temperature of air inside so that the whistle is just lifted up?




**Ans.** 327°C

**Sol.**




$F = PA = mg + P_0A$

$P \times 0.1 \times 10^{-4} = 100 \times 10^{-3} \times 10 + 10^5 \times 10^{-4} \times 0.1$

$P = 2 \times 10^5$

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

$$\frac{P}{T} = \frac{10^5}{300}$$

$T = 600$

**2.** A mixture of 4 gm helium and 28 gm of nitrogen is enclosed in a vessel of constant volume 300 K. Find the quantity of heat absorbed by the mixture to doubled the root mean velocity of its molecules. (R = Universal gas constant)

**Ans.** 3600 R

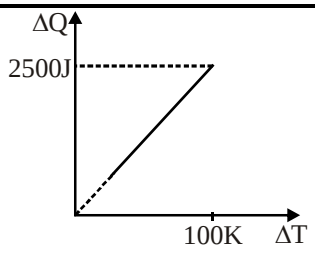
**Sol.** $T \rightarrow 4T$

$$\left(\frac{3}{2}R\right)+1\left(\frac{5}{2}R\right)(4\times300-300)$$

***HCV Exercises (Chapter No.24- {4,7,10,12,14,17,20,24,26,31,36,40})***

***HCV Worked out Examples(Chapter No.26 - {3,5,8,10,11})***

**3.** One mole of a gas mixture is heated under constant pressure, and heat required $\Delta Q$ is plotted against temperature difference acquired. Find the value of $\gamma$ for mixture.




**Ans.** 1.5

**Sol.** $C_P\Delta T = 2500$

$$100 \times 8.31 \times \frac{\gamma}{\gamma - 1} = 2500$$

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

$$\gamma = 1.5$$

**4.** If heat is added at constant volume, 6300 J of heat are required to raise the temperature of an ideal gas by 150 K. If instead, heat is added at constant pressure, 8800 joules are required for the same temperature change. When the temperature of the gas changes by 300 K, determine the change is the internal energy of the gas.

**Ans.** 12600 J

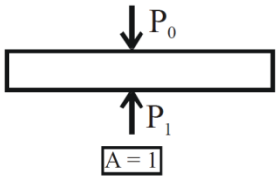
**Sol.** $6300 = nC_V \times 150$ $\quad nC_V 300$ = will be the answer

$8000 = nC_P 150$

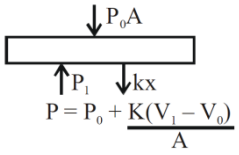
**5.** Consider one mole of perfect gas in a cylinder of unit cross section with a piston attached (Fig.). A spring (spring constant k) is attached (unstretched length L ) to the piston and to the bottom of the cylinder. Initially the spring is unstretched and the gas is in equilibrium. A certain amount of heat Q is
supplied to the gas causing an increase of volume from $V_0$ to $V_1$.
(a) What is the initial pressure of the system?
(b) What is the final pressure of the system?
(c) Using the first law of thermodynamics, write down a relation between Q, $P_a$, V, $V_0$ and k.

**Ans.** (a) $P_i = P_a$ ; (b) $P_f = P_a + k(V - V_0)$ ; (c) $\Delta Q = P_a(V - V_0) + \frac{1}{2} k (V - v_0)^2 + C_v (T - T_0)$

**Sol.** (A)




(B)




(C) $W = P_0(V_1 - V_0) + \frac{1}{2} K (V_1 - V_0)^2$

$$W = P_0Ax_0 + \frac{kx_0^2}{2}$$

$$= P_0A\left(\frac{V-V_0}{A}\right)+\frac{K}{2}\left(\frac{V-V_0}{A}\right)^2$$

**6.** A cylinder with a movable piston contains 3 moles of hydrogen at standard temperature and pressure. The walls of the cylinder are made of a heat insulator, and the piston is insulated by having a pile of sand on it. By what factor does the pressure of the gas increase if the gas is compressed to half its original volume ?

**Ans.** 2.64

**Sol.** $P_1V_1^{\gamma} = P_2\left(\frac{V_1}{2}\right)^{\gamma} \Rightarrow \frac{P_2}{P_1} = (2)^{7/5} = 2^{1.4} = 2.64$

**7.** Two cylinders A and B of equal capacity are connected to each other via a stopcock. A contains a gas at standard temperature and pressure. B is completely evacuated. The entire system is thermally insulated. The stopcock is suddenly opened. Answer the following :

(a) What is the final pressure of the gas in A and B?

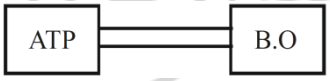
(b) What is the change in internal energy of the gas?

(c) What is the change in the temperature of the gas?

(d) Do the intermediate states of the system (before settling to the final equilibrium state) lie on its P-V-T surface?

**Ans.** (a) 0.5 atm ; (b) zero (c) zero (d) no

**Sol.** Free expansion so work done by the gas will be zero. Since system is thermally insulated so $\Delta Q$ will be zero.




**8.** An electric heater supplies heat to a system at a rate of 100W. If system performs work at a rate of 75 joules per second. At what rate is the internal energy increasing?

**Ans.** 25 W

**Sol.** $\frac{d\theta}{dt} = 100$ J/s

$\frac{dw}{dt} = 75$ J/s

$\frac{d\theta}{dt} = \frac{du}{dt} + \frac{dw}{dt}$

$\frac{du}{dt} = \frac{d\theta}{dt} - \frac{dw}{dt}$

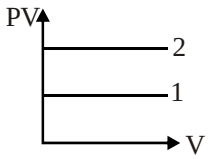
= 100 J/s – 75 J/s

= 25 J/s

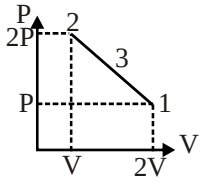
***HCV Exercises (Chapter No.26- {2,3, 6,14,16,20,21,22})***

***HCV Worked out Examples(Chapter No.27- {1,3,4,7,9,10,11,12})***

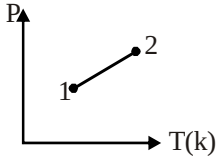
**9.** Examine the following plots and predict whether in (i) $P_1 < P_2$ and $T_1 > T_2$, in (ii) $T_1 = T_2 < T_3$, in (iii) $V_1 > V_2$, in (iv) $P_1 > P_2$ or otherwise.



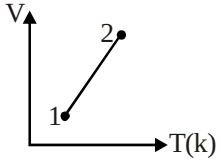
(i)



(ii)



(iii)



(iv)

**Ans.** (i) $P_1 < P_2$, $T_1 < T_2$ ; (ii) $T_1 = T_2 < T_3$; (iii) $V_1 > V_2$; (iv) $P_1 > P_2$

**Sol.** (i) From the figure pressure at 2 is greater than one. Temperature can find by the product of pressure and volume.

**(ii)** $\frac{P}{3P_0}+\frac{V}{3V_0}=1$

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

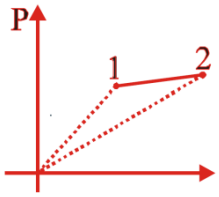
$\frac{P}{3P_0}+\frac{1}{2}=1$

$P = \frac{3P_0}{2}$

$PV = \frac{9P_0 n}{4} = nRT_3^1$

$T_B^1 > T_2$

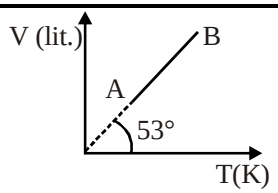
(iii) $PV = nRT$ $\quad P = \left(\frac{nR}{V}\right)T$




Slope = $\frac{TnR}{V}$

(iv) Slope is $\frac{nR}{P}$

**10.** V-T curve for 2 moles of a gas is straight line as shown in the graph here. Find the pressure of gas at A.




**Ans.** $1.25 \times 10^4$ N/m$^2$

**Sol.** $\frac{V}{T} = \frac{nR}{P} = \tan 53$

$\Rightarrow P = \frac{2 \times 0.0821}{\tan 53}$ atm

**11.** A piston divides a closed gas cylinder into two parts. Initially the piston is kept pressed such that one part has a pressure P and volume 5V and the other part has pressure 8P and volume V. The piston is now left free. Find the new pressures and volumes for the adiabatic and isothermal processes. For this gas $\gamma = 1.5$.

**Ans.** 1.84 P, 10 V/3, 8V/3 (adiabatic), 13 P/6, 30V/13, 48V/13 (Isothermal)

**Sol.**

| Initially | | Finally | |
|---|---|---|---|
| P, 5V | 8 P, V | $P'$ $V_0$ | $P'$ $(6V - V_0)$ |

(a) For adiabatic process

$P.(5V)^{\gamma} = P'V_0^{\gamma}$ …(i)

$8P\,(V)^{\gamma} = P'(6V - V_0)^{\gamma}$ …(ii)

(i) / (ii)

$$\frac{(5)^{\gamma}}{8} = \left(\frac{V_0}{6V - V_0}\right)^{\gamma}$$

$$\left(\frac{5}{4}\right)^{3/2} = \left(\frac{V_0}{6V - V_0}\right)^{3/2}$$

$$\frac{5}{4} = \frac{V_0}{6V - V_0}$$

$30\,V - 5V_0 = 4V_0$

$V_0 = \frac{30}{9}V = \frac{10V}{3}$

From (i)

$$P(5V)^{\gamma} = P'\left(\frac{30}{9}V\right)^{\gamma}$$

$$P(5V)^{\gamma} = P'\left(\frac{10}{3}V\right)^{\gamma}$$

$$P' = \left(\frac{15}{10}\right)^{3/2}.P$$

$$P' = \left(\frac{3}{2}\right)^{3/2}.P$$

$$P' = 1.89\ P$$

$$\text{Volume of other compartment} = 6V - \frac{10V}{3} = \frac{8V}{3}$$

**12.** Find the molecular mass of a gas if the specific heats of the gas are $C_P = 0.2$ cal/gm°C and $C_V = 0.15$ cal/gm°C. [Take R = 2 cal/mole°C]

**Ans.** The molar mass of the gas is 40 gm, the number of degrees of freedom of the gas molecules is 6

**Sol.** the molar mass of the gas is 40 gm, the number of degrees of freedom of the gas molecules is 6

$$(0.2 - 0.15)M = 2$$

$$\Rightarrow M = \frac{2}{.05} = 40$$

$$C_V = 0.15 \times 40 = 6$$

$$C_V = \frac{fR}{2}$$

**13.** A gas undergoes a process in which the pressure and volume are related by $VP^n$ = constant. Find the bulk modulus of the gas.

**Ans.** P/n

**Sol.** $VP^n$ = Constant

$$\beta = -V.\left(\frac{\Delta P}{\Delta V}\right) = -V.\left(\frac{dP}{dV}\right) \qquad \ldots(i)$$

$$dvp^n + V.n.p^{n-1}.dp = 0$$

$$\frac{dP}{dV} = \frac{-P^n}{nV.P^{(n-1)}}$$

From 1 & 2

$$\beta = V \cdot \frac{1}{n} \cdot \frac{P}{V} = \frac{P}{n}$$

(b) isothermally.

$$P(5V) = P'V_0 \qquad \ldots(1)$$

$$8P(V) = P'(6V - V_0) \qquad \ldots(2)$$

(1) / (2)

$$\frac{5}{8}=\frac{V_0}{6V-V_0}$$

$$30V-5V_0=8V_0$$

$$V_0=\frac{30V}{13},\ (6V-V_0)=6V-\frac{30V}{13}$$

$$=\frac{48V}{13}$$

From (i)

$$P(5V)=P'\cdot\frac{30V}{13}$$

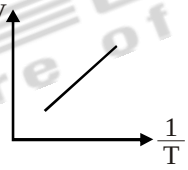
$$P'=\frac{65}{30}P=\frac{13P}{6}$$

**14.** Ideal diatomic gas is taken through a process $\Delta Q = 2\Delta U$. Find the molar heat capacity for the process(where $\Delta Q$ is the heat supplied and $\Delta U$ is change in internal energy)

**Ans.** 5R

**Sol.** $2C_V=\frac{2\times5}{2}R=5R$

**15.** One mole of an ideal monoatomic gas undergoes a process as shown in the figure. Find the molar specific heat of the gas in the process.

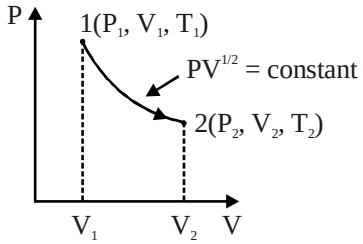



**Ans.** R/2

**Sol.** $\frac{V}{1/T}=VT=\text{constant}=PV^2$

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

**16.** Consider a P-V diagram in which the path followed by one mole of perfect gas in a cylindrical container is shown in figure.



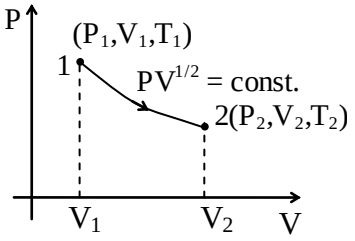

(a) Find the work done when the gas is taken from state 1 to state 2.

(b) What is the ratio of temperature $T_1/T_2$, if $V_2 = 2V_1$?

(c) Given the internal energy for one mole of gas at temperature T is (3/2) RT, find the heat supplied to the gas when it is taken from state 1 to 2, with $V_2 = 2V_1$

**Ans.** (a) $\Delta W = 2P_1V_1^{1/2}\left[v_2^{1/2} - V_1^{1/2}\right]$; (b) $\frac{T_2}{T_1} = \sqrt{\frac{V_2}{V_1}} = \sqrt{2}$ (c) $\Delta Q = (7/2)RT_1\ (\sqrt{2} - 1)$

**Sol.**




(a) Work–done in adiabatic process.

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

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

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

$$= -2R\left(\frac{P_1V_1}{R} - \frac{P_2V_2}{R}\right)$$

$$= -2(P_1V_1 - P_2V_2) \qquad \ldots(1)$$

$$P_1V_1^{1/2} = P_2V_2^{1/2}$$

$$P_2 = P_1\left(\frac{V_1}{V_2}\right)^{1/2} \qquad \ldots(2)$$

From (1) & (2)

$$W.D = -2P_1V_1^{1/2}\left[V_1^{1/2} - V_2^{1/2}\right]$$

(b) $T_1V_1^{x-1} = T_2V_2^{x-1}$

$$\frac{T_1}{T_2} = \left(\frac{V_2}{V_1}\right)^{x-1}$$

$$x = \frac{1}{2}$$

$$\frac{T_1}{T_2} = \left(\frac{2V_1}{V_1}\right)^{\frac{1}{2}-1}$$

$$\frac{T_1}{T_2} = \frac{1}{\sqrt{2}}$$

(c) $\Delta U = \frac{3}{2}RT$

$\Delta Q = \Delta U + W$

$= \frac{3}{2}R(T_2 - T_1) + \frac{R}{1-x}(T_2 - T_1)$

$= \frac{3}{2}R(T_2 - T_1) + 2R(T_2 - T_1)$

$= \frac{7R}{2}(T_2 - T_1)$

$\Delta Q = \frac{7R}{2}T_1(\sqrt{2} - 1)$

**17.** In changing the state of a gas adiabatically from an equilibrium state A to another equilibrium state B, an amount of work equal to 22.3 J is done on the system. If the gas is taken from state A to B via a process in which the net heat absorbed by the system is 9.35 cal, how much is the net work done by the system in the latter case ? (Take 1 cal = 4.19 J)

**Ans.** 16.9 J

**Sol.** $\Delta U$ will be same

$(\Delta Q - \Delta w)_1 = (\Delta Q - \Delta w)_2 \Rightarrow -22.3 = 9.35 \times 4.19 - \Delta w = \Delta w = 16.87$

***HCV Exercises (Chapter No.27- {1,3,6,9,12,15,18,20,25,27,28,30,33,35})***

***HCV Worked out Examples(Chapter No.26- {1,2,6,7,9})***

**18.** A cycle followed by an engine (made of one mole of perfect gas in a cylinder with a piston) is shown in figure.

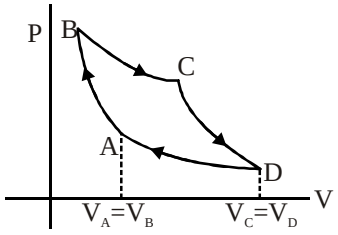
A to B : volume constant

B to C : adiabatic

C to D : volume constant

D to A : adiabatic

$V_C = V_D = 2V_A = 2V_B$




(a) In which part of the cycle heat is supplied to the engine from outside?

(b) In which part of the cycle heat is being given to the surrounding by the engine?

(c) What is the work done by the engine in one cycle? Write your answer in term of $P_A$, $P_B$, $V_A$

(d) What is the efficiency of the engine?

[$\gamma = \frac{5}{3}$ for the gas], ($C_v = \frac{3}{2}R$ for one mole)

**Ans.** (a) A to B; (b) C to D ; (c) $W_{AB} = \frac{1}{1-\gamma}(2^{1-\gamma}-1)(P_B - P_A)V_A = \frac{3}{2}\left(1-\left(\frac{1}{2}\right)^{2/3}\right)(P_B - P_A)V_A$

(d) $\left[1-\left(\frac{1}{2}\right)^{2/3}\right]$

**Sol.** $P_B V_0^{\gamma} = P_C (2V)^{\gamma} \Rightarrow P_B = P_C(2^{\gamma})$

$P_A V_0^{\gamma} = P_0 (2v)^{\gamma} \Rightarrow P_D \times (2)^{\gamma} = P_A$

$$\Delta W = \frac{P_C V_C - P_B V_B}{1-\gamma} + \frac{P_A V_A - V_D P_B}{1-\gamma} = \frac{\frac{P_B}{2^{\gamma}} 2V_A - P_B V_A + P_A V_B - 2V_A \frac{P_A}{2^{\gamma}}}{1-\gamma}$$

$$\frac{1}{1-\gamma}\left[P_B A(2^{1-\gamma}-1) - P_A V_A(2^{1-\gamma}-1)\right]$$

$$\Delta Q = n\frac{3}{2}R(\Delta T) = \frac{3}{2}(P_B V_A - P_A V_A)$$

**19.** An ideal gas is taken through a cyclic thermodynamic process through four steps. The amounts of heat involved in these steps are $Q_1 = 5960$ J, $Q_2 = -5585$ J, $Q_3 = -2980$ J and $Q_4 = 3645$ J respectively. The corresponding works involved are $W_1 = 2200$ J, $W_2 = -825$ J, $W_3 = -1100$ J and $W_4$ respectively.

(i) Find the value of $W_4$.

(ii) What is the efficiency of the cycle ?

**Ans.** (i) 765 J, (ii) 10.83%

**Sol.** $\Delta Q_{net} = \Delta U + W_{net}$ …(1)

$Q_{net} = 5960 + (-5585) + (-2980) + 3645 = 1040$ J

$W_{net} = 2200 + (-825) + (-1100) + W_4$

$= 275 + W_4$ J

From (1)

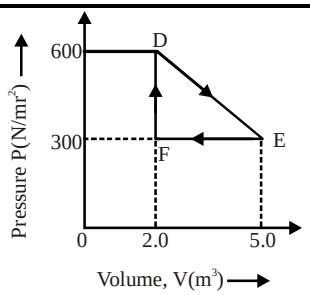
$1040 = 0 + 275 + W_4$

$W_4 = 765$ J

(ii) $\eta = \frac{W.D \times 100\%}{Q_{supplied}} = \frac{1040}{9605} \times 100\%$

$= 10.83\%$

**20.** A thermodynamic system is taken from an original state to an intermediate state by the linear process shown in figure. Its volume is then reduced to the original value from E to F by an isobaric process. Calculate the total work done by the gas from D to E to F




**Ans.** 450 J

**Sol.** $\frac{1}{2}\times 300\times 3 = 450\text{J}$

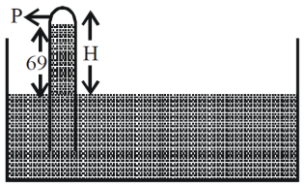
***HCV Exercises (Chapter No.26- {7,9,10,12,17,18})***
***HCV Exercises (Chapter No.27- {13,14})***

## EXERCISE # (S-2)

**1.** A barometer is faulty. When the true barometer reading are 73 and 75 cm of Hg, the faulty barometer reads 69 cm and 70 cm respectively.
(i) What is the total length of the barometer tube?
(ii) What is the true reading when the faulty barometer reads 69.5 cm ?
(iii) What is the faulty barometer reading when the true barometer reads 74 cm?

**Ans.** (i) 74 cm; (ii) 73.94 cm; (iii) 69.52 cm

**Sol.** (i)




$73 = P + 69$

$P = 4$

Now $PV = nRT$

$4 \times (H - 69) = nRT$ ….(i)

$\because 75 = P_1 + 70$

$P_1 = 5$

Now $5(H - 70) = nRT$ ….(ii)

for (i) & (ii)

$4(H - 69) = 5(H - 70)$

$H = 74$

(ii) $69.5 + P = h$

$PV = nRT$

$(h - 69.5)(74 - 69.5) = nRT$ …(iii)

from (i) & (ii)

$(h - 69.5)(74 - 69.5) = 4 \times (5)$

$h - 69.5 = \frac{20}{4.5} \quad \Rightarrow h = 73.94$

(iii) $74 = h + p$

Now $p \times v = nRT \Rightarrow (74 - h)(74 - h) = 5 \times 4 \Rightarrow h = 69.52$

**2.** A vessel of volume V = 30*l* is separated into three equal parts by stationary semipermeable thin membranes as shown in the Figure. The left , middle and right parts are filled with 2Hm= 30g of hydrogen $m_{O_2} = 160g$, of oxygen, and $m_{N_2} = 70g$ of nitrogen respectively. The left partition lets through only hydrogen, while the right partition lets through hydrogen and nitrogen. What will be the pressure in each part of the vessel after the equilibrium has been set in if the vessel is kept at a constant temperature T = 300K?

| $H_2$ | $O_2$ | $N_2$ |
|---|---|---|

**Ans.** $p_1 = p_{H_2} \simeq 1.25 \times 10^6 Pa;\ p_2 = p_{H_2} + p_{O_2} + p_{N_2} \simeq 2.8125 \times 10^6 Pa;$

$p_3 = p_{H_2} + p_{N_2} \simeq 1.5625 \times 10^6 Pa;$

**Sol.**

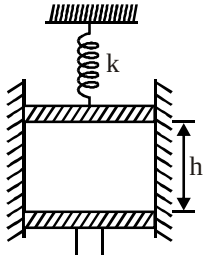
| $H_2(5)$ | $H_2(5)$<br>$O_2(5)$<br>$N_2(5/4)$ | $H_2(5)$<br>$N_2(5/4)$ |
|---|---|---|

$P_1 = \frac{5 \times 0.0821 \times 300}{10}$

$P_2 = \frac{\left(5 + 5 + \frac{5}{4}\right) \times 0.0821 \times 300}{10}$

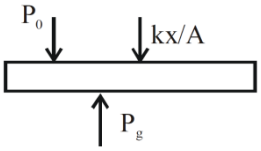
$P_3 = \frac{\left(5 + \frac{5}{4}\right) \times 0.0821 \times 300}{10}$

**3.** An ideal gas at NTP is enclosed in a adiabatic vertical cylinder having area of cross section A = 27 $cm^2$, between two light movable pistons as shown in the figure. Spring with force constant k = 3700 N/m is in a relaxed state initially. Now the lower piston is moved upwards a height h/2, h being the initial length of gas column. It is observed that the upper piston moves up by a distance h/16. Find h taking $\gamma$ for the gas to be 1.5. Also find the final temperature of the gas.



**Ans.** 1.6 m, 364 K

**Sol.**




$$P_g = P_0 + \frac{kx}{A} = P_0 + \frac{kh}{16A}$$

$$P_0(hA)^{\gamma} = P_g\left[\left(\frac{h}{2}+\frac{h}{16}\right)A\right]^{\gamma}$$

$$10^5(hA)^{\gamma} = \left[10^5 + \frac{3700\times h}{16\times 27\times 10^{-4}}\right]\left[\frac{9h}{16}A\right]^{\gamma}$$

$$\frac{64}{27} = 1+\frac{370\times h}{16\times 27}$$

$$\frac{37}{27} = \frac{370\times h}{16\times 27} \Rightarrow h = \frac{16}{10}$$

$PV = nRT$

$P_0hA = nR \times 273$ (initial)

$$\left\{P_0 + \frac{kh}{16A}\right\}\left\{\frac{Ph}{16}A\right\} = nRT \quad \text{(final)}$$

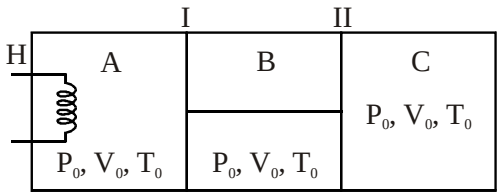
divide

$$\left\{1+\frac{kh}{16A\times P_0}\right\}\frac{9}{16} = \frac{T}{273}$$

$$T = 273 \times \frac{9}{16}\left[1+\frac{370}{270}\right]$$

$$T = 273 \times \frac{4}{3} = 364\ k$$

**4.** The figure shows an insulated cylinder divided into three parts A, B and C. Pistons I and II are connected by a rigid rod and can move without friction inside the cylinder. Piston I is perfectly conducting while piston II is perfectly insulating. The initial state of the gas ($\gamma = 1.5$) present in each compartment A, B and C is as shown. Now, compartment A is slowly given heat through a heater H such that the final volume of C becomes $\frac{4V_0}{9}$. Assume the gas to be ideal and find.




(a) Final pressures in each compartment A, B and C

(b) Final temperatures in each compartment A, B and C

(c) Heat supplied by the heater
(d) Work done by gas in A and B.
(e) Heat flowing across piston I.

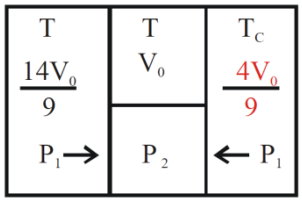
**Ans.** (a) Final pressure in $A = \frac{27}{8} P_0$ = Final pressure in C, Final pressure in $B = \frac{27}{4} P_0$

(b) Final temperature in A (and B) = $\frac{21}{4} T_0$, Final temperature in C = $\frac{3}{2} T_0$.

(c) $18 P_0 V_0$ (d) work done by gas in A = $+ P_0 V_0$, work done by gas in B = 0 (e) $\frac{17}{2} P_0 V_0$

**Sol.** Pressure of A & C will be same & temperature of A & B will same

For "C"




$$P_0 V_0^{1.5} = P_1 \left(\frac{4V_0}{9}\right)^{1.5} \Rightarrow P_1 = \frac{27}{8} P_0$$

For "C'

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

$$T_0 V_0^{0.5} = T_C \left(\frac{4V_0}{9}\right)^{0.5} \Rightarrow T_C = \frac{3T_0}{2}$$

**For (A)**

$$\frac{PV}{RT} = n$$

$n_i = n_f$

$$\frac{P_0 V_0}{RT_0} = \frac{\left(\frac{27}{8} P_0\right)\left(\frac{14}{9} V_0\right)}{nT}$$

$$T = \frac{21}{4} T_0$$

**For (B)**

$$\frac{P_0 V_0}{PT_0} = \frac{P_2 \times V_0}{PT}$$

$$\frac{P_0 V_0}{T_0} = \frac{4P_2 V_0}{21T_0}$$

$$\frac{21P_0}{4} = P_2$$

(C) Net work done will be zero.

$\Delta Q = \Delta U_A + \Delta U_B + \Delta U_C + (w_{net})$

$\Delta Q = \Delta U_A + \Delta U_B + \Delta U_C$

$= 2 \times 2nR(T_f - T_i) + 2Rn\left[\frac{3T_0}{2} - T_0\right]$

$= 4 \times \left(\frac{21}{4}P_0V_0 - P_0V_0\right) + P_0V_0$

$= 17P_0V_0 + P_0V_0 = 18\ P_0V_0$

$\Delta Q = \Delta U_B + \Delta W_B$

$\Delta Q = nC_V\Delta T\ (\Delta W_B = 0)$

$= n2R\ (T_f - T_i)$

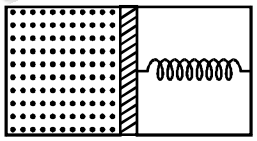
$= 2\left[\frac{21}{4}P_0V_0 - P_0V_0\right] = \frac{17}{2}P_0V_0$

(D) $\Delta w_B = 0$

$\Delta w_A = -\Delta w_C = -[-nC_V\Delta T]_C = nC_V\Delta T_C = 2nR[T_{fC} - T_{iC}]$

$= 2\left[\frac{27}{8}P_0 \times \frac{4V_0}{9} - P_0V_0\right] = P_0V_0$

**5.** A thermally insulated vessel is divided into two parts by a heat-insulating piston which can move in the vessel without the friction. The left part of the vessel contains one mole of an ideal monatomic gas, & the right part is empty. The piston is connected to the right wall of the vessel through a spring whose length in free state is equal to the length of the vessel as shown in the figure. Determine the heat capacity C of the system, neglecting the heat capacities of the vessel, piston and spring.



**Ans.** $C = 2R$

**Sol.** $C = C_V + \frac{PdV}{dT}$

Now

$PdV + VdP = nRdT$

$PdV = \frac{k\ell}{A}Adx = k\ell dx$

$\left(\frac{k\ell}{A}\right)(Adx) + (A\,\ell)\frac{kdx}{A} = 1 \times RdT$

$\frac{2k\ell dx}{dT} = R$

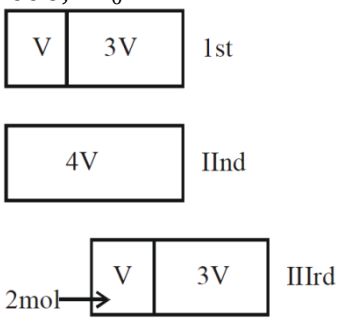
$\frac{k\ell dx}{dT} = \frac{R}{2}$

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

**6.** A weightless piston divides a thermally insulated cylinder into two parts of volumes V and 3V. 2 moles of an ideal gas at pressure P = 2 atmosphere are confined to the part with volume V = 1 litre. The remainder of the cylinder is evacuated. The piston is now released and the gas expands to fill the entire space of the cylinder. The piston is then pressed back to the initial position. Find the increase of internal energy in the process and final temperature of the gas. The ratio of the specific heat of the gas $\gamma = 1.5$.

**Ans.** 400 J, $2T_0$

**Sol.**




Calculation for IInd to IIIrd stage

$T_2(4V)^{\gamma-1} = T_3(V)^{\gamma-1}$

$T_3 = 2T_2$

for $T_1$ $\quad PV = nRT$

$2 \times 1 = 2 \times RT_3$

$$T_2 = \frac{1}{R} = \frac{1}{0.0821}$$

$T_3 = 2/R$

temp of $T_1 = T_2$

since no work $\Delta W = 0$

$$\Delta U = nC_V\Delta T = 2 \times 2R(T_3 - T_2) = 4 \times 8.31\left(T_3 - \frac{T_3}{2}\right) = 400J$$

**7.** Two moles of an ideal monoatomic gas are confined within a cylinder by a massless & frictionless spring loaded piston of cross-sectional area $4 \times 10^{-3}$ $m^2$. The spring is, initially in its relaxed state. Now the gas is heated by an electric heater, placed inside the cylinder, for some time. During this time, the gas expands and does 50 J of work in moving the piston through a distance 0.10 m. The temperature of the gas increases by 50 K. Calculate the spring constant & the heat supplied by the heater. [$P_0 = 10^5$ Pa]

**Ans.** 2000 N/m, 1295 J

**Sol.** $w_g = P\Delta V + \frac{1}{2}kx^2$

$$50 = 10^5 \times (4 \times 10^{-3} \times 0.1) + \frac{1}{3} \times k\,[0.1]^2$$

$$10 = \frac{1}{2}\frac{k}{100}$$

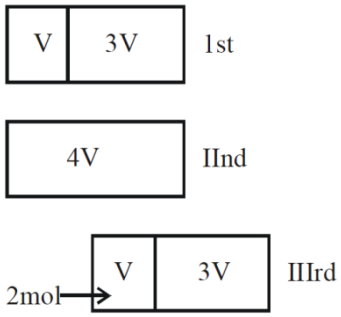
$k = 2000$ N/m

$\Delta Q = \Delta U + w$

$\Delta U = nC_V\Delta T = 2 \times \frac{3}{2} \times 8.3(50) = 1245$

$\Delta Q = 1295$ J

**Sol.**




Calculation for IInd to IIIrd stage

temp of $T_1 = T_2$

since no work $\Delta W = 0$

$T_2(4V)^{\gamma-1} = T_3(V)^{\gamma-1}$

$T_3 = 2T_2$

for $T_1$

$PV = nRT$

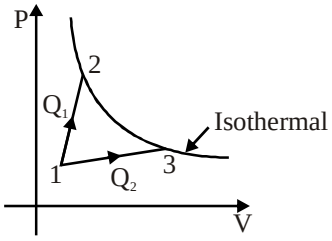
$2 \times 1 = 2 \times RT_3$

$T_2 = \frac{1}{R} = \frac{1}{0.0821}$

$T_3 = 2/R$

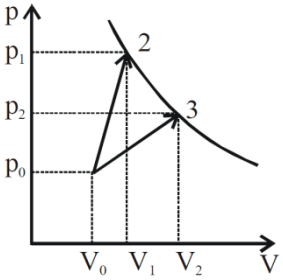
$\Delta U = nC_V\Delta T = 2 \times 2R(T_3 - T_2) = 4 \times 8.31\left(T_3 - \frac{T_3}{2}\right) = 400J$

**8.** A gas takes part in two processes in which it is heated from the same initial state 1 to the same final temperature. The processes are shown on the P-V diagram by the straight line 1-2 and 1-3. 2 and 3 are the points on the same isothermal curve. $Q_1$ and $Q_2$ are the heat transfer along the two processes. Then in which case will the heat transfer be more.




**Ans.** $Q_1 < Q_2$

**Sol.**



According to the first law of thermodynamics, the amount of heat $\Delta Q_1$ receiced by a gas going over from state 1 ($p_0$, $V_0$) to state 2 ($p_1$, $V_1$) is

$\Delta Q_1 = \Delta U_1 + W_1$

where $\Delta U_1$ is the change in its internal energy, and $W_1$ is the work done by the gas,

$$W_1 = \frac{(p_0 + p_1)(V_1 - V_0)}{2}$$

As the gas goes over from state 1 to state 3 ($p_2$, $V_2$) (points 2 and 3 lie on the same isotherm), the following relations are fulfilled :

$\Delta Q_2 = \Delta U_2 + W_2$,

$$W_2 = \frac{(p_0 + p_2)(V_2 - V_0)}{2}$$

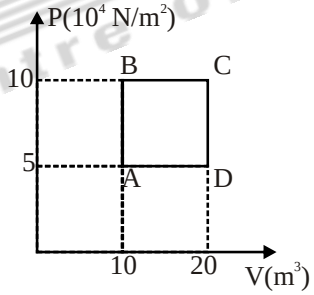
Since the final temperature of the gas in states 2 and 3 is the same, $\Delta U_1 = \Delta U_2$. In order to find out in which process the gas receives a larger amount of heat, we must compare the works $W_1$ and $W_2$ :

$$W_1 - W_2 = \frac{(p_0 + p_1)(V_1 - V_0)}{2} - \frac{(p_0 + p_2)(V_2 - V_0)}{2}$$

$$= \frac{(p_0 V_1 - p_0 V_2) + (p_2 V_0 - p_1 V_0)}{2} < 0$$

since $p_0V_1 < p_0V_2$ and $p_2V_0 < p_1V_0$. Consequently, $W_2 > W_1$ and $\Delta Q_2 > \Delta Q_1$, i.e. the amount of heat receives by the gas in the process $1 \rightarrow 3$ is larger.

**9.** A sample of 2 kg of monoatomic Helium (assumed ideal) is taken through the process ABC and another sample of 2 kg of the same gas is taken through the process ADC as in figure. Given, molecular mass of Helium = 4




(i) What is the temperature of Helium in each of the states A, B, C & D ?

(ii) Is there any way of telling afterwards which sample of Helium went through the process ABC and which went through the process ADC?
Write Yes or No.

(iii)How much is the heat involved in each of the processes ABC ADC.

**Ans.** (i) $T_A$= 120.33 K, $T_B$ = 240.66 K, $T_C$ = 481.32 K, $T_D$ = 240.66 K, (ii) No;
(iii) $\Delta Q_{ABC} = 3.25 \times 10^6$ J; $\Delta Q_{ADC} = 2.75 \times 10^6$ J;

**Sol.** $$T_A = \frac{PV}{nR} = \frac{5\times10^4\times10}{\frac{2000}{4}\times8.37} = 120.33$$

$T_B = 2T_A$

$T_C = 4T_A$

$T_D = 2T_A$

(ii) No since temperature pressure & volume of each sample will be same.

(iii) $\Delta Q_{ABC} \Rightarrow nC_V\Delta T + P\Delta V$

$= \frac{2000}{4} \times \frac{3}{2} \times 8.31 \times 3T_A + 10 \times 10^4 \times (10)$

$= 3.25 \times 10^6 J$

$\Delta Q_{ADC} = \frac{2000}{4} \times \frac{3}{2} \times 8.3 \times 3T_A$

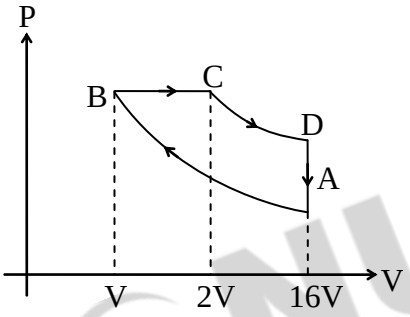
$+ 5 \times 10^4 \times 10$

$= 2.75 \times 10^6 J$

**10.** One mole of a diatomic ideal gas ($\gamma = 1.4$) is taken through a cyclic process starting from point A. The process A $\rightarrow$ B is an adiabatic compression. B$\rightarrow$C is isobaric expansion. C$\rightarrow$D an adiabatic expansion & D $\rightarrow$ A is isochoric. The volume ratios are $V_a/V_b = 16$ and $V_c/V_b = 2$ & the temperature at A is $T_A = 300$ K. Calculate the temperature of the gas at the points B & D and find the efficiency of the cycle. [$(16^{0.4} = 3.03)$ $(1/8)^{0.4} = 0.435$]

**Ans.** $T_B = 909$ K, $T_D = 791$ K, $\eta = 61.4\%$

**Sol.**




AB $\rightarrow$ Adiabatic compression
BC $\rightarrow$ Isobaric expansion
CD $\rightarrow$ Adiabatic expansion
DA $\rightarrow$ Isochoric

(a) Temperature at B

$T_A V_A^{\gamma-1} = T_B V_B^{\gamma-1}$

$300(16\ V)^{\gamma-1} = T_B\ (V)^{\gamma-1}$

$T_B = 300\ (16)^{0.4} = 300 \times 3.03$

$= 909$ K

Temperature at C

$\frac{V_B}{T_B} = \frac{V_C}{T_C}$

$T_C = \frac{V_C}{V_B} \times T_B = 2 \times 909 = 1818$ K

Temperature at D

$T_C V_C^{\gamma-1} = T_D V_D^{\gamma-1}$

$T_D = T_C \times \left(\frac{V_C}{V_D}\right)^{\gamma-1} = 1818 \times \left(\frac{1}{8}\right)^{0.4}$

$= 1818 \times 0.435$

$= 790.83$ K $\simeq$ 791 K

(b) Efficiency of Cycle

$$\eta = 1-\frac{Q_{rejected}}{Q_{supplied}} = 1-\frac{Q_{DA}}{Q_{BC}}$$

$Q_{BC} = W_{BC} + \Delta U_{BC}$ (BC $\rightarrow$ Isobaric)

$$= \left(\frac{f}{2}+1\right)nR\Delta T = \frac{7}{2}\times R\times 909$$

$Q_{DA} = W_{DA} + \Delta U_{DA}$ (DA $\rightarrow$ Isochoric)

$$= \frac{f}{2}nR\Delta T = \frac{5}{2}\times R\times 491$$

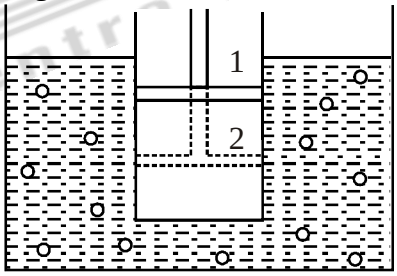
$$\eta = 1-\frac{\frac{5R}{2}\times 491}{\frac{7R}{2}\times 909}$$

$$= 1-\frac{491\times 5}{7\times 909}$$

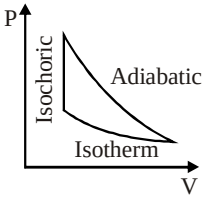
$= 0.6141$

$\eta = 61.4\%$

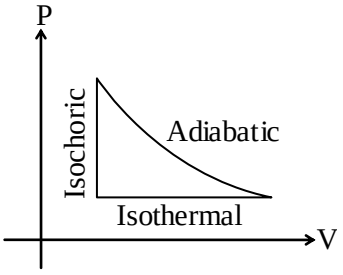
**11.** A cylinder containing a gas is closed by a movable piston. The cylinder is submerged in an ice-water mixture. The piston is quickly pushed down from position 1 to position 2. The piston is held at position 2 until the gas is again at 0°C and then slowly raised back to position 1. Represent the whole process on P-V diagram. If m = 100 gm of ice are melted during the cycle, how much work is done on the gas. Latent heat of ice = 80 cal/gm.




**Ans.** 8000 cal.




**Sol.**



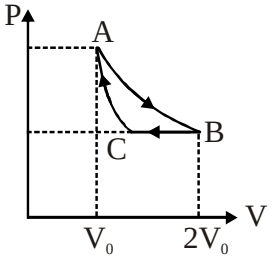

$Q_{cyclic} = W_{cyclic}$

$= m \times L$

$= 100 \times 80$

$= 8000$ Cal.

**12.** In a cyclic process ABCA consisting of isothermal expansion AB, isobaric compression BC and adiabatic compression CA, find the efficiency of cycle (Given : $T_A = T_B = 400$ K, $\gamma = 1.5$)




**Ans.** $1-\frac{3\left(1-\frac{1}{2^{1/3}}\right)}{l\,n\,2}$

## EXERCISE # (O-1)

**1.** Find the approx. number of molecules contained in a vessel of volume 7 litres at 0°C at $1.3 \times 10^5$ pascal

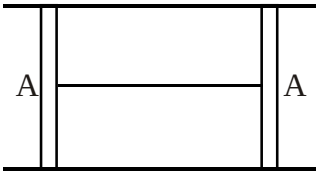
(A) $2.4 \times 10^{23}$ (B) $3 \times 10^{23}$ (C) $6 \times 10^{23}$ (D) $4.8 \times 10^{23}$

**Ans.** (A)

**Sol.** $1.3 \times 10^5 \times 7 \times 10^{-3} = n \times 8.31 \times 273$

$n = 0.4$

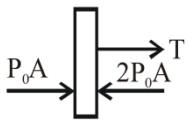
**2.** A cylindrical tube of cross-sectional area A has two air tight frictionless pistons at its two ends. The pistons are tied with a straight piece of metallic wire. The tube contains a gas at atmospheric pressure $P_0$ and temperature $T_0$. If temperature of the gas is doubled then the tension in the wire is




(A) $4\,P_0\,A$ (B) $P_0A/2$ (C) $P_0\,A$ (D) $2\,P_0\,A$

**Ans.** (C)

**Sol.** $P \rightarrow 2P$



**3.** A rigid tank contains 35 kg of nitrogen at 6 atm. Sufficient quantity of oxygen is supplied to increase the pressure to 9 atm, while the temperature remains constant. Amount of oxygen supplied to the tank is :

(A) 5 kg (B) 10 kg (C) 20 kg (D) 40 kg

**Ans.** (C)

**Sol.** V constant $P \propto n$

$$\frac{\frac{3}{28}}{\frac{m}{32}} = \frac{6}{3}$$

**4.** At a temperature T K, the pressure of 4.0g argon in a bulb is p. The bulb is put in a bath having temperature higher by 50K than the first one. 0.8g of argon gas had to be removed to maintained original pressure. The temperature T is equal to

(A) 510 K (B) 200 K (C) 100 K (D) 73 K

**Ans.** (B)

**Sol.** $P \times V = \frac{4}{40} \times R \times T$

$P \times V = \frac{3.2}{40} R(T+50)$

$T = 0.8(T + 50)$

$2T = 400$

$T = 200$

**5.** When 2 gms of a gas are introduced into an evacuated flask kept at 25°C the pressure is found to be one atmosphere. If 3 gms of another gas added to the same flask the pressure becomes 1.5 atmospheres. The ratio of the molecular weights of these gases will be

(A) 1 : 3 (B) 3 : 1 (C) 2 : 3 (D) 3 : 2

**Ans.** (A)

**Sol.** $P \times V = 2/m_1 \times R \times 298$

$1.5\ PV = (2/m_1 + 3/m_2)\ R \times 298 \Rightarrow 1 + \frac{m_1}{m_2} \times \frac{3}{2} = \frac{3}{2}$

**6.** 28 gm of $N_2$ gas is contained in a flask at a pressure of 10 atm and at a temperature of 57°. It is found that due to leakage in the flask, the pressure is reduced to half and the temperature reduced to 27°C.The quantity of $N_2$ gas that leaked out is

(A) 11/20 gm (B) 20/11 gm (C) 5/63 gm (D) 63/5 gm

**Ans.** (D)

**Sol.** $\frac{10 \times v}{5 \times v} = \frac{1}{n} \times \frac{R \times 330}{R \times 300}$

$300n = 330$

$n = \frac{330}{300} = \frac{11}{10} \times 14$

**7.** A vessel contains 1 mole of $O_2$ gas (molar mass 32) at a temperature T. The pressure of the gas is P. An identical vessel containing one mole of He gas (molar mass 4) at a temperature 2T has a pressure of

(A) P/8 (B) P (C) 2P (D) 8P

**Ans.** (C)

**Sol.** $P \times V = 1 \times RT$

$P_1 \times V = 1 \times R \times 2T$

**8.** A container X has volume double that of container Y and both are connected by a thin tube. Both contains same ideal gas. The temperature of X is 200K and that of Y is 400K. If mass of gas in X ism then in Y it will be:

(A) m/8 (B) m/6 (C) m/4 (D) m/2

**Ans.** (C)

**Sol.** $P \times 2V_0 = m \times R \times 200$

$P \times V_0 = M_1R \times 400$

$M_1 \times 400 = m \times 100$

$M_1 = \frac{m}{4}$

**9.** One mole of an ideal gas at STP is heated in an insulated closed container until the average speed of its molecules is doubled. Its pressure would therefore increase by factor.

(A) 1.5 (B) $\sqrt{2}$ (C) 2 (D) 4

**Ans.** (D)

**Sol.** $T \rightarrow 4T$

$\mathbf{P \rightarrow 4P}$

**10.** Three particles have speeds of 2u, 10u and 11u. Which of the following statements is correct?

(A) The r.m.s. speed exceeds the mean speed by about u.

(B) The mean speed exceeds the r.m.s. speed by about u.

(C) The r.m.s. speed equals the mean speed.

(D) The r.m.s. speed exceeds the mean speed by more than 2u.

**Ans.** (A)

**Sol.** $Vm = \frac{24+104+164}{3}$

$v_m = \frac{234}{3}$

$v_{rms} = \sqrt{\frac{4u^2+100u^2+121u^2}{3}} = \sqrt{\frac{225}{3}u^2} = u\sqrt{75}$

**11.** A gas mixture consists of 2 moles of oxygen and 4 moles of argon at temperature T. Neglecting all vibrational modes, the total internal energy of the system is

(A) 4 RT (B) 15 RT (C) 9 RT (D) 11 RT

**Ans.** (D)

**Sol.** $2 \times \frac{5}{2} RT + 4 \times \frac{8}{2} RT = 11RT$

**12.** One mole of an ideal gas is contained with in a cylinder by a frictionless piston and is initially at temperature T. The pressure of the gas is kept constant while it is heated and its volume doubles. If R is molar gas constant, the work done by the gas in increasing its volume is

(A) RT *l*n2 (B) 1/2 RT (C) RT (D) 3/2 RT

**Ans.** (C)

**Sol.** P(2V– V)

= PV = nRT

**13.** In thermodynamic process pressure of a fixed mass of gas is changed in such a manner that the gas releases 30 joule of heat and 18 joule of work was done on the gas. If the initial internal energy of the gas was 60 joule, then, the final internal energy will be :

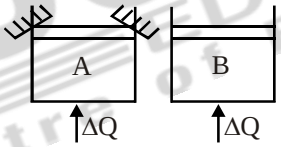
(A) 32 joule (B) 48 joule (C) 72 joule (D) 96 joule

**Ans.** (B)

**Sol.** $-30 = -18 + U_f - 60$

$U_f = 48$

**14.** Two identical vessels A & B contain equal amount of ideal monoatomic gas. The piston of A is fixed but that of B is free. Same amount of heat is absorbed by A & B. If B's internal energy increases by 100 J the change in internal energy of A is




(A) 100 J (B) $\frac{500}{3}$ J (C) 250 J (D) None of these

**Ans.** (B)

**Sol.** $\frac{3}{2} nR\Delta T = 100$

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

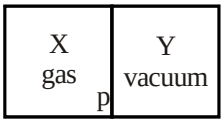
For isobaric $\Delta Q = n\frac{3}{2} R\Delta T + Rn\Delta T$

$= \frac{5}{2}(nR\Delta T)$

$\Delta Q = \frac{5}{3}\left(\frac{3}{2} nR\Delta T\right) = \frac{500}{3}$

$\Delta Q = \Delta U = \frac{500}{3}$

**15.** A closed container is fully insulated from outside. One half of it is filled with an ideal gas X separated by a plate P from the other half Y which contains a vacuum as shown in figure. When P is removed, X moves into Y. Which of the following statements is correct?




(A) No work is done by X (B) X decreases in temperature
(C) X increases in internal energy (D) X doubles in pressure

**Ans.** (A)

**16.** The first law of thermodynamics can be written as $\Delta U = \Delta Q + \Delta W$ for an ideal gas. Which of the following statements is correct?

(A) $\Delta U$ is always zero when no heat enters or leaves the gas

(B) $\Delta W$ is the work done by the gas in this written law.

(C) $\Delta U$ is zero when heat is supplied and the temperature stays constant

(D) $\Delta Q = -\Delta W$ when the temperature increases very slowly.

**Ans.** (C)

**17.** Water is heated in an open pan where the air pressure is $10^5$ Pa. The water remains a liquid, which expands by a small amount as it is heated. Determine the ratio of the heat absorbed by the water to the work done by water. (g for water = $10^{-3}$/C, S = 1 cal/gm°C)

(A) $4.2 \times 10^3$ (B) $4.2 \times 10^5$ (C) $4.2 \times 10^2$ (D) $4.2 \times 10^4$

**Ans.** (D)

**Sol.** $\dfrac{\Delta Q}{\Delta W} = \dfrac{ms\Delta T}{P\Delta V}$

**18.** An ideal gas mixture filled inside a balloon expands according to the relation $PV^{2/3}$ = constant. The temperature inside the balloon is

(A) increasing (B) decreasing (C) constant (D) can't be said

**Ans.** (A)

**Sol.** $\dfrac{PV}{V^{1/3}} = \dfrac{nRT}{V^{1/3}}$ = constant

$V \uparrow \Rightarrow T \uparrow$

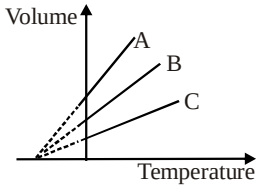
**19.** During an experiment an ideal gas obeys an addition equation of state $P^2V$ = constant. The initial temperature and pressure of gas are T and V respectively. When it expands to volume 2V, then its temperature will be:

(A) T (B) $\sqrt{2}T$ (C) 2T (D) $2\sqrt{2}T$

**Ans.** (B)

**Sol.** $\dfrac{T^2}{V} = \text{constant}$, $\dfrac{T_1}{T_2} = \sqrt{\dfrac{V_1}{V_2}}$

**20.** The expansion of an ideal gas of mass m at a constant pressure P is given by the straight line B. Then the expansion of the same ideal gas of mass 2 m at a pressure 2P is given by the straight line




(A) C (B) A (C) B (D) None of these

**Ans.** (C)

**Sol.** $\frac{nR}{P}$ = slope

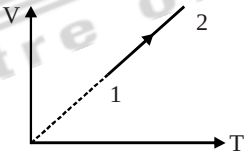
**21.** Two monoatomic ideal gas at temperature $T_1$ and $T_2$ are mixed. There is no loss of energy. If the masses of molecules of the two gases are m1 and m2 and number of their molecules are $n_1$ and $n_2$ respectively. The temperature of the mixture will be :

(A) $\frac{T_1+T_2}{n_1+n_2}$ (B) $\frac{T_1}{n_1}+\frac{T_2}{n_2}$ (C) $\frac{n_2T_1+n_1T_2}{n_1+n_2}$ (D) $\frac{n_1T_1+n_2T_2}{n_1+n_2}$

**Ans.** (D)

**Sol.** $\frac{3n_1}{N_A}\frac{f}{2}RT_1+\frac{n_2}{N_A}\frac{3}{2}fRT_2=\left(\frac{n_1+n_2}{N_A}\right)\left(\frac{3f}{2}R\right)T_f$

**22.** An ideal gas undergoes the process $1 \rightarrow 2$ as shown in the figure, the heat supplied and work done in the process is $\Delta Q$ and $\Delta W$ respectively. The ratio $\Delta Q : \Delta W$ is




(A) $\gamma : \gamma - 1$ (B) $\gamma$ (C) $\gamma - 1$ (D) $\gamma - 1/\gamma$

**Ans.** (A)

**23.** A reversible adiabatic path on a P-V diagram for an ideal gas passes through state A where $P = 0.7 \times 10^5$ N/m$^{-2}$ and V = 0.0049 m$^3$. The ratio of specific heat of the gas is 1.4. The slope of path at A is :

(A) $2.0 \times 10^7$ Nm$^{-5}$ (B) $1.0 \times 10^7$ Nm$^{-5}$ (C) $-2.0 \times 10^7$ Nm$^{-5}$ (D) $-1.0 \times 10^7$ Nm$^{-5}$

**Ans.** (C)

**Sol.** $PV^\gamma$ = constant

$dPV^\gamma + (\gamma v^{\gamma-1}\, dv)P = 0$

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

**24.** Monoatomic, diatomic and triatomic gases whose initial volume and pressure are same, are compressed till their volume becomes half the initial volume.

(A) If the compression is adiabatic then monoatomic gas will have maximum final pressure.

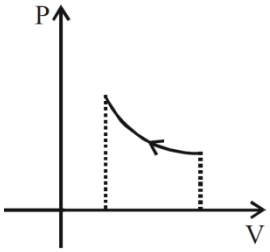
(B) If the compression is adiabatic then triatomic gas will have maximum final pressure.

(C) If the compression is adiabatic then their final pressure will be same.

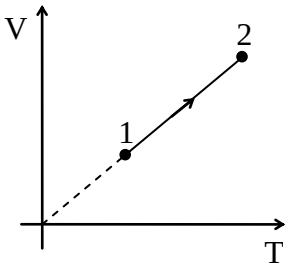
(D) If the compression is isothermal then their final pressure will be different.

**Ans.** (A)

**Sol.**




**Sol.**




$$\frac{V}{T} = \text{Constant}$$

$VT^{-1} = K$

$\Delta Q = \Delta U + W$

$$\Delta Q = n\frac{f}{2}R\Delta T + nR(\Delta T)$$

$$\frac{\Delta Q}{\Delta W} = \frac{n\frac{f}{2}R\Delta T + nR(\Delta T)}{nR(\Delta T)}$$

$$\frac{\Delta Q}{\Delta W} = \frac{f}{2} + 1 \qquad \ldots(1)$$

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

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

$$\frac{f}{2} = \frac{1}{\gamma - 1} \qquad \ldots(2)$$

From (1) & (2)

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

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

**25.** A polyatomic gas with six degrees of freedom does 25J of work when it is expanded at constant pressure. The heat given to the gas is

(A) 100J (B) 150J (C) 200J (D) 250J

**Ans.** (A)

**Sol.** $\Delta W = 25 = nR\Delta T$

$\Delta U = 3nR\Delta T = 75$

**26.** An ideal gas expands from volume $V_1$ to $V_2$. This may be achieved by either of the three processes: isobaric, isothermal and adiabatic. Let $\Delta U$ be the change in internal energy of the gas, Q be the quantity of heat added to the system and W be the work done by the system on the gas. Identify which of the following statements is false for $\Delta U$?

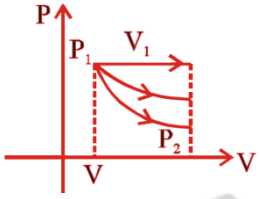
(A) $\Delta U$ is least under adiabatic process. (B) $\Delta U$ is greatest under adiabatic process.

(C) $\Delta U$ is greatest under the isobaric process.

(D) $\Delta U$ in isothermal process lies in-between the values obtained under isobaric and adiabatic processes.

**Ans.** (B)

**Sol.**




$\Delta U$ least in isobaric

$$\Delta U = \frac{3}{2}nR\Delta T = \frac{3}{2}nR[P_1V_2 - P_1V_1]$$

$$\Delta U = \frac{3}{2}nR\Delta T = \frac{3}{2}nR[P_2V_2 - P_1V_1] = \frac{3}{2}nR(P_1V_1 - P_2V_2) \Rightarrow P_2 < P_1$$

**27.** One mole of an ideal gas at temperature $T_1$ expends according to the law $\frac{P}{V^2} = a$ (constant). The work done by the gas till temperature of gas becomes $T_2$ is

(A) $\frac{1}{2}R(T_2 - T_1)$ (B) $\frac{1}{3}R(T_2 - T_1)$ (C) $\frac{1}{4}R(T_2 - T_1)$ (D) $\frac{1}{5}R(T_2 - T_1)$

**Ans.** (B)

**Sol.** $PV^{-2}$ = constant

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

**28.** The adiabatic Bulk modulus of a diatomic gas at atmospheric pressure is

(A) 0 $Nm^{-2}$ (B) 1 $Nm^{-2}$ (C) $1.4 \times 10^4$ $Nm^{-2}$ (D) $1.4 \times 10^5$ $Nm^{-2}$

**Ans.** (D)

**Sol.** $\gamma P = \frac{7}{5}\times 10^5$

**29.** A given quantity of an ideal gas is at pressure P and absolute temperature T. The isothermal bulk modulus of the gas is :

(A) 2P/3 (B) P (C) 3P/2 (D) 2P

**Ans.** (B)

**30.** 2 moles of a monoatomic gas are expanded to double its initial volume, through a process P/V = constant. If its initial temperature is 300 K, then which of the following is not true.

(A) $\Delta T = 900$ K (B) $\Delta Q = 3200$ R (C) $\Delta Q = 3600$ R (D) $W = 900$ R

**Ans.** (B)

**Sol.** $PV^{-1}$ = constant

$\Delta V = 2 \times 3R \times 900 = 2700$ R

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

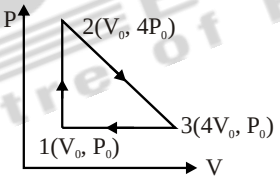
**31.** One mole of an ideal diatomic gas is taken through the cycle as shown in the figure.

$1 \rightarrow 2$ : isochoric process

$2 \rightarrow 3$ : straight line on P-V diagram

$3 \rightarrow 1$ : isobaric process

The average molecular speed of the gas in the states 1, 2 and 3 are in the ratio




(A) 1 : 2 : 2 (B) $1:\sqrt{2}:\sqrt{2}$ (C) 1 : 1 : 1 (D) 1 : 2 : 4

**Ans.** (A)

**Sol.** For point (i)

$P_0V_0 = nRT_1$

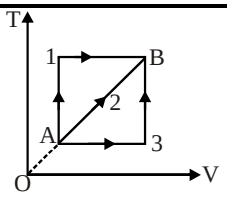
For point (ii)

$V_0 \times 4P_0 = nRT_2$

For point (iii)

$4V_0 \times P_0 = nRT_3$

**32.** A given mass of a gas expands from a state A to the state B by three paths 1, 2 and 3 as shown in T-V indicator diagram. If $W_1$, $W_2$ and $W_3$ respectively be the work done by the gas along the three paths, then




(A) $W_1 > W_2 > W_3$ (B) $W_1 < W_2 < W_3$ (C) $W_1 = W_2 = W_3$ (D) $W_1 < W_2$, $W_1 > W_3$

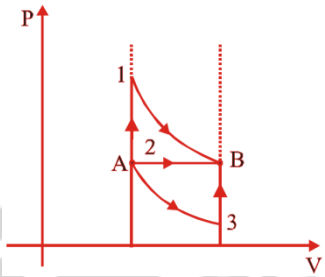
**Ans.** (A)

**Sol.** $W_1 = nRT_2 \ell n\left(\frac{v_2}{v_1}\right)$ $\frac{v_1}{T_1} = \frac{v_2}{T_2}$

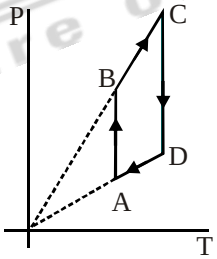
$= nRT_2\left(\ell n\left(\frac{T_2}{T_1}\right)\right)$

$W_2 = nR\Delta T = nR(T_2 - T_1) = nRT_2\left(1 - \frac{T_1}{T_2}\right)$

$W_2 = nRT_1 \ell n\left(\frac{v_2}{v_1}\right)$




**33.** Pressure versus temperature graph of an ideal gas is shown in figure
(A) During the process AB work done by the gas is positive
(B) During the process CD work done by the gas is negative
(C) During the process BC internal energy of the gas is increasing
(D) None



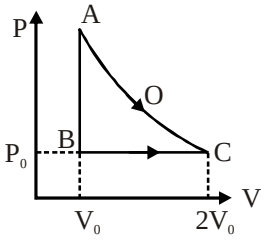

**Ans.** (C)

**Sol.** P↑V↓

isobaric

ΔT↑

**34.** An ideal gas is taken from point A to point C on P-V diagram through two process AOC and ABC as shown in the figure. Process AOC is isothermal

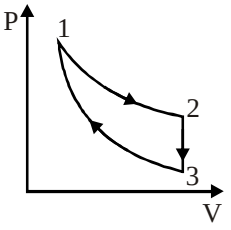


(A) Process AOC requires more heat than process ABC.
(B) Process ABC requires more heat than process AOC.
(C) Both process AOC & ABC require same amount of heat.
(D) Data is insufficient for comparison of heat requirement for the two processes.

**Ans.** (A)

**Sol.** $\omega_{ADC} > \omega_{ABC}$

**35.** Three processes form a thermodynamic cycle as shown on P-V diagram for an ideal gas. Process $1 \rightarrow 2$ takes place at constant temperature (300K). Process $2 \rightarrow 3$ takes place at constant volume. During this process 40J of heat leaves the system. Process $3 \rightarrow 1$ is adiabatic and temperature $T_3$ is 275K. Work done by the gas during the process $3 \rightarrow 1$ is




(A) –40J (B) –20J (C) +40J (D) +20J

**Ans.** (A)

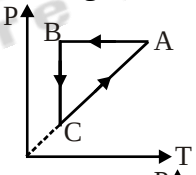
**Sol.** $\Delta U_{Cycl} = 0 = U_{1-2} + U_{2-3} + U_{3-1} = 0$

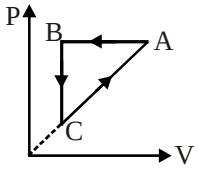
$0 + (-40) + U_{3-1} = 0$

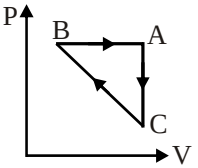
$-\Delta U_{3-1} = W_{3-1}$

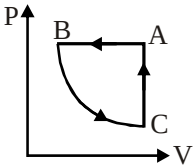
$W_{3-1} = -40$

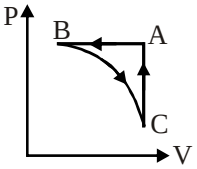
**36.** A cyclic process ABCA is shown in PT diagram. When presented on PV, it would



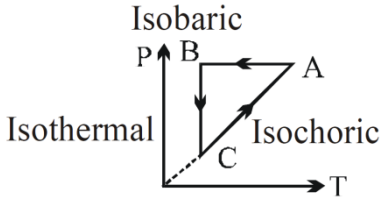

(A) 


(B) 


(C) 


(D) 


**Ans.** (C)

**Sol.** 


**37.** A student records $\Delta Q$, $\Delta U$ & $\Delta W$ for a thermodynamic cycle $A \rightarrow B \rightarrow C \rightarrow A$. Certain entries are missing. Find correct entry in following options.

| | AB | BC | CA |
|---|---|---|---|
| $\Delta W$ | 40 J | | 30 J |
| $\Delta U$ | | 50J | |
| $\Delta Q$ | 150J | 10J | |

(A) $W_{BC} = -70$ J (B) $\Delta Q_{CA} = 130$ J (C) $\Delta U_{AB} = 190$ J (D) $\Delta U_{CA} = -160$ J

**Ans.** (D)

**Sol.** $\Sigma\Delta U = 0$

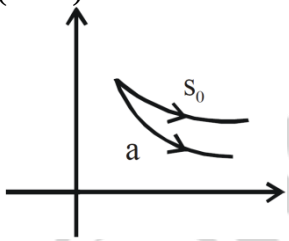
$\Sigma\Delta w = \Sigma Q$

## MULTIPLE CORRECT TYPE QUESTIONS

**38.** Two gases have the same initial pressure, volume and temperature. They expand to the same final volume, one adiabatically and the other isothermally
(A) The final temperature is greater for the isothermal process
(B) The final pressure is greater for the isothermal process
(C) The work done by the gas is greater for the isothermal process
(D) All the above options are incorrect

**Ans.** (ABC)

**Sol.**




## COMPREHENSION BASED QUESTIONS

Five moles of helium are mixed with two moles of hydrogen to form a mixture. Take molar mass of helium $M_1 = 4g$ and that of hydrogen $M_2 = 2g$

**39.** The equivalent molar mass of the mixture is

(A) 6g (B) $\frac{13g}{7}$ (C) $\frac{18g}{7}$ (D) None

**Ans.** (D)

**Sol.** $n_1 = 5$ (He)

$n_2 = 2$ (He)

$$\text{Molar mass of mixture} = \frac{\text{Total Mass}}{\text{Total No Moles}}$$

$$= \frac{5\times 4 + 2\times 2}{7} = \frac{24}{7}\text{g}$$

**40.** The equivalent degree of freedom f of the mixture is

(A) 3.57 (B) 1.14 (C) 4.4 (D) none

**Ans.** (A)

**Sol.** $C_{P(mix)} = \frac{n_1 Cp_1 + n_2 Cp_2}{n_1 + n_2}$

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

$= \frac{39\ R}{14}$

$C_{V(mix)} = \frac{n_1 Cv_1 + n_2 Cv_2}{n_1 + n_2} = \frac{5 \times \frac{3}{2} R + 2 \times \frac{5}{2} R}{7}$

$= \frac{25\ R}{14}$

$\gamma_{mix} = \frac{(C_P)_{mix}}{(C_v)_{mix}} = \frac{\frac{39R}{14}}{\frac{25R}{14}} = \frac{39}{25}$

$\gamma_{mix} = 1.56$

$\gamma_{mix} = 1 + \frac{2}{f}$

$\frac{2}{f} = 0.56$

$f = \frac{2}{0.56} = 3.57$

**41.** The equivalent value of $\gamma$ is

(A) 1.59 (B) 1.53 (C) 1.56 (D) none

**Ans.** (C)

**Sol.** Same as solution to above question

**42.** If the internal energy of He sample is 100J and that of the hydrogen sample is 200J, then the internal energy of the mixture is

(A) 900 J (B) 128.5 J (C) 171.4 J (D) 300 J

**Ans.** (D)

**Sol.** $\Delta U_{He} = 100$ J

$\Delta U_{H_2} = 200$ J

$\Delta U_{mix} = \Delta U_{He} + \Delta U_{H_2}$

$= 100 + 200 = 300$ J

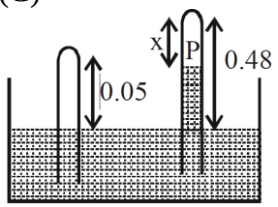
# EXERCISE # (O-2)

**1.** An open and wide glass tube is immersed vertically in mercury in such a way that length 0.05 m extends above mercury level. The open end of the tube is closed and the tube is raised further by 0.43m. The length of air column above mercury level in the tube will be : Take $P_{atm}$ = 76 cm of mercury

(A) 0.215 m (B) 0.2 m (C) 0.1 m (D) 0.4 m

**Ans.** (C)

**Sol.**




$$\frac{(0.05A)76}{RT} = \frac{(P \times xA)}{RT}$$

$0.05 \times 76 = Px$ …(i)

$P + (48 - x) = 76$

$P = 76 - 48 + x$

$P = 28 + x$ …(ii)

Now $3.80 = (28 + x)x$

$x^2 + 28x - 3.8 = 0$

$x = 0.135$ & $-28.13$

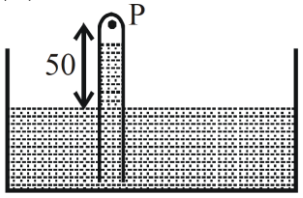
$x = 0.135$ ans.

**2.** A barometer tube, containing mercury, is lowered in a vessel containing mercury until only 50 cm of the tube is above the level of mercury in the vessel. If the atmospheric pressure is 75 cm of mercury, what is the pressure at the top of the tube?

(A) 33.3 kPa (B) 66.7 kPa (C) 3.33 MPa (D) 6.67 MPa

**Ans.** (A)

**Sol.**




$P_{at}. 75 \rho g = 10^5$

$P + 50 \times \rho g = 75 \rho g$

$P = 25 \rho g$

$= \frac{10^5}{3} = 33.3 \times 10^3$ Pa

**3.** At temperature T, N molecules of gas A each having mass m and at the same temperature 2N molecules of gas B each having mass 2m are filled in a container. The mean square velocity of

molecules of gas B is $v^2$ and mean square of x component of velocity of molecules of gas A is $w^2$. The ratio of $w^2/v^2$ is :

(A) 1 (B) 2 (C) 1/3 (D) 2/3

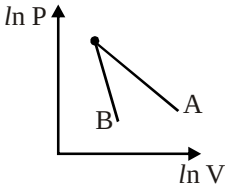
**Ans.** (D)

**Sol.** For gas A For B

$\omega^2 = \frac{1}{2}\left(\frac{3R}{M}\right)$ $v^2 = \frac{3RT}{2M}$

$\frac{v^2}{\omega^2} = \frac{2}{3}$

**4.** The figure, shows the graph of logarithmic reading of pressure and volume for two ideal gases A and B under going adiabatic process. From figure it can be concluded that




(A) gas B is diatomic (B) gas A and B both are diatomic

(C) gas A is monoatomic (D) gas B is monoatomic & gas A is diatomic

**Ans.** (D)

**Sol.** $PV^{\gamma} = C$

$\ell nP + \gamma \ell nV = \ell mC$

$\ell nP = -\gamma \ell nV + \ell nC$

$\gamma = mx + C$

$m = -\gamma$

Slope of B > slope A

**5.** When unit mass of water boils to become steam at 100°C, it absorbs Q amount of heat. The densities of water and steam at 100°C are $\rho_1$ and $\rho_2$ respectively and the atmospheric pressure is $p_0$. The increase in internal energy of the water is

(A) Q (B) $Q + P_0\left(\frac{1}{\rho_1} - \frac{1}{\rho_2}\right)$ (C) $Q + P_0\left(\frac{1}{\rho_2} - \frac{1}{\rho_1}\right)$ (D) $Q - P_0\left(\frac{1}{\rho_2} + \frac{1}{\rho_1}\right)$

**Ans.** (B)

**Sol.** $\Delta Q = \Delta U + \Delta w$

$\Delta U + \Delta Q - \Delta w$

$W = P_0\Delta V = P_0(V_f - V_i) = P_0\left[\frac{1}{\rho_2} - \frac{1}{\rho_1}\right]$

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

**6.** A cylinder made of perfectly non conducting material closed at both ends is divided into two equal parts by a heat proof piston. Both parts of the cylinder contain the same masses of a gas at a temperature $t_0 = 27°$ C and pressure $P_0 = 1$ atm. Now if the gas in one of the parts is slowly heated to t = 57°C while the temperature of first part is maintained at $t_0$ the distance moved by the piston from the middle of the cylinder will be (length of the cylinder = 84 cm)

(A) 3 cm (B) 5 cm (C) 2 cm (D) 1 cm

**Ans.** (C)

**Sol.** $\Delta U$ same

$16 - 20 = 9 - W$

$W = 9 + 4$

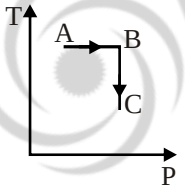
**7.** 1 kg of a gas does 20 kJ of work and receives 16 kJ of heat when it is expanded between two states. A second kind of expansion can be found between the initial and final state which requires a heat input of 9 kJ. The work done by the gas in the second expansion is :

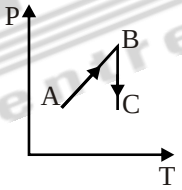
(A) 32 kJ (B) 5 kJ (C) – 4 kJ (D) 13 kJ

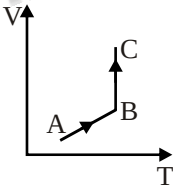
**Ans.** (D)

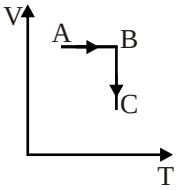
**8.** A process is shown in the diagram. Which of the following curves may represent the same process?




(A) 


(B) 


(C) 


(D) 


**Ans.** (C)

**Sol.** AB $\rightarrow$ isobaric

BC $\rightarrow$ May be isothermal

**9.** An ideal gas expands in such a way that $PV^2$ = constant throughout the process.

(A) The graph of the process of T-V diagram is a parabola.

(B) The graph of the process of T-V diagram is a straight line.

(C) Such an expansion is possible only with heating.

(D) Such an expansion is possible only with cooling.

**Ans.** (D)

**Sol.** $PV^2 = con$

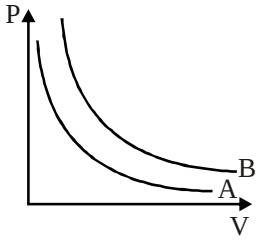
$(nRT)V = com$ (D)

$TV = con \Rightarrow$ V increase T decrease

Hypberbola

$$C_{proe} = C_V + \frac{R}{1-m} = C_V + \frac{R}{1-2} = C_V - R$$

**10.** Figure shows the pressure P versus volume V graphs for two different gas sample at a given temperature. $M_A$ and $M_B$ are masses of two samples, $n_A$ and $n_B$ are numbers of moles. Which of the following must be incorrect




(A) $M_A > M_B$ (B) $M_A < M_B$ (C) $n_A > n_B$ (D) $n_A < n_B$

**Ans.** (C)

**Sol.** Equation of hyperbola

$PV = nRT$

$(nRT)_B > (nRT)_A$

$n_B > n_A$

there is no necessary condition of mass.

**11.** A vertical cylinder with heat-conducting walls is closed at the bottom and is fitted with a smooth light piston. It contains one mole of an ideal gas. The temperature of the gas is always equal to the surrounding's temperature, $T_0$. The piston is moved up slowly to increase the volume of the gas to $\eta$ times. Which of the following is incorrect?

(A) Work done by the gas is $RT_0 \ln \eta$.

(B) Work done against the atmosphere is $RT_0(\eta - 1)$.

(C) There is no change in the internal energy of the gas.

(D) The final pressure of the gas is $\frac{1}{(\eta - 1)}$ times its initial pressure.

**Ans.** (D)

**Sol.** Isobaric process

(A) $_{RT0}\ell n\, V_f/V_i$

(B) $P\Delta V = P(\eta - 1)V_0 = 1RT_0 (\eta - 1)$

(C) No change in temperature

(D) Initial & final pressure are same

**12.** A gas is enclosed in a vessel at a constant temperature at a pressure of 5 atmosphere and volume 4 litre. Due to a leakage in the vessel, after some time, the pressure is reduced to 4 atmosphere. As a result, the

(A) volume of the gas decreased by 20%

(B) average K.E. of gas molecule decreases by 20%

(C) 20% of the gas escaped due to the leakage

(D) 25% of the gas escaped due to the leakage

**Ans.** (C)

**Sol.** $PV = nRT$

$5 \times 4 = n_1RT$

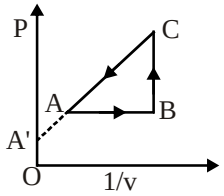
$4 \times 4 = n_2RT$

Now – volume of vessel remain same.

Now – Temperature is same so KE same.

$$\text{leakage} = \frac{n_1 - n_2}{n_1} \times 100 = \frac{4}{20} \times 100 = 20\%$$

**13.** An enclosed ideal gas is taken through a cycle as shown in the figure. Then




(A) Along AB, temperature decreases while along BC temperature increases
(B) Along AB, temperature increases while along BC the temperature decreases.
(C) Along CA work is done by the gas and the internal energy remains constant.
(D) Along CA work is done on the gas and internal energy of the gas increases.

**Ans.** (A)

**Sol.** For AB : Pressure constant $\frac{1}{V}$ increases so V decreases

so $PV \rightarrow$ decreases

Temperature decreases

For BC:

V constant $\Rightarrow$ P increases so

PV increases $\Rightarrow$ Temp increase

$$P = \frac{m}{V} + C$$

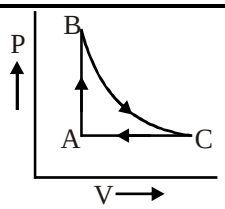
$PV = m + CV$

$nRT = m + CV$

$\frac{1}{V}$ decreases so V increase

T increase, work done by the gas.

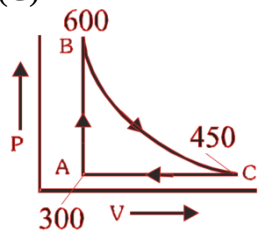
**14.** One mole of diatomic ideal gas undergoes a cyclic process ABCA as shown in figure. Process BC is adiabatic. The temperatures at A, B and C are 300, 600 and 450K respectively. Choose the correct statement(s).




(A) In process CA change in internal energy is 225R.
(B) In process AB change in internal energy is –150R.
(C) In process BC change in internal energy is –375R.
(D) Change in internal energy during the whole cyclic process is +150R.

**Ans.** (C)

**Sol.**




$\Delta U = nC_V\Delta T$ $\quad\quad$ $\Delta T_{AB} = 300$

$= 1 \times \frac{3}{2} R(\Delta T)$ $\quad\quad$ $\Delta T_{BC} = -150$

$\Delta U_{cycle} = 0$ $\quad\quad$ $T_{CA} = -150$

## MULTIPLE CORRECT TYPE QUESTIONS

**15.** Let $v_{av}$, $v_{rms}$ and $v_p$ respectively denote mean speed, root mean square speed and the most probable speed of the molecule in an ideal monoatomic gas at absolute temperature T. The mass of a molecule is m then :

(A) no molecule can have speed greater than $\sqrt{2}\, v_{rms}$

(B) no molecule can have speed less than $v_p / \sqrt{2}$

(C) $v_p < v_{av} < v_{rms}$

(D) the average kinetic energy of a molecule is $3/4mv_p^2$

**Ans.** (CD)

**Sol.** No condition for greater and least speed

$V_R > V_a > V_P$

$KE = \frac{1}{2} m (V_{rms})^2$

$\frac{V_{rms}}{V_P} - \frac{\sqrt{3}}{\sqrt{2}}$

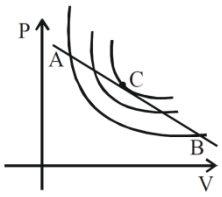
**16.** A gas expands such that its initial and final temperature are equal. Also, the process followed by the gas traces a straight line on the P-V diagram :

(A) The temperature of the gas remains constant throughout.
(B) The temperature of the gas first increases and then decreases
(C) The temperature of the gas first decreases and then increases

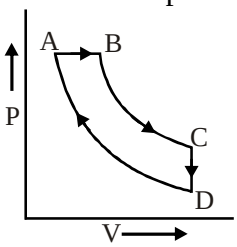
(D) The straight line has a negative slope.

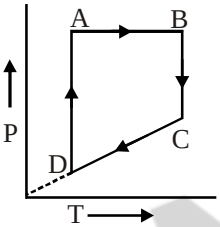
**Ans.** (BD)

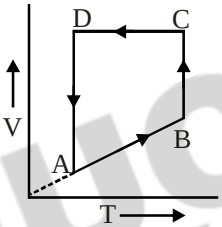
**Sol.** Temp increases from A to C them decrease from C to B

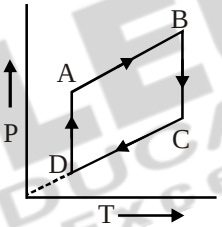


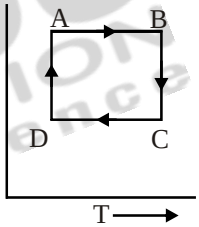

**17.** A cyclic process ABCD is shown in the p-V diagram. Which of the following curves represents the same process if BC & DA are isothermal processes




(A) 


(B) 


(C) 


(D) 


**Ans.** (AB)

**Sol.** $A \rightarrow B$ isobaric

$C \rightarrow D$ isochoric

in PT graph CD will be the line passing from origin

in VT graph AB

**18.** During the melting of a slab of ice at 273 K at atmospheric pressure

(A) Positive work is done by the ice-water system on the atmosphere

(B) Positive work is done on the ice-water system by the atmosphere

(C) The internal energy of the ice-water increases

(D) The internal energy of ice-water system decreases

**Ans.** (BC)

**Sol.** $\delta_{wa} > \delta_{ice}$

volume decrease

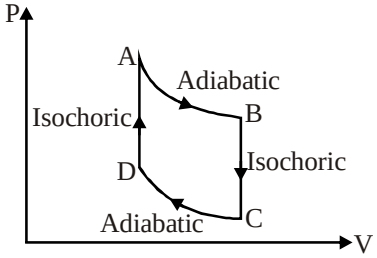
work done on the gas W(–ve)

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

$O = \Delta U + \Delta W$

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

**19.** Two moles of helium gas is taken through the cycle ABCDA as shown in the figure. If $T_A$ = 1000 K, $2P_A = 3P_B = 6P_C$.




(A) work done by the gas in the process A to B is 3741 J.
(B) heat lost by the gas in the process B to C is 10600 J.
(C) temperature $T_D$ is 2000 K.
(D) None of these

**Ans.** (AB)

**Sol.** A + B

$$T_A^{\gamma} P^{1-\gamma} = T_B^{\gamma} P_B^{1-\gamma}$$

$$T_B = 1000 \left(\frac{3}{2}\right)^{-2/5}$$

$$W = -nC_V\Delta T = -2 \times \frac{3}{2} \times R[T_B - T_A]$$

for BC

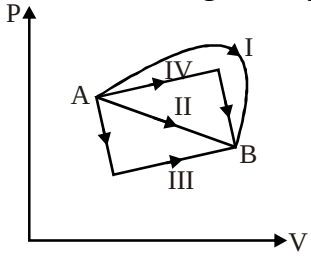
$$\frac{P_B}{T_B} = \frac{P_C}{T_C} \Rightarrow T_C = T_B \times \frac{P_C}{P_B} = 2000\left(\frac{3}{2}\right)^{-2/5}$$

$$\Delta Q_{BC} = nC_V\Delta T$$

$$= 2 \times \frac{3}{2} R(T_C - T_B)$$

$$= 3R \left(1000 \times \left(\frac{3}{2}\right)^{-2/5}\right)$$

**20.** Figure shows the P-V diagram of an ideal gas undergoing a change of state from A to B. Four different parts I, II, III and IV as shown in the figure may lead to the same change of state.




(A) Change in internal energy is same in IV and III cases, but not in I and II.
(B) Change in internal energy is same in all the four cases.
(C) Work done is maximum in case I
(D) Work done is minimum in case II.

**Ans.** (BC)

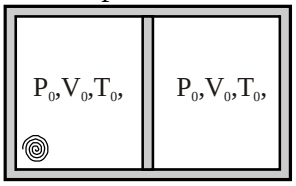
**Sol.** (1) $\Delta U$ does not depends on path

(2) Work done depends area of PV graph

## COMPREHENSION BASED QUESTIONS

**Paragraph for Question No. 21 to 23**

One mole of a monoatomic ideal gas occupies two chambers of a cylinder partitioned by means of a movable piston. The walls of the cylinder as well as the piston are thermal insulators. Initially equal amounts of gas fill both the chambers at ($P_0$, $V_0$, $T_0$). A coil is burnt in the left chamber which absorbs heat and expands, pushing the piston to the right. The gas on the right chamber is compressed until to pressure becomes 32 $P_0$.




**21.** The final volume of left chamber is

(A) $\frac{V_0}{8}$ (B) $\frac{15}{8}V_0$ (C) $\frac{7}{8}V_0$ (D) $\frac{9}{8}V_0$

**Ans.** (B)

**Sol.** for right chamber

$PV^{\gamma}$ = constant

$P_0 V_0^{5/3} = (32P_0)(V_5)^{5/3}$

$V_f = \frac{V_0}{(32)^{3/5}} = \frac{V_0}{8}$

$V_{left} = 2V_0 - \frac{V_0}{8} = \frac{15V_0}{8}$

**22.** The work done on the gas in the right chamber is

(A) $\frac{9}{2}P_0V_0$ (B) $-\frac{9}{2}P_0V_0$ (C) $\frac{13}{2}P_0V_0$ (D) $\frac{17}{2}P_0V_0$

**Ans.** (A)

**Sol.** $W = -nC_V\Delta T$

$= \frac{3}{2}\left[P_0V_0 - (32V_0)\left(\frac{V_0}{8}\right)\right] = -\frac{9}{2}P_0V_0$

on the gas $\frac{9}{2}P_0V_0$

**23.** The change in internal energy of the gas in the left chamber is

(A) $\frac{186}{4}RT_0$ (B) $\frac{177}{4}RT_0$ (C) $\frac{59}{2}RT_0$ (D) $\frac{131}{4}RT_0$

**Ans.** (B)

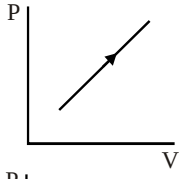
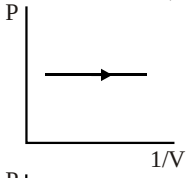
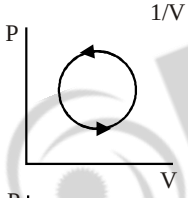
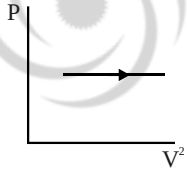
**Sol.** $\Delta U = nC_V\Delta T = \frac{3}{2}nR(T_f - T_i) = \frac{3}{2}\left[(32P_0)\left(\frac{15V_0}{8}\right) - P_0V_0\right] = \frac{3}{2}[59P_0V_0]$

$= \frac{177}{2}P_0V_0 \qquad \left(P_0V_0 = \frac{1}{2}RT_0\right)$

$\Delta U = \frac{177}{4}RT_0$

## MATRIX MATCH TYPE QUESTION

**24.**

| **Column-I (Pressure volume graph)** | | **Column II (W is work done by gas, Q heat supply to gas)** | |
|---|---|---|---|
| (A) |   | (P) | $W > 0$ |
| (B) |   | (Q) | $W < 0$ |
| (C) |   | (R) | $Q > 0$ |
| (D) |   | (S) | $Q < 0$ |

**Ans.** (A) → PR; (B) → QS; (C) → QS; (D) → PR;

**Sol.** (A) volume increase so $W > 0$

PV product increase so temperature increase

$\Delta U > 0$ so $\Delta Q > 0$

(B) Volume decrease so $W < 0$

PV product decreases so temperature decreases

$\Delta U < 0$ so $\Delta Q < 0$

(C) Cycle is anticlock wise $W < 0$

$W_{cycle} = Q_{cycle}$

(D) Isobaric process with increases in pressure

so $W > 0$ & $Q > 0$

# EXERCISE # (JM)

**1.** Two rigid boxes containing different ideal gases are placed on a table. Box A contains one mole of nitrogen at temperature $T_o$, while box B contains one mole of helium at temperature $(7/3)T_o$. The boxes are then put into thermal contact with each other, and heat flows between them until the gases reach a common final temperature. (Ignore the heat capacity of boxes). Then, the final temperature of the gases, $T_f$ in terms of $T_0$ is : **[AIEEE-2006]**

(1) $T_f = \frac{3}{7}T_0$ (2) $T_f = \frac{7}{3}T_0$ (3) $T_f = \frac{3}{2}T_0$ (D) $T_f = \frac{5}{2}T_0$

**Ans.** (3)

**Sol** Equating internal energy,

$$1\times\frac{5}{2}RT_0 + 1\times\frac{3}{2}R\left(\frac{7}{3}T_0\right) \quad \Rightarrow \quad T_f = \frac{3}{2}T_0$$

**2.** The work of 146 kJ is performed in order to compress one kilo mole of a gas adiabatically and in this process the temperature of the gas increases by 7°C. The gas is **[AIEEE–2006]**
($R = 8.3\ J\ mol^{-1}\ K^{-1}$)

(1) diatomic (2) triatomic
(3) mixture of monoatomic and diatomic (4) monoatomic

**Ans.** (1)

**Sol.** For adiabatic , $W = \frac{P_1V_1 - P_2V_2}{\gamma - 1} = \frac{nR(T_1 - T_2)}{\gamma - 1}$

Putting values, we get $\gamma = 1.4$, hence diatomic.

**3.** A Carnot engine, having an efficiency of $\eta = 1/10$ as heat engine, is used as a refrigerator. If the work done on the system is 10 J, the amount of energy absorbed from the reservoir at lower temperature is **[AIEEE - 2007]**

(1) 99 J (2) 90 J (3) 1 J (4) 100 J

**Ans.** (2)

**Sol.** For Carnot engine using as refrigerator

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

It is given $\eta = \frac{1}{10} \quad \Rightarrow \quad \eta = 1 - \frac{T_2}{T_1} \quad \Rightarrow \quad \frac{T_2}{T_1} = \frac{9}{10}$

So, $Q_2 = 90$ J (as W = 10 J)

**4.** If $C_p$ and $C_V$ denote the specific heats of nitrogen per unit mass at constant pressure and constant volume respectively, then **[AIEEE - 2007]**

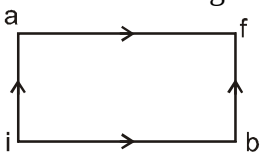
(1) $C_p - C_v = R/28$ (2) $C_p - C_v = R/14$ (3) $C_p - C_v = R$ (4) $C_p - C_v = 28R$

**Ans.** (1)

**Sol.** According to Mayer's relation,

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

**5.** When a system is taken from state i to state f along the path iaf, it is found that Q = 50 cal and W = 20 cal. Along the path ibf Q = 36 cal. W along the path ibf is : **[AIEEE - 2007]**




(1) 6 cal (2) 16 cal (3) 66 cal (4) 14 cal

**Ans.** (1)

**Sol.** From first law of thermodynamics,

$Q = \Delta U + W$

For path iaf,

$50 = \Delta U + 20$

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

For path ibf,

or $Q = \Delta U + W$

$W = Q - \Delta U$

$= 36 - 30 = 6$ cal.

**6.** An insulated container of gas has two chambers separated by an insulating partition. One of the chambers has volume $V_1$ and contains ideal gas at pressure $p_1$ and temperature $T_1$. The other chamber has volume $V_2$ and contains ideal gas at pressure $p_2$ and temperature $T_2$. If the partition is removed without doing any work on the gas, the final equilibrium temperature of the gas in the container will be - **[AIEEE-2008]**

(1) $\frac{T_1T_2(p_1V_1 + p_2V_2)}{p_1V_1T_2 + p_2V_2T_1}$ (2) $\frac{p_1V_1T_1 + p_2V_2T_2}{p_1V_1 + p_2V_2}$

(3) $\frac{p_1V_1T_2 + p_2V_2T_1}{p_1V_1 + p_2V_2}$ (4) $\frac{T_1T_2(p_1V_1 + p_2V_2)}{p_1V_1T_1 + p_2V_2T_2}$

**Ans.** (1)

**Sol.** 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, $U = U_1 + U_2$

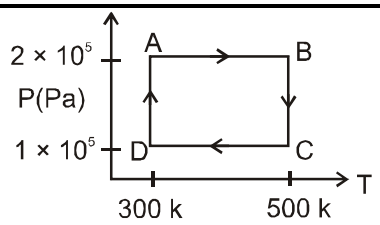
Assuming both gases have same degree of freedom, then

$U = \frac{f(n_1 + n_2)RT}{2}$ and $U_1 = \frac{fn_1RT_1}{2}$, $\quad U_2 = \frac{fn_2RT_2}{2}$

Solving we get $T = \frac{(p_1V_1 + p_2V_2)T_1T_2}{p_1V_1T_2 + p_2V_2T_1}$

**Directions : Question number 7, 8 and 9 are based on the following paragraph.**

Two moles of helium gas are taken over the cycle ABCDA, as shown in the P-T diagram. **[AIEEE-2009]**




**7.** Assume the gas to be ideal the work done on the gas in taking it from A to B is :
(1) 200 R (2) 300 R (3) 400 R (4) 500 R

**Ans.** (3)

**Sol.** n (moles) = 2
A to B is isobaric process
$W_{AB} = P\Delta V = nR\Delta T$
$= (2)(R)(200)$
$= 400\ R$
$W_{AB} = 400\ R$
$(W_{AB})_{\text{on the gas}} = -400\ R$

**8.** The work done on the gas in taking it from D to A is
(1) –414 R (2) + 414 R (3) – 690 R (4) + 690 R

**Ans.** (2)

**Sol.** D to A is isothermal process
Work done by the gas in D to A is

$$W_{DA} = nRT \ln \frac{V_2}{V_1} = nRT \ln \frac{P_1}{P_2}$$

$$= (2)(R)(300) \ln \frac{10^5}{2\times10^5}$$

$= (600\ R)[-\ln 2]$
$= -(600\ R)(0.693)$
$= -414\ R$
$W_{DA} = -414$ R, it is work done by the gas
So work done on the gas is + 414 R

**9.** The net work done on the gas in the cycle ABCDA is:
(1) Zero (2) 276 R (3) 1076 R (4) 1904 R

**Ans.** (2)

**Sol.** $W_{ABCDA} = W_{AB} + W_{BC} + W_{CD} + W_{DA}$

$$= nR(\Delta T)_{AB} + nR(T_B)\ln\frac{P_B}{P_C}$$

$$+ nR(\Delta T)_{CD} + nR(T_D)\ln\frac{P_D}{P_A}$$

$$= nR(200) + 500\ nR\ln 2 + nR(-200) + 300\ nR\ln\frac{1}{2}$$

$= 2\ln 2\ [500\ R - 300\ R]$
$= (400\ R)(\ln 2) = (400\ R)(0.693) = 276\ R$

$W_{ABCDA} = 276\ R$

**10.** One kg of a diatomic gas is at a pressure of $8 \times 10^4$ N/m$^2$. The density of the gas is 4 kg/m$^3$. What is the energy of the gas due to its thermal motion? **[AIEEE-2009]**

(1) $5 \times 10^4$J (2) $6 \times 10^4$J (3) $7 \times 10^4$J (4) $3 \times 10^4$J

**Ans.** (1)

**Sol.** $\frac{m}{d} = \frac{1}{4} m^3$

kE = for diatomic

$kE = \frac{5}{2} PV = \frac{5}{2} \times 8 \times 10^4 \times \frac{1}{4} = 5 \times 10^4$ J

**11.** A diatomic ideal gas is used in a Carnot engine as the working substance. If during the adiabatic expansion part of the cycle the volume of the gas increases from V to 32 V, the efficiency of the engine is : **[AIEEE-2010]**

(1) 0.5 (2) 0.75 (3) 0.99 (4) 0.25

**Ans.** (2)

**Sol.** $TV^{\gamma - 1}$ = constant

$T_1 V^{\frac{7}{5}-1} = T_2 (32V)^{\frac{7}{5}-1}$

$\frac{T_2}{T_1} = \frac{1}{(32)^{2/5}} = \frac{1}{4}$

$\eta = 1 - \frac{T_2}{T_1} = 1 - \frac{1}{4} = \frac{3}{4}$

**12.** 100g of water is heated from 30ºC to 50ºC ignoring the slight expansion of the water, the change in its internal energy is (specific heat of water is 4184 J/Kg/K) : **[AIEEE-2011]**

(1) 4.2 kJ (2) 8.4 kJ (3) 84 kJ (4) 2.1 kJ

**Ans.** (2)

**Sol.** $\Delta Q = M,S,\Delta T$

$= 100 \times 10^{-3} \times 4.184 \times 20$

$= 8.4 \times 10^3$

$\Delta Q = 8.4$ kJ, $\Delta W = 0$

$\Delta Q = \Delta u + \Delta W$

$\therefore \quad \Delta u = 8.4$ kJ.

**13.** A Carnot engine operating between temperatures $T_1$ and $T_2$ has effeiciency $\frac{1}{6}$. When $T_2$ is lowered by 62 K, its efficiency increases to $\frac{1}{3}$. Then $T_1$ and $T_2$ are, respectively :

**[AIEEE-2011]**

(1) 372 K and 310 K (2) 372 K and 330 K (3) 330 K and 268 K (4) 310 K and 248 K

**Ans.** (1)

**Sol.** $\eta = 1 - \frac{T_2}{T_1} = \frac{1}{6} \quad \Rightarrow \quad \frac{T_2}{T_1} = 1 - \frac{1}{6} = \frac{5}{6}$

$$\frac{1}{3} = 1 - \frac{(T_2 - 62)}{T_1} \quad \Rightarrow \quad \frac{T_2 - 62}{T_1} = \frac{2}{3}$$

$$\frac{5(T_2 - 62)}{T_2} = \frac{2}{3}$$

$$5T_2 - 310 = 4T_2$$

$$T_2 = 310 \qquad \text{and} \qquad T_1 = \frac{6 \times 310}{5}$$

$$T_1 = 372 \text{ K}$$

**14.** Three perfect gases at absolute temperature $T_1, T_2$ and $T_3$ are mixed. The masses of molecules are $m_1, m_2$ and $m_3$ and the number of molecules are $n_1, n_2$ and $n_3$ respectively. Assuming no loss of energy, the final temperature of the mixture is : **[AIEEE-2011]**

(1) $\frac{(T_1 + T_2 + T_3)}{3}$ (2) $\frac{n_1T_1 + n_2T_2 + n_3T_3}{n_1 + n_2 + n_3}$ (3) $\frac{n_1T_1^2 + n_2T_2^2 + n_3T_3^2}{n_1T_1 + n_2T_2 + n_3T_3}$ (4) $\frac{n_1^2T_1^2 + n_2^2T_2^2 + n_3^2T_3^2}{n_1T_1 + n_2T_2 + n_3T_3}$

**Ans.** (2)

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

**15.** A thermally insulated vessel contains an ideal gas of molecular mass M and ratio of specific heats $\gamma$. It is moving with speed v and is suddenly brought to rest. Assuming no heat is lost to the surroundings, its temperature increases by : **[AIEEE-2011]**

(1) $\frac{(\gamma - 1)}{2(\gamma + 1)R} Mv^2K$ (2) $\frac{(\gamma - 1)}{2\gamma R} Mv^2K$ (3) $\frac{\gamma Mv^2}{2R} K$ (4) $\frac{(\gamma - 1)}{2R} Mv^2K$

**Ans.** (4)

**Sol.** $\frac{1}{2} Mv^2 = C_V.\Delta T$

$$\frac{1}{2} Mv^2 = \frac{R}{\gamma - 1}.\Delta T$$

$$\Delta T = \frac{M.v^2(\gamma - 1)}{2R}$$

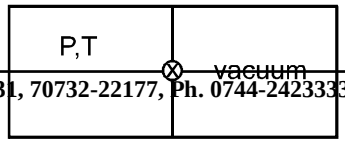
$$= \frac{(\gamma - 1)Mv^2}{2R}$$

**16.** A container with insulating walls is divided into equal parts by a partition fitted with a valve. One part is filled with an ideal gas at a pressure P and temperature T, whereas the other part is completely evacuated. If the valve is suddenly opened, the pressure and temperature of the gas will be : **[AIEEE 2011]**

(1) $\frac{P}{2}, \frac{T}{2}$ (2) P, T (3) P, $\frac{T}{2}$ (4) $\frac{P}{2}$, T

**Ans.** (4)

**Sol** It is the free expansion
So, T remain constant



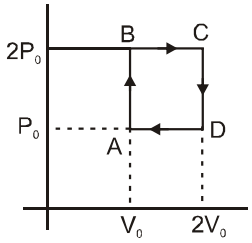
$P_1V_1 = P_2V_2$

$P\frac{V}{2} = P_2(V)$

$P_2 = \left(\frac{P}{2}\right)$.

**17.** Helium gas goes through a cycle ABCDA (consisting of two isochoric and isobaric lines) as shown in figure. Efficiency of this cycle is nearly : (Assume the gas to be close to ideal gas)

**[AIEEE 2012]**



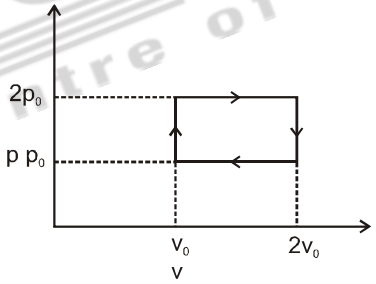

(1) 15.4% (2) 9.1% (3) 10.5% (4) 12.5%

**Ans.** (1)

**Sol.** $\eta = \frac{p_0v_0}{\frac{f}{2}(p_0v_0)+\frac{f}{2}(2p_0)v_0+2p_0v_0} = \frac{1}{\frac{3}{2}+3+2} = \frac{200}{13} = 15.4\%$

**18.** The below p-v diagram represents the thermodynamic cycle of an engine, operating with an ideal monoatomic gas. The amount of heat, extracted from the source in a single cycle is :

**[JEE-Mains 2013]**



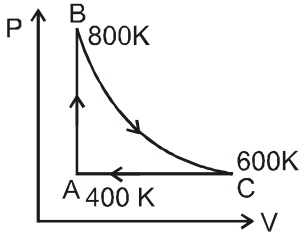

(1) $p_0v_0$ (2) $\left(\frac{13}{2}\right)p_0v_0$ (3) $\left(\frac{11}{2}\right)p_0v_0$ (4) $4p_0v_0$

**Ans.** (2)

**Sol.** $\frac{3}{2}P_0V_0 + \frac{5}{2}2P_0V_0$

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

**19.** One mole of diatomic ideal gas undergoes a cyclic process ABC as shown in figure. The process BC is adiabatic. The temperatures at A, B and C are 400K, 800K and 600 K respectively. Choose the correct statement : **[JEE-Mains 2014]**




(1) The change in internal energy in whole cyclic process is 250 R.
(2) The change in internal energy in the process CA is 700 R
(3) The change in internal energy in the process AB is – 350 R
(4) The change in internal energy in the process BC is – 500 R

**Ans.** (4)

**Sol.** $\Delta U = \frac{f}{2} nR\Delta T$

For cyclic process $\Delta U = 0$

For process CA

$\Delta U = 1\times \frac{5}{2} R\,(-200)$

$= -500R$

For process AB : -

$\Delta U = 1\times \frac{5}{2} R \times(+400)$

$= 1000R$

For process BC :-

$\Delta U = 1\times \frac{5}{2} R \times(-200)$

$= -500R$

**20.** An open glass tube is immersed in mercury in such a way that a length of 8 cm extends above the mercury level. The open end of the tube is then closed and sealed and the tube is raised vertically up by additional 46 cm. What will be length of the air column above mercury in the tube now ?
(Atmospheric pressure = 76 cm of Hg) **[JEE-Mains 2014]**
(1) 16 cm (2) 22 cm (3) 38 cm (4) 6 cm

**Ans.** (1)

**Sol.** $\Delta U = \frac{f}{2} nR\Delta T$

For cyclic process $\Delta U = 0$

For process CA

$\Delta U = 1\times \frac{5}{2} R\,(-200)$

$= -500R$

For process AB : -

$\Delta U = 1\times \frac{5}{2} R \times(+400)$

$= 1000R$

For process BC :-

$\Delta U = 1\times \frac{5}{2} R \times(-200)$

$= -500R$

**21.** Consider a spherical shell of radius R at temperature T. The black body radiation inside it can be considered as an ideal gas of photons with internal energy per unit volume $u = \frac{U}{V} \propto T^4$ and pressure $p = \frac{1}{3}\left(\frac{U}{V}\right)$. If the shell now undergoes an adiabatic expansion the relation between T and R is : **[JEE-Mains 2015]**

(1) $T \propto e^{-3R}$ (2) $T \propto \frac{1}{R}$ (3) $T = \frac{1}{R^3}$ (4) $T \propto e^{-R}$

**Ans.** (2)

**Sol.** $dQ = dU + dW$

$dU = -pdV$

$\frac{dU}{dV} = -p = -\frac{1}{3}\frac{U}{V}$

$\frac{dU}{U} = -\frac{1}{3}\frac{dV}{V}$

$\ln U = -\frac{1}{3}\ln V + \ln C$

$U\cdot V^{1/3} = C$

$VT^4 \cdot V^{1/3} = C'$

$T \propto \frac{1}{R}$

**22.** Consider an ideal gas confined in an isolated closed chamber. As the gas undergoes an adiabatic expansion the average time of collision between molecules increases as $V^q$, where V is the volume of the gas. The value of q is : **[JEE-Mains 2015]**

$\left(\gamma \frac{C_p}{C_v}\right)$

(1) $\frac{3\gamma-5}{6}$ (2) $\frac{\gamma-1}{2}$ (3) $\frac{\gamma+1}{2}$ (4) $\frac{3\gamma+5}{6}$

**Ans.** (2)

**Sol.** Average time between collision = $\frac{\text{Mean free Path}}{V_{rms}}$

$t = \frac{1}{\frac{\pi d^2 N/V}{\sqrt{\frac{3RT}{M}}}}$ ; $t = \frac{CV}{\sqrt{T}}$ (where $C = \frac{\sqrt{M}}{\pi d^2 N\sqrt{3R}}$ = constant)

$\Rightarrow T \propto \frac{V^2}{t^2}$

For adiabatic

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

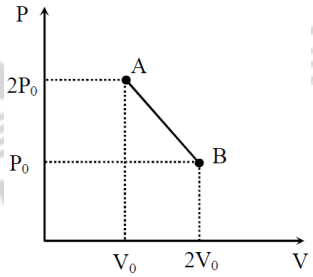
$\frac{V^2}{t^2} V^{\gamma-1} = k$

$\frac{V^{\gamma+1}}{t^2} = k$

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

so, $q = \frac{\gamma+1}{2}$

**23.** 'n' moles of an ideal gas undergoes a process A $\rightarrow$ B as shown in the figure. The maximum temperature of the gas during the process will be : **[JEE-Mains 2016]**




(1) $\frac{3P_0V_0}{2nR}$ (2) $\frac{9P_0V_0}{2nR}$ (3) $\frac{9P_0V_0}{nR}$ (4) $\frac{9P_0V_0}{4nR}$

**Ans.** (4)

**Sol.** Equation of line is

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

Also $PV = nRT$ ....(ii)

for $T_{max}$, $\frac{dT}{dV} = 0$

$\Rightarrow V = \frac{3V_0}{2}$, $P = \frac{3P_0}{2}$

$\Rightarrow T_{max} = \frac{9P_0V_0}{4nR}$

**24.** An ideal gas undergoes a quasi static, reversible process in which its molar heat capacity C remains constant. If during this process the relation of pressure P and volume V is given by

$PV^n$ = constant, then n is given by (Here $C_P$ and $C_v$ are molar specific heat at constant pressure and constant volume, respectively): **[JEE-Mains 2016]**

(1) $n = \frac{C - C_P}{(C - C_V)}$ (2) $\frac{C_P - C}{(C - C_V)}$ (3) $\frac{C - C_V}{(C - C_P)}$ (4) $n = \frac{C_P}{C_V}$

**Ans.** (1)

**Sol.** $C = C_V - \frac{R}{n-1}$

$\frac{R}{n-1} = C_V - C \qquad \frac{dT}{dV}$

$n = \frac{C - C_P}{C - C_V}$

**25.** $C_P$ and $C_v$ are specific heats at constant pressure and constant volume respectively. It is observed that

$C_p - C_v$ = a for hydrogen gas

$C_p - C_v$ = b for nitrogen gas

The correct relation between a and b is: **[JEE-Mains 2017]**

(1) $a = \frac{1}{14}$ b (2) a = b (3) a = 14b (4) a = 28b

**Ans.** (3)

**Sol.** For ideal gas

$C_P - C_V = \frac{R}{M}$

If $C_P$ and $C_V$ are specific heats (J/kg - °C)

M = molar mass of gas

$\Rightarrow \quad a = \frac{R}{2}$ and $b = \frac{R}{28}$

$\Rightarrow \quad a = 14b$

**26.** The temperature of an open room of volume 30 $m^3$ increases from 17ºC to 27ºC due to the sunshine. The atmospheric pressure in the room remains $1 \times 10^5$Pa. If $n_i$ and $n_f$ are the number of molecules in the room before and after heating, then $n_f - n_i$ will be : **[JEE-Mains 2017]**

(1) $-1.61 \times 10^{23}$ (2) $1.38 \times 10^{23}$ (3) $2.5 \times 10^{25}$ (4) $-2.5 \times 10^{25}$

**Ans.** (4)

**Sol.** Using, $n = \left(\frac{PV}{RT}\right)$

$$n_f - n_i = \frac{PV}{R}\left(\frac{1}{T_f} - \frac{1}{T_i}\right) \text{moles}$$

$$= \frac{1\times10^5\times30}{8.32}\left(\frac{1}{300} - \frac{1}{290}\right)\times 6.023\times10^{23} \text{ molecules}$$

$$= -2.5 \times 10^{25} \text{ molecules}$$

**27.** Two moles of an ideal monoatomic gas occupies a volume V at 27ºC. the gas expands adiabatically to a volume 2V. Calculate (a) the final temperature of the gas and (b) change in its internal energy. **[JEE-Mains 2018]**

(1) (a) 195 K (b) 2.7 kJ (2) (a) 189 K (b) 2.7 kJ

(3) (a) 195 K (b) –2.7 kJ (2) (a) 189 K (b) –2.7 kJ

**Ans.** (4)

**Sol.** $T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1}$

$\Rightarrow T_2 = 189$ K

$\Delta U = nC_v \Delta T = -2.7$ kJ

**28.** The mass of hydrogen molecule is $3.32\times10^{-27}$ Kg. If $10^{23}$ hydrogen molecules strike, per second, a fixed wall of area 2 $cm^2$ at an angle of 45º to the normal, and rebound elastically with a speed of $10^3$ m/s, then the pressure on the wall is nearly: **[JEE-Mains 2018]**

(1) $4.70\times10^2$ N/$m^2$ (2) $2.35\times10^3$ N/$m^2$ (3) $4.70\times10^3$ N/$m^2$ (4) $2.35\times10^2$ N/$m^2$

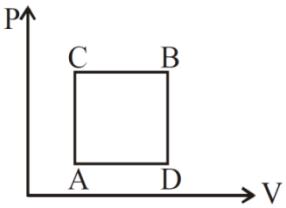
**Ans.** (2)

**Sol.** $P = \dfrac{(2mv\cos45°)n}{A}$ (P → Pressure, A → Area)

$$= \frac{2\times3.32\times10^{-27}\times10^3\times\frac{1}{\sqrt{2}}\times10^{23}}{2\times10^{-4}}$$

$= 2.35 \times 10^3$ N/$m^2$

**29.** A gas can be taken from A to B via two different processes ACB and ADB.




When path ACB is used 60 J of heat flows into the system and 30 J of work is done by the system. If path ADB is used work done by the system is 10 J. The heat Flow into the system in path ADB is : **[JEE Main-2019]**

(1) 80 J (2) 20 J (3) 100 J (4) 40 J

**Ans.** **(4)**

**Sol.** $\Delta Q_{ACB} = \Delta W_{ACB} + \Delta U_{ACB}$

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

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

$\Rightarrow \Delta U_{ADB} = \Delta U_{ACB} = 30$ J

$\Rightarrow Q_{ACD} = \Delta U_{ACB} + \Delta W_{ADB}$

$= 10$ J $+ 30$ J $= 40$ J

**30.** A mixture of 2 moles of helium gas (atomic mass = 4 u), and 1 mole of argon gas (atomic mass = 40 u) is kept at 300 K in a container. The ratio of their rms speeds $\left[\frac{V_{rms}(\text{helium})}{V_{rms}(\text{argon})}\right]$, is close to :

**[JEE Main-2019]**

(1) 2.24 (2) 0.45 (3) 0.32 (4) 3.16

**Ans.** **(4)**

**Sol.** $\frac{V_{rms}(He)}{V_{rms}(Ar)} = \sqrt{\frac{M_{Ar}}{M_{He}}} = \sqrt{\frac{40}{4}} = 3.16$

**31.** A 15 g mass of nitrogen gas is enclosed in a vessel at a temperature 27°C. Amount of heat transferred to the gas, so that rms velocity of molecules is doubled, is about :

[Take R = 8.3 J/ K mole] **[JEE Main-2019]**

(1) 0.9 kJ (2) 14 kJ (3) 6 kJ (4) 10 kJ

**Ans.** **(4)**

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

$v_{rms} \rightarrow$ doubled

$\Rightarrow$ T $\rightarrow$ 4 times = 4× 300 K = 1200 K

$\Delta Q = nC_v\Delta T$ ($\therefore$ volume vessel if constant)

$= \frac{15}{28} \times \frac{5}{2} R \times (1200–300) \cong 10kJ$

**32.** Two Carnot engines A and B are operated in series. The first one, A, receives heat at $T_1$(= 600 K) and rejects to a reservoir at temperature $T_2$. The second engine B receives heat rejected by the first engine and, in turn, rejects to a heat reservoir at $T_3$(= 400 K). Calculate the temperature $T_2$ if the work outputs of the two engines are equal : **[JEE Main-2019]**

(1) 500 K (2) 300 K (3) 600 K (4) 400 K

**Ans.** **(1)**

**Sol.** Method I :

$T_2$ should lie b/w 400k & 600k, only position option is 500K

Method II : $\eta_1 = 1 - \frac{T_2}{T_1} = \frac{W}{Q_0}$

$\Rightarrow \quad 1 - \frac{T_2}{600} = \frac{W}{Q_0} \qquad ...(1)$

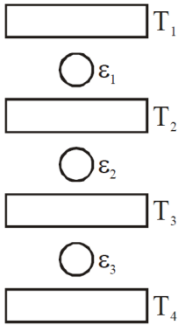
For Second Engine,

Q Supplied = $Q_0 - W$

$$\eta_2 = 1 - \frac{400}{T_2} = \frac{W}{Q_{supp}} = \frac{W}{Q_0 - W} \qquad ...(2)$$

Solving (1) & (2) $\Rightarrow T_2 = 500K$

**33.** Three Carnot engines operate in series between a heat source at a temperature $T_1$ and a heat sink at temperature $T_4$ (see figure). There are two other reservoirs at temperature $T_2$, and $T_3$, as shown, with $T_2 > T_2 > T_3 > T_4$. The three engines are equally efficient if:




**[JEE Main-2019]**

(1) $T_2 = \left(T_1 T_4^2\right)^{1/3}; T_3 = \left(T_1^2 T_4\right)^{1/3}$ (2) $T_2 = \left(T_1 T_4\right)^{1/2}; T_3 = \left(T_1^2 T_4\right)^{1/3}$

(3) $T_2 = \left(T_1^2 T_4\right)^{1/3}; T_3 = \left(T_1 T_4^2\right)^{1/3}$ (4) $T_2 = \left(T_1^3 T_4\right)^{1/4}; T_3 = \left(T_1 T_4^3\right)^{1/4}$

**Ans.** **(3)**

**Sol.** Efficiency of all the three engines should be equal

$$\eta = 1 - \frac{T_2}{T_1} = 1 - \frac{T_2}{T_2} = 1 - \frac{T_4}{T_3}$$

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

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

$$T_3 = \sqrt{T_2 T_4}$$

$$T_2^{3/4} = \sqrt{T_1^{1/2} T_4^{1/4}}$$

$$T_2 = T_1^{2/3} T_4^{1/3}$$

**34.** Half mole of an ideal monoatomic gas is heated at constant pressure of 1atm from 20ºC to 90ºC. Work done by gas is close to : ( Gas constant R = 8.31 J /mol.K) **[JEE Main-2019]**

(1) 146J (2) 291 J (3) 581 J (4) 73 J

**Ans.** **(2)**

**Sol.** $w = nR\Delta T$

$$w = \frac{1}{2} \times 8.31 \times 70 = 291 \text{ J}$$

**35.** Two kg of a monoatomic gas is at a pressure of $4 \times 10^4$ N/m$^2$. The density of the gas is 8 kg /m$^3$. What is the order of energy of the gas due to its thermal motion ? **[JEE Main-2019]**

(1) $10^6$ J (2) $10^4$ J (3) $10^3$ J (4) $10^5$ J

**Ans.** **(2)**

**Sol.** $U = \frac{3}{2}\pi RT$

$U = \frac{3}{2}Pv = \frac{3}{2}\times 4\times 10^4 \times \frac{2}{8} = \frac{3}{2}\times 10^4$

**36.** A rigid diatomic ideal gas undergoes an adiabatic process at room temperature,. The relation between temperature and volume of this process is $TV^x$ = constant, then x is :

**[JEE Main-2019]**

(1) $\frac{5}{3}$ (2) $\frac{2}{5}$ (3) $\frac{2}{3}$ (4) $\frac{3}{5}$

**Ans.** **(2)**

**Sol.** $TV^{r-1}$ = constant

$r - 1 = X$

$\frac{7}{5} - 1 = n$

$n = \frac{2}{5}$

**37.** A gas mixture consists of 3 moles of oxygen and 5 moles of argon at temperature T. Considering only translational and rotational modes, the total inernal energy of the system is:

**[JEE Main-2019]**

(1) 4 RT (2) 12 RT (3) 20 RT (4) 15 RT

**Ans.** **(4)**

**Sol.** $U = \frac{f_1}{2}n_1RT + \frac{f_2}{2}n_2RT$

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

$U = 15RT$

**38.** In a process, temperature and volume of one mole of an ideal monoatomic gas are varied according to the relation VT = K, where K is a constant. In this process the temperature of the gas is increased by $\Delta T$. The amount of heat absorbed by gas is (R is gas constant) :

**[JEE Main-2019]**

(1) $\frac{1}{2}R\Delta T$ (2) $\frac{2K}{3}\Delta T$ (3) $\frac{1}{2}KR\Delta T$ (4) $\frac{3}{2}R\Delta T$

**Ans.** **(1)**

**Sol.** Solving with help of Polytrophic process

$VT$ = constant

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

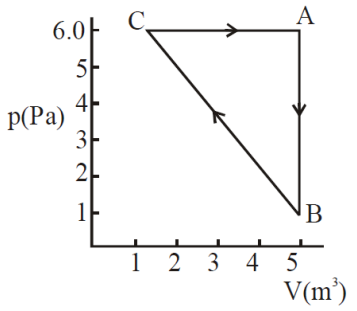
$PV^2$ = constant

$\boxed{a = 2}$

for polytropic process $Q = n\left(\frac{R}{V-1}+\frac{R}{1-a}\right)\Delta T$

$Q = \frac{1}{2}R\Delta T$

**39.** For the given cyclic process CAB as shown for a gas, the work done is :




**[JEE Main-2019]**

(1) 1 J (2) 30 J (3) 10 J (4) 5 J

**Ans.** **(3)**

**Sol.** Work done by gas

= Area under P-V curve

$= \frac{1}{2} \times 4 \times 5 = 10J$

**40.** An ideal gas occupies a volume of $2m^3$ at a pressure of $3 \times 10^6$ Pa. The energy of the gas is:

(1) $6 \times 10^4$ J (2) $3 \times 10^2$ (3) $9 \times 10^6$ J (4) $10^8$ J

**[JEE Main-2019]**

**Ans.** **(3)**

**Sol.** Energy of gas $= \frac{3}{2}nRT = \frac{3}{2}PV = 9 \times 10^6$ J

**41.** An ideal gas is enclosed in a cylinder at pressure of 2 atm and temperature, 300 K. The mean time between two successive collisions is $6 \times 10^{-8}$ s. If the pressure is doubled and temperature is increased to 500 K, the mean time between two successive collisions will be close to:

**[JEE Main-2019]**

(1) $3 \times 10^{-6}$s (2) $2 \times 10^{-7}$s (3) $0.5 \times 10^{-8}$s (4) $4 \times 10^{-8}$s

**Ans.** **(4)**

**Sol.** $\tau = \dfrac{1}{n\pi v_{av} d^2}$, where d is diameter of the molecule & n is no of molecules per unit volume

$$\Rightarrow \tau = \frac{1}{\sqrt{2}n\pi\sqrt{\frac{8RT}{\pi M}}d^2}$$

Volume is const but P & T are not changed in same proportion, so number of moles($\mu$) must change

$$\therefore PV = \mu RT \Rightarrow \frac{\mu}{V} \propto \frac{P}{T}$$

$$\Rightarrow \tau \propto \frac{1}{\frac{P}{T}\sqrt{T}} = \frac{\sqrt{T}}{P}$$

$$\Rightarrow \frac{\tau_2}{\tau_1} = \sqrt{\frac{T_2}{T_1}} \times \frac{P_1}{P_2} = \sqrt{\frac{5}{3}} \times \frac{1}{2}$$

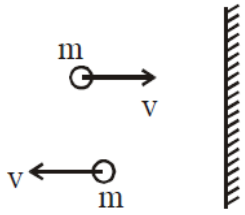
$$\Rightarrow \tau_2 = 3.86 \times 10^{-8}\,S \cong 4 \times 10^{-8}\,S$$

**42.** If $10^{22}$ gas molecules each of mass $10^{-26}$ kg collide with a surface (perpendicular to it) elastically per second over an area 1 $m^2$ with a speed $10^4$ m/s, the pressure exerted by the gas molecules will be of the order of **[JEE Main-2019]**

(1) $10^4$ N/$m^2$ (2) $10^{16}$ N/$m^2$ (3) $10^8$ N/$m^2$ (4) $10^3$ N/$m^2$

**Ans.** **(NTA Answer Key) - (4)**
**Correct Answer is 2 N/$m^2$**
**As none of the option matches question should be BONUS**

**Sol.**

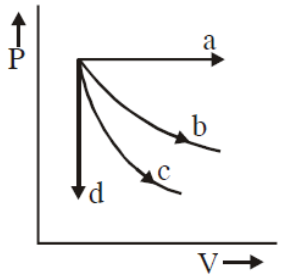



Magnitude of change in momentum per collision = 2mv

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}} = \frac{N(2mv)}{1} = \frac{10^{22} \times 2 \times 10^{-26} \times 10^4}{1} = 2\ N/m^2$$

**43.** The given diagram shows four processes i.e., isochoric, isobaric, isothermal and adiabatic. The correct assignment of the processes, in the same order is given by :

**[JEE Main-2019]**

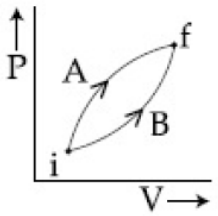



(1) d a b c (2) a d c b (3) d a c b (4) a d b c

**Ans.** **(1)**

**Sol.** isochoric → Process d
isobaric → Process a
Adiabatic slope will be more than isothermal
so
Isothermal → Process b
Adiabatic → Process c
order → d a b c

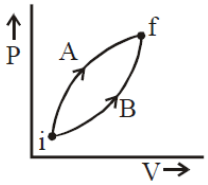
**44.** Following figure shows two processes A and B for a gas. If $\Delta Q_A$ and $\Delta Q_B$ are the amount of Heat absorbed by the system in two cases, and $\Delta U_A$ and $\Delta U_B$ are changes in internal energies, respectively, then: **[JEE Main-2019]**




(1) $\Delta Q_A > \Delta Q_B$ ; $\Delta U_A = \Delta U_B$ (2) $\Delta Q_A = \Delta Q_B$ ; $\Delta U_A = \Delta U_B$
(3) $\Delta Q_A < \Delta Q_B$ ; $\Delta U_A < \Delta U_B$ (4) $\Delta Q_A > \Delta Q_B$ ; $\Delta U_A > \Delta U_B$

**Ans.** **(1)**

Sol. d




Initial and final states for both the processes are same.

$\therefore \quad \Delta U_A = \Delta U_B$

Work done during process A is greater than in process B.

By First Law of thermodynamics

$\Delta Q = \Delta U + W$

$\Rightarrow \Delta Q_A > \Delta Q_B$

**45.** An HCl molecule has rotational, translational and vibrational motions,. If the rms velocity of HCl molecules in its gaseous phase is $\bar{\upsilon}$, m is its mass and $k_B$ is Boltzmann constant, then its temperature will be **[JEE Main-2019]**

(1) $\frac{m\bar{\nu}^2}{5k_B}$ (2) $\frac{m\bar{\nu}^2}{3k_B}$ (3) $\frac{m\bar{\nu}^2}{7k_B}$ (4) $\frac{m\bar{\nu}^2}{6k_B}$

**Ans. (4)**

Sol. According to equi-partition energy theorem

$$\frac{1}{2}m\left(v_{rms}^2\right) = 3\times\frac{1}{2}K_bT$$

$$T = \ T = \frac{m\bar{v}_{rms}^2}{3k}$$

$\therefore$ correct option should be (3)

**46.** For a given gas at 1atm pressure, rms speed of the molecules is 200 m/s at 127°C. At 2 atm pressure and at 227°C, the rms speed of the molecules will be: **[JEE Main-2019]**

(1) $100\sqrt{5}$ m/s (2) 80 m/s (3) $80\sqrt{5}$ m/s (4)100 m/s

**Ans. (1)**

**Sol.** $V_{rms} = \sqrt{\frac{3RT}{M_w}} \Rightarrow v_{rms} \propto \sqrt{T}$

Now, $\frac{v}{200} = \sqrt{\frac{500}{400}} \Rightarrow \frac{v}{200} = \frac{\sqrt{5}}{2}$

$\Rightarrow v = 100\ \sqrt{5}$ m/s

**47.** The specific heats, $C_P$ and $C_V$ of a gas of diatomic molecules, A, are given (in units of J $mol^{-1}$ $K^{-1}$) by 29 and 22, respectively. Another gas of diatomic molecules, B, has the corresponding values 30 and 21. If they are treated as ideal gases, then :

**[JEE Main-2019]**

(1) A is rigid but B has a vibrational mode
(2) A has one vibrational mode and B has two
(3) Both A and B have a vibrational mode each
(4) A has a vibrational mode but B has none

**Ans. (4)**

**Sol.** For A

$R = C_p - C_v = 7$

$$C_V = \frac{fR}{2} = 22 \Rightarrow f = \frac{44}{7} = 6.3$$

$f \simeq 6 \begin{cases} \nearrow 5 \text{ (Rotation + Translational)} \\ \searrow 1 \text{ (Vibration)} \end{cases}$

For B

$R = C_p - C_v = 9$

$C_V = \frac{fR}{2} = 21 \Rightarrow f = \frac{42}{9}$

$f \simeq 5 \begin{cases} \nearrow 5 \text{ (Rotation + Translational)} \\ \searrow 0 \text{ (Vibration)} \end{cases}$

**48.** A cylinder with fixed capacity of 67.2 lit contains helium gas at STP. The amount of heat needed to raise the temperature of the gas by 20° is : [ Given that R = 8.31 J $mol^{-1}$

**[JEE Main-2019]**

(1) 374 J (2) 700J (3) 748 J (4) 350 J

**Ans.** **()**

**Sol.** Volume = constant

67.2 lit. = 3 mole

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

$= \frac{3}{2} \times 3 \times 8.3 \times 20 = 747 \text{ J}$

**49.** A $25 \times 10^{-3}$ $m^3$ volume cylinder is filled with 1 mol of $O_2$ gas at room temperature (300k). The molecular diameter of $O_2$, and its room mean square speed, are found to be 0.3 nm and 200 m/s, respectively. What is the average collision rate (per second) for an $O_2$ molecule ?

**[JEE Main-2019]**

(1) $\sim 10^{10}$ (2) $\sim 10^{13}$ (3) $\sim 10^{12}$ (4) $\sim 10^{11}$

**Ans.** **(3)**

**Sol.** $v = \frac{V_{av}}{\lambda}$

$\lambda = \frac{RT}{\sqrt{2}\pi\sigma^2 N_A P}$

$\sigma = 2 \times 0.3 \times 10^{-9}$

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

$\Rightarrow \lambda = \frac{V}{\sqrt{2}\pi\sigma^2 N_A}$

$V_{av} = \sqrt{\frac{8}{3\pi}} \times V_{rms}$

$\therefore \; v = 200 \times \frac{\sqrt{2\pi} \times \sigma^2 N_A}{25 \times 10^{-3}} \times \sqrt{\frac{8}{3\pi}}$

$=17.68 \times 10^8$ /sec

$=0.1768 \times 10^{10}$ /sec ~ $10^{10}$

**50.** n moles of an ideal gas with constant volume heat capacity $C_v$ undergo an isobaric expansion by certain volume. The ratio of the work done in the process, to the heat supplied is : **[JEE Main-2019]**

(1) $\frac{nR}{C_v + nR}$ (2) $\frac{4nR}{C_v - nR}$ (3) $\frac{4nR}{C_v + nR}$ (4) $\frac{nR}{C_v - nR}$

**Ans.** **(1)**

**Sol.** $w = nR\Delta T$

$\Delta H = (C_v + nR)\,\Delta T$

$$\frac{w}{\Delta H} = \frac{nR}{C_v + nR}$$

**51.** When heat Q is supplied to a diatomic gas of rigid molecules, at constant volume its temperature increase by $\Delta T$. The heat required to produce the same change in temperature, at a constant pressure is : **[JEE Main-2019]**

(1) $\frac{2}{3}Q$ (2) $\frac{5}{3}Q$ (3) $\frac{7}{5}Q$ (4) $\frac{3}{2}Q$

**Ans.** **(3)**

**Sol.** At constant volume

$Q = nC_V\Delta T = n\frac{5}{2}R\Delta T$

At constant pressure :

$Q' = nC_P\Delta T = n\frac{7}{2}R\Delta T$

$\Rightarrow Q' = \frac{7}{5}Q$

**52.** One mole of an ideal gas passes through a process where pressure and volume obey the relation $P = P_0\left[1 - \frac{1}{2}\left(\frac{V_0}{V}\right)^2\right]$. Here $P_0$ and $V_0$ are constants. Calculate the change in the temperature of the gas if its volume changes from $V_0$ to $2V_0$. **[JEE Main-2019]**

(1) $\frac{1}{2}\frac{P_0V_0}{R}$ (2) $\frac{3}{4}\frac{P_0V_0}{R}$ (3) $\frac{1}{4}\frac{P_0V_0}{R}$ (4) $\frac{5}{4}\frac{P_0V_0}{R}$

**Ans.** **(4)**

**Sol.** $P = P_0\left[1 - \frac{1}{2}\left(\frac{V_0}{V}\right)^2\right]$

Pressure at $V_0 = P_0\left(1 - \frac{1}{2}\right) = \frac{P_0}{2}$

Pressure at $2V_0 = P_0\left(1-\frac{1}{2}\times\frac{1}{4}\right)=\frac{7}{8}P_0$

Temperature at $V_0 = \frac{\frac{P_0}{2}V_0}{nR}=\frac{P_0V_0}{2nR}$

Temperature at $2V_0 = \frac{\left(\frac{7}{8}P_0\right)(2V_0)}{nR}=\frac{\frac{7}{4}P_0V_0}{nR}$

Change in temperature $= \left(\frac{7}{4}-\frac{1}{2}\right)\frac{P_0V_0}{nR}$

$= \frac{5}{4}\frac{P_0V_0}{nR}=\frac{5P_0V_0}{4R}$

**53.** Two moles of helium gas is mixed with three moles of hydrogen molecules (taken to be rigid). What is the molar specific heat of mixture at constant volume? (R = 8.3 J/mol K)

**[JEE Main-2019]**

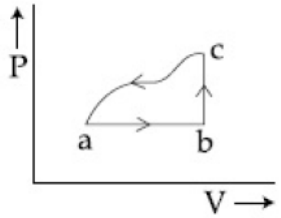
(1) 19.7 J/mol K (2) 17.4 J/mol K (3) 21.6 J/mol K (4) 15.7 J/mol K

**Ans.** **(2)**

**Sol.** $f_{mix} = \frac{n_1f_1+n_2f_2}{n_1+n_2}=\frac{2\times3+3\times5}{5}=\frac{21}{5}$

$C_v = \frac{fR}{2}=\frac{21}{5}\times\frac{R}{2}$ = 17.4 J/mol K

**54.** A sample of an ideal gas is taken through the cycle process abca as shown in the figure. The change in the internal energy of the gas along the path ca is –180 J. The gas absorbs 250 J of heat along the path ab and 60 J along the path bc. The work done by the gas along the path abc is **[JEE Main-2019]**




(1) 130 J (2) 100 J (3) 120 J (4) 140 J

**Ans.** **(1)**

**Sol.**

| | ΔE | ΔW | ΔQ |
|---|---|---|---|
| ab | | | 250 |
| bc | | 0 | 60 |
| ca | –180 | | |

| | ΔE | ΔW | ΔQ |
|---|---|---|---|
| ab | 120 | 130 | 250 |
| bc | 60 | 0 | 60 |
| ca | –180 | | |

**55.** A Carnot engine has an efficiency of 1 /6. When the temperature of the sink is reduced by 62°C, its efficiency is doubled. The temperatures of the source and the sink are, respectively,

**[JEE Main-2019]**

(1) 124°C, 62°C (2) 37°C, 99°C (3) 99°C, 37°C (4) 62°C, 124°C

**Ans.** **(3)**

**Sol.** Efficiency $(\eta) = 1-\frac{T_{sink}}{T_{source}}$

$\Rightarrow \quad \frac{T_{sink}}{T_{source}} = \frac{5}{6} \quad \ldots.(1)$

Also, $\frac{1}{3}=1-\frac{T_{sink}-62}{T_{source}} \quad \ldots(2)$

$\Rightarrow \quad T_{source} = 99°C$

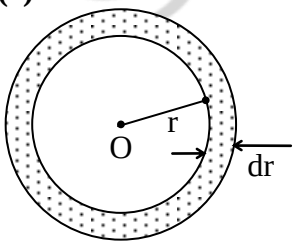
**56.** The number density of molecules of a gas depends on their distance r from the origin as, $n(r) = -n_0 e^{-\alpha r^4}$. Then the total number of molecules is proportional to :

**[JEE Main-2019]**

(1) $n_0\alpha^{-3/4}$ (2) $n_0\alpha^{1/4}$ (3) $n_0\alpha^{-3}$ (4) $\sqrt{n_0}\alpha^{1/2}$

**Ans.** **(1)**

**Sol.**




$dN = n(r)dV = n(r)(4\pi r^2 dr)$

$\Rightarrow \quad N = \int dN = \int n_0 e^{-\alpha r^4}(4\pi r^2)\,dr$

**57.** A diatomic gas with rigid molecules does 10 J of work when expanded at constant pressure. What would be the heat energy absorbed by the gas, in this process ?

**[JEE Main-2019]**

(1) 25 J (2) 30 J (3) 35 J (4) 40 J

**Ans.** **(3)**

**Sol.** $Q = W + \Delta U$

$Q = 10 + nC_V\Delta T \quad \ldots..(1)$

For diatomic $f = 5, C_V = \frac{5R}{2}$

Also, At constant P

$P\Delta V = nR\Delta T$ …(2)

$\Rightarrow \quad Q = 10 + \frac{5}{2}(P\Delta V)$

$= 10 + \frac{5}{2}W = 35$ J

## EXERCISE # (JA)

**1.** An insulated container containing monoatomic gas of molar mass m is moving with a velocity $v_0$. If the container is suddenly stopped, find the change in temperature. **[IIT JEE- 2003]**

**Ans.** $\Delta T = \frac{mv_0^2}{3R}$

**Sol.** Decrease in kinetic energy = Increase in internal energy.

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

$$\frac{1}{2}v^2 = \frac{1}{M}\frac{3}{2}R\Delta T$$

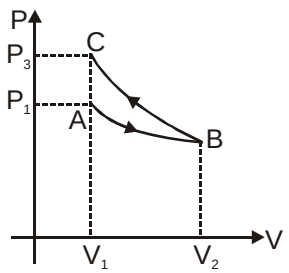
$$\Delta T = \frac{Mv^2}{3R}$$

**2.** An ideal gas expands isothermally from a volume $V_1$ to $V_2$ and then compressed to original volume $V_1$ adiabatically. Initial pressure is $P_1$ and final pressure is $P_3$. The total work done is W. Then **[JEE' 2004 (Scr)]**

(A) $P_3 > P_1$, $W > 0$ (B) $P_3 < P_1$, $W < 0$ (C) $P_3 > P_1$, $W < 0$ (D) $P_3 = P_1$, $W = 0$

**Ans.** (C)

**Sol.** Slope of adiabatic process at a given state (P,V,T) is more than the slope of isothermal process. The corresponding P–V graph for the two process is as shown in figure.




In the graph, AB is isothermal and BC is adiabatic.

$W_{AB}$ = positive (as volume is increasing)

and $W_{BC}$ = negative (as volume is decreasing)

$|W_{BC}| > |W_{AB}|$, as area under P–V graph gives the work done.

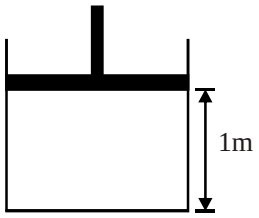
Hence, $W_{AB} + W_{BC} = W < 0$

From the graph itself, it is clear that $P_3 > P_1$.

Hence, the correct option is (A).

**Note :** At point B, slope of adiabatic (process BC) is greater than the slope of isothermal (process AB).

**3.** The piston cylinder arrangement shown contains a diatomic gas at temperature 300 K. The cross-sectional area of the cylinder is1 $m^2$. Initially the height of the piston above the base of the cylinder is 1 m. The temperature is now raised to 400 K at constant pressure. Find the new height of the piston above the base of the cylinder. If the piston is now brought back to its original height without any heat loss, find the new equilibrium temperature of the gas. You can leave the answer in fraction. **[IIT JEE- 2004]**




**Ans.** (a) 4/3 m, (b) $T_3 = 400\left(\frac{4}{3}\right)^{0.4}$ K

**Sol.** At constant pressure, $V \propto T$

or $\frac{V_2}{V_1} = \frac{T_2}{T_1}$ or $\frac{Ah_2}{Ah_1} = \frac{T_2}{T_1}$

$\therefore \quad h_2 = h_1\left(\frac{T_2}{T_1}\right) = (1.0)\left(\frac{400}{300}\right) m = \frac{4}{3} m$

The process is adiabatic when gas is compressed without exchange of heat

$$\frac{T_1}{T_2} = \left(\frac{V_2}{V_1}\right)^{\gamma-1}$$

$$T_1 = 400\left(\frac{4}{3}\right)^{0.4} K.$$

**4.** An ideal gas is filled in a closed rigid and thermally insulated container. A coil of 100 Ω resistor carrying current 1A for 5 minutes supplies heat to the gas. The change in internal energy of the gas is **[JEE' 2005 (Scr)]**

(A) 10 KJ (B) 20 KJ (C) 30 KJ (D) 0 KJ

**Ans.** (C)

**Sol.** $\Delta U = Q = I^2RT = 1^2 \times 100 \times 5 \times 60$ J = 30 KJ

**5.** When the pressure is changed from $p_1 = 1.01 \times 10^5$ Pa to $p_2 = 1.165 \times 10^5$ a then the volume changes by 10%. The bulk modulus is **[JEE' 2005 (Scr)]**

(A) $1.55 \times 10^5$ Pa (B) $0.0015 \times 10^5$ Pa (C) $0.015 \times 10^5$Pa (D) None of these

**Ans.** (A)

**Sol.** $\beta = \dfrac{-vdP}{dV} = \dfrac{-dP}{\left(\dfrac{dV}{V}\right)}$

$\dfrac{dV}{V} \times 100 = 10 \Rightarrow \dfrac{dV}{V} = 0.1$

$\beta = \dfrac{0.155 \times 10^5}{0.1} = 1.55 \times 10^5$

**6.** A cylinder of mass 1 kg is given heat of 20000 J at atmospheric pressure. If initially temperature of cylinder is 20°C, find **[IIT JEE- 2005]**

(a) final temperature of the cylinder

(b) work done by the cylinder.

(c) change in internal energy of the cylinder.

(Given that specific heat of cylinder = 400 J $kg^{-1}$ $°C^{-1}$,Coefficient of volume expansion = $9 \times 10^{-5}$ $°C^{-1}$, Atmospheric pressure = $10^5$ $N/m^2$ and density of cylinder = 9000 $kg/m^3$)

**Ans.** (a) $T_{final}$ = 70°C, (b) 0.05 J, (c) 19999.95 J

**Sol.** (a) $\Delta Q = ms\Delta T$

$\Rightarrow \quad \Delta T = \dfrac{20000J}{1kg \times (400\,J/\,kg^o\,C)} = 50°C$

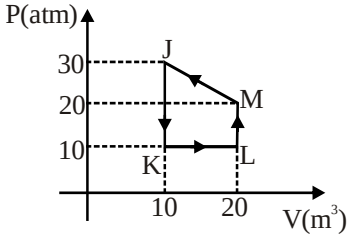
$T_{final}$ = 70°C

(b) $W = P_{atm}\,\Delta V = Patm\ V_0 \gamma \Delta T$

$= (10^5\ N/\ m^2)\left(\dfrac{1}{9\times10^3}m^3\right)(9\times10^{-5}/°C)\,(50°C) = 0.05\,J$

(c) $\Delta U = \Delta Q - W = 20000\ J - 0.05\ J = 19999.95\ J$

**7.** Match the following for the given process : **[IIT JEE- 2006]**




| | **Column-I** | | **Column-II** |
|---|---|---|---|
| (A) | Process J → K | (P) | W > 0 |
| (B) | Process K → L | (Q) | W < 0 |
| (C) | Process L → M | (R) | Q > 0 |
| (D) | Process M → J | (S) | Q < 0 |

**Ans.** (A) → S; (B) → P and R; (C) → R; (D) → Q and S;

**Sol.** (A) for J → K

at const. V , dW= 0

and $P \propto T$

$\therefore$ $dQ = dU$ (At constant volume)
Now dU is negative , because temperature is decreasing
$\therefore$ dQ is negative
hence $Q < 0$

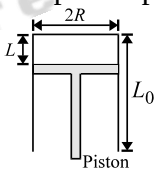
(B) for $K \rightarrow L$
at const P , $V \propto T$
As volume increases ; Temperature will increase
$\therefore$ $dW = PdV$
hence $W > 0$ , $Q > 0$

(C) for $L \rightarrow M$
at constant V, $dW = 0$
$\therefore$ $P \propto T$ , Temperature will increase
Now $dQ = dU$
but dU is positive
$\therefore$ $Q > 0$

(D) For $M \rightarrow J$
V is decreasing therefore $W < 0$
$(PV)_J < (PV)_M$
$T_J < T_M$
$\Delta U < 0$
hence $Q < 0$

**Paragraph for Question Nos. 8 to 10**

A fixed thermally conducting cylinder has a radius $R$ and length $L_0$. The cylinder is open at its bottom and has a small hole at its top. A piston of mass $M$ is held at a distance $L$ from the top surface, as shown in the figure. The atmospheric pressure is $P_0$. **[IIT JEE-2007]**




**8.** The piston is now pulled out slowly and held at a distance $2L$ from the top. The pressure in the cylinder between its top and the piston will then be

(A) $P_0$ (B) $P_0/2$ (C) $\frac{P_0}{2} + \frac{Mg}{\pi R^2}$ (D) $\frac{P_0}{2} - \frac{Mg}{\pi R^2}$

**Ans.** (A)

**9.** While the piston is at a distance $2L$ from the top, the hole at the top is sealed. The piston is then released, to a position where it can stay in equilibrium. In this condition, the distance of the piston from the top is

(A) $\left(\frac{2P_0\pi R^2}{\pi R^2 P_0 + Mg}\right)(2L)$ (B) $\left(\frac{P_0\pi R^2 - Mg}{\pi R^2 P_0}\right)(2L)$

(C) $\left(\frac{P_0\pi R^2 + Mg}{\pi R^2 P_0}\right)(2L)$ (D) $\left(\frac{P_0\pi R^2}{\pi R^2 P_0 - Mg}\right)(2L)$

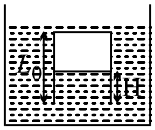
**Ans.** (D)

**Sol.** $Mg + P(\pi R^2) = P_0\pi R^2$

$P_0(2L\pi R^2) = P(x\pi R^2)$ $\quad (P_1 \cdot V_1 = P_2 \cdot V_2$ for isothermal process)

$$x = \left(\frac{P_0\pi R^2}{\pi P^2 P_0 - Mg}\right)(2L)$$

**10.** The piston is taken completely out of the cylinder. The hole at the top is sealed. A water tank is brought below the cylinder and put in a position so that the water surface in the tank is at the same level as the top of the cylinder as shown in the figure. The density of the water is ρ. In equilibrium, the height *H* of the water column in the cylinder satisfies




(A) $\rho g(L_0 - H)^2 + P_0(L_0 - H) + L_0P_0 = 0$ (B) $\rho g(L_0 - H)^2 - P_0(L_0 - H) - L_0P_0 = 0$

(C) $\rho g(L_0 - H)^2 + P_0(L_0 - H) - L_0P_0 = 0$ (D) $\rho g(L_0 - H)^2 - P_0(L_0 - H) + L_0P_0 = 0$

**Ans.** (C)

**Sol.** $\pi R^2P_0L_0 = P(L_0 - H)\pi R^2$ .....(i)

$P = P_0 + \rho g(L_0 - H)$ .....(ii)

Solving (i) and (ii), we get the answer.

**11.** **STATEMENT- 1 :** The total translational kinetic energy of all the molecules of a given mass of an ideal gas is 1.5 times the product of its pressure and its volume. **[JEE 2007]**

because

**STATEMENT- 2 :** The molecules of a gas collide with each other and the velocities of the molecules change due to the collision.

(A) Statement-1 is True, Statement-2 is True; Statement-2 **is** a correct explanation for Statement-1

(B) Statement-1 is True, Statement-2 is True; Statement-2 **is NOT** a correct explanation for Statement-1

(C) Statement-1 is True, Statement-2 is False

(D) Statement-1 is False, Statement-2 is True.

**Ans.** (B)

**12.** An ideal gas is expanding such that $PT^2$ = constant. The coefficient of volume expansion of the gas is **[JEE 2008]**

(A) $\frac{1}{T}$ (B) $\frac{2}{T}$ (C) $\frac{3}{T}$ (D) $\frac{4}{T}$

**Ans.** (C)

**Sol.** $PT^2 = C$

using $PV = nRT$ in $PT^2 = C$

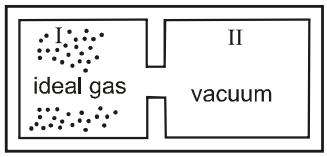
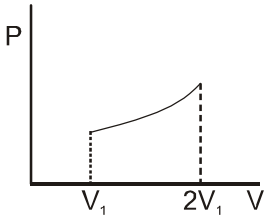
$$\left(\frac{nRT}{V}\right)T^2 = C \Rightarrow \quad T^3 \propto V$$

Differentiating we get

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

Coefficient of volume expansion ($\gamma$) = $\frac{1}{V}\frac{dV}{dT} = \frac{3}{T}$

**13.** **Column I** contains a list of processes involving expansion of an ideal gas. Match this with **Column II** describing the thermodynamic change during this process. Indicate your answer by darkening the appropriate bubbles of the 4 × 4 matrix given in the ORS. **[JEE 2008]**

| | **Column I** | | **Column II** |
|---|---|---|---|
| (A) | An insulated container has two chambers separated by a valve. Chamber I contains an ideal gas and the Chamber II has vacuum. The valve is opened.   | (P) | The temperature of the gas decreases |
| (B) | An ideal monoatomic gas expands to twice its original volume such that its pressure $P \propto \frac{1}{V^2}$, where V is the volume of the gas. | (Q) | The temperature of the gas increases or remains constant |
| (C) | An ideal monoatomic gas expands to twice its original volume such that its pressure $P \propto \frac{1}{V^{4/3}}$, where V is its volume | (R) | The gas loses heat |
| (D) | An ideal monoatomic gas expands such that its pressure P and volume V follows the behaviour shown in the graph   | (S) | The gas gains heat |

**Ans.** (A) → Q; (B) → PR; (C) → PS; (D) → QS;

**Sol.** Column-I : Expansion of ideal gas

Column-II : Thermodynamic change.

(A) $\Delta Q = 0$ (as boundary is non conducting)

in the case of free expansion W = 0

$Q = \Delta U + W$

$0 = \Delta U + 0 \quad \Delta U = 0$

$U = \text{const.}$

(A) $\rightarrow$ (q) (As temp remains constant).

(B) $P \propto \frac{1}{V^2}$

$PV^2 = C$

$n RTV = C$

$TV = C'$

Since volume increases the temperature decreases.

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

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

$C = \frac{R}{2} \Rightarrow Q = n\frac{R}{2}\Delta T$

$\Delta T$ is negative so Q is negative

means heat is lost

So for (B) $\rightarrow$ (p, r)

(C) $PV^{4/3} = C$

$TV^{1/3} = C'$

So when volume increases temperature decreases

Now $C = C_v + \frac{R}{-\frac{4}{3}+1} = \frac{3}{2}R - 3R \Rightarrow C = -\frac{3}{2}R$

$Q = nC\Delta T \Rightarrow Q = n\left(-\frac{3}{2}R\right)(\Delta T)$

as $\Delta T$ is negative Q will be positive.

Hence (C) $\rightarrow$ p,s

(D) $T = \frac{PV}{nR}$

as product of P and V increases, so temperature increases

$Q = \Delta U + W$

$\Delta U$ = +ve ($\Delta T$ = +ve)

W = +ve (As volume increases)

So Q = +ve

Hence gas gains heat

SO, (D) $\rightarrow$ (q, s)

**14.** $C_v$ and $C_p$ denote the molar specific heat capacities of a gas at constant volume and constant pressure, respectively. Then **[JEE, 2009]**

(A) $C_p - C_v$ is larger for a diatomic ideal gas than for a monoatomic ideal gas

(B) $C_p + C_v$ is larger for a diatomic ideal gas than for a monoatomic ideal gas

(C) $C_p / C_v$ is larger for a diatomic ideal gas than for a monoatomic ideal gas

(D) $C_p . C_v$ is larger for a diatomic ideal gas than for a monoatomic ideal gas

**Ans.** (BD)

**Solution :** For monoatomic gas, $C_p = \frac{5}{2}R$, $C_v = \frac{3}{2}R$. $C_p - C_v = R$

For diatomic gas $C_p = \frac{7}{2}R$, $C_v = \frac{5}{2}R$. $C_p - C_v = R$

$C_p - C_v$ is same for both

$C_p + C_v = 6R$ (for diatomic)

$C_p + C_v = 4R$ (for mono)

so $(C_p + C_v)_{dia} > (C_p + C_v)_{mono}$

$\frac{C_p}{C_v} = \frac{7}{5} = 1.4$ (for diatomic)

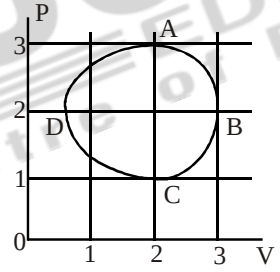
$\frac{C_p}{C_v} = \frac{5}{3} = 1.66$ (for monoatomic)

$(C_p)(C_v) = \frac{35}{4}R^2$ (for diatomic)

$(C_p)(C_v) = \frac{15}{4}R^2$ (for monoatomic)

so $(C_p \,.\, C_v)_{diatomic} > (C_p \,.\, C_v)_{monoatomic}$

**15.** The figure shows the P-V plot of an ideal gas taken through a cycle ABCDA. The part ABC is a semi-circle and CDA is half of an ellipse. Then, **[JEE, 2009]**




(A) the process during the path $A \to B$ is isothermal

(B) heat flows out of the gas during the path $B \to C \to D$

(C) work done during the path $A \to B \to C$ is zero

(D) positive work is done by the gas in the cycle ABCDA

**Ans.** (BD)

**Sol.** (A) process is not isothermal

(B) volume decreases and temperature decreases

$\Delta U$ = negative

$\Delta W$ = negative

so $\Delta Q$ = negative

(C) Work done in process $A \to B \to C$ is positive

(D) Cycle is clockwise, so work done by the gas is positive.

**16.** A real gas behaves like an ideal gas if its

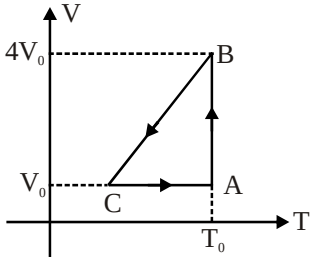
(A) pressure and temperature are both high (B) pressure and temperature are both low

(C) pressure is high and temperature is low (D) pressure is low and temperature is high

**Ans.** (D)

**Sol.** At low pressure and high temperature inter molecular forces become ineffective. So a real gas behaves like an ideal gas.

**17.** One mole of an ideal gas in initial state A undergoes 1 a cyclic process ABCA, as shown in the figure. its pressure at A is $P_0$. Choose the correct option(s) from the following. **[JEE-2010]**




(A) Internal energies at A and B are the same

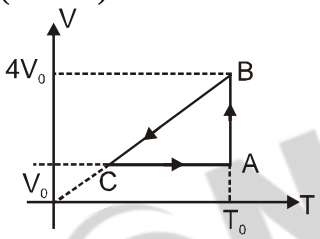
(B) Work done by the gas in process AB is $P_0V_0 \ln 4$

(C) Pressure at C is $\frac{P_0}{4}$

(D) Temperature at C is $\frac{T_0}{4}$

**Ans.** (ABCD)

**Sol.**




$\because \quad U = \frac{f}{2} nRT$, where f, n, R are constants. Also temperature T is same at A & B.

$\therefore \quad U_A = U_B$

Also, $\Delta W_{AB} = nRT_0 \ \ell n \left(\frac{V_f}{V_i}\right) = nRT_0 \ \ell n \ \frac{4V_0}{V_0} = nRT_0 \ \ell n 4 = P_0V_0 \ \ell n 4$

**18.** A diatomic ideal gas is compressed adiabatically to 1/32 of its initial volume. In the initial temperature of the gas is $T_i$ (in Kelvin) and the final temperature is $aT_i$, the value of a is **[JEE-2010]**

**Ans.** 4

**Sol.** For adiabatic process,

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

$T_2 = T_1\left(\frac{V_1}{V_2}\right)^{\gamma-1}$

$T_2 = T_1(32)^{\frac{7}{5}-1} \qquad T_2 = 4T_1 \qquad \Rightarrow \qquad a = 4$

**19.** 5.6 litre of helium gas at STP is adiabatically compressed to 0.7 litre. Taking the initial temperature to be $T_1$, the work done in the process is : **[JEE 2011]**

(A) $\frac{9}{8}\ RT_1$ (B) $\frac{3}{2}\ RT_1$ (C) $\frac{15}{8}\ RT_1$ (D) $\frac{9}{2} RT_1$

**Ans.** (A)

**Sol.** Number of moles of He = $\frac{1}{4}$

Now $T_1\ (5.6)^{\gamma-1} = T_2\ (0.7)^{\gamma-1}$

$$T_1 = T_2\left(\frac{1}{8}\right)^{2/3}$$

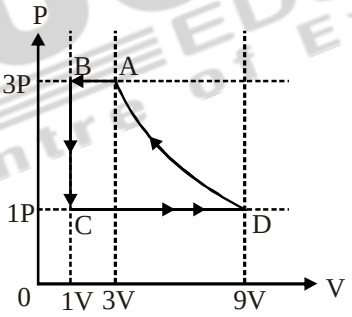
$$4T_1 = T_2$$

$$\text{Work done} = -\frac{nR[T_2 - T_1]}{\gamma - 1}$$

$$= -\frac{\frac{1}{4}R[3T_1]}{\frac{2}{3}}$$

$$= -\frac{9}{8}RT_1$$

**20.** One mole of a monatomic ideal gas is taken through a cycle ABCDA as shown in the P-V diagram. Column II gives the characteristics involved in the cycle. Match them with each of the processes given in Column I. **[JEE, 2011]**




| | **Column I** | | **Column II** |
|---|---|---|---|
| (A) | Process A → B | (P) | Internal energy decreases |
| (B) | Process B → C | (Q) | Internal energy increases |
| (C) | Process C → D | (R) | Heat is lost |
| (D) | Process D → A | (S) | Heat is gained |
| | | (T) | Work is done on the gas. |

**Ans.** (A) → PRT; (B) → PR; (C) → QS; (D) → RT;

**Sol.** $A \to B \Rightarrow$ $V \downarrow$ P const $\Rightarrow$ $T \downarrow$ $U \downarrow$ (p), (r), (t)

$B \to C \Rightarrow$ $d\omega \downarrow 0$

$P \downarrow T \downarrow$

$d\phi = du + d\omega$ (p), (r)

$C \to D \Rightarrow$ $V \uparrow \Rightarrow T \uparrow$

| | | |
|---|---|---|
| | $du \Rightarrow +ve$ | |
| | $d\omega = +ve$ | (q), (s) |
| $D \to A \Rightarrow$ | $dw \Rightarrow -ve$ | (r), (t) |
| | $dq \Rightarrow -ve$ | |
| | $du = 0$ | |

**21.** A mixture of 2 moles of helium gas (atomic mass = 4 amu), and 1 mole of argon gas (atomic mass = 40 amu) is kept at 300 K in a container. The ratio of the rms speeds $\left(\frac{v_{rms}(\text{helium})}{v_{rms}(\text{argon})}\right)$ is : **[IIT JEE-2012]**

(A) 0.32 (B) 0.45 (C) 2.24 (D) 3.16

**Ans.** (D)

**Sol.** $A \to B \Rightarrow$ $V \downarrow$ P const $\Rightarrow$ $T\downarrow$ $U\downarrow$ (p), (r), (t)

| | | |
|---|---|---|
| $B \to C \Rightarrow$ | $d\omega \downarrow 0$ | |
| | $P \downarrow T \downarrow$ | |
| | $d\phi = du + d\omega$ | (p), (r) |
| $C \to D \Rightarrow$ | $V\uparrow \Rightarrow T\uparrow$ | |
| | $du \Rightarrow +ve$ | |
| | $d\omega = +ve$ | (q), (s) |
| $D \to A \Rightarrow$ | $dw \Rightarrow -ve$ | (r), (t) |
| | $dq \Rightarrow -ve$ | |
| | $du = 0$ | |

**22.** Two moles of ideal helium gas are in a rubber balloon at 30° C .The balloon is fully expandable and can be assumed to require no energy in its expansion. The temperature of the gas in the balloon is slowly changed to 35°C.The amount of heat required in raising the temperature is nearly (take R = 8.31 J/mol.K) **[IIT-JEE-2012]**

(A) 62J (B) 104 J (C) 124 J (D) 208 J

**Ans.** (D)

**Sol.** $\Delta Q = nC_p \Delta T$

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

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

$= 2 \times \frac{5}{2} \times 8.31 \times 5$

$= 208$ J

**23.** Two non-reactive monoatomic ideal gases have their atomic masses in the ratio 2 : 3. The ratio of their partial pressures, when enclosed in a vessel kept at a constant temperature, is 4 : 3. The ratio of their densities is: **[JEE-2013]**

(A) 1 : 4 (B) 1 : 2 (C) 6 : 9 (D) 8 : 9

**Ans.** (D)

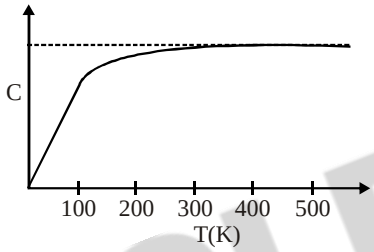
**Sol.** $P_1 = \frac{\rho_1 RT}{M_1}$ ...(i)

$P_2 = \frac{\rho_2 RT}{M_2}$ ...(ii)

by (i) and (ii)

$\frac{\rho_1}{\rho_2} = \frac{8}{9}$

**24.** The figure below shows the variation of specific heat capacity (C) of a solid as a function of temperature (T). The temperature is increased continuously from 0 to 500 K at a constant rate. Ignoring any volume change, the following statement(s) is (are) correct to a reasonable approximation. **[IIT JEE-2013]**




(A) the rate at which heat is absorbed in the range 0–100 K varies linearly with temperature T.
(B) heat absorbed in increasing the temperature from 0–100 K is less than the heat required for increasing the temperature from 400–500 K.
(C) there is no change in the rate of heat absorption in the range 400–500 K.
(D) the rate of heat absorption increases in the range 200–300 K.

**Ans.** (ABCD or BCD)

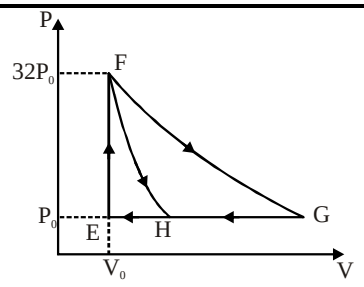
**Sol.** $q = mCT$

$\frac{dq}{dt} = mc\frac{dT}{dt}$

R = rate of absortion of heat = $\frac{dq}{dt} \propto C$

(i) in 0 – 100 k
C increases, so R increases but not linearly
(ii) $\Delta q = mC\Delta T$ as C is more in (400 k – 500 k) then (0 – 100 k) so heat is increasing.
(iii) C remains constant so there no change in R from (400 k – 500 k)
(iv) C is increases so R is increases in range (200 k – 300 k)

**25.** One mole of a monatomic ideal gas is taken along two cyclic processes $E \rightarrow F \rightarrow G \rightarrow E$ and $E \rightarrow F \rightarrow H \rightarrow E$ as shown in the PV diagram. The processes involved are purely isochoric, isobaric, isothermal or adiabatic.




Match the paths in List I with the magnitudes of the work done in List II and select the correct answer using the codes given below the lists.

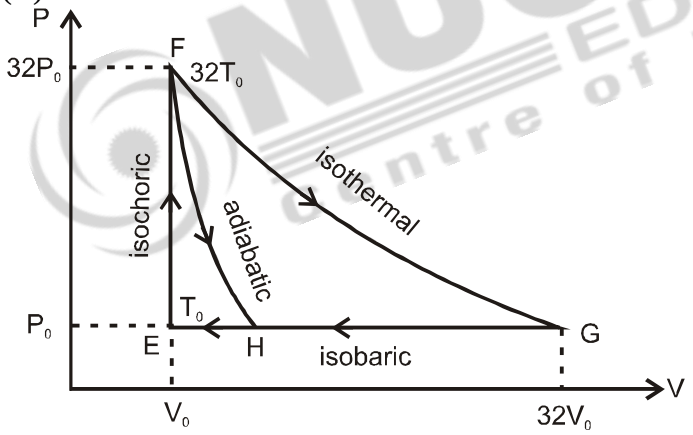
| | **List I** | | **List II** |
|---|---|---|---|
| P. | $G \rightarrow E$ | 1. | $160\ P_0V_0 \ln 2$ |
| Q. | $G \rightarrow H$ | 2. | $36\ P_0V_0$ |
| R. | $F \rightarrow H$ | 3. | $24\ P_0V_0$ |
| S. | $F \rightarrow G$ | 4. | $31\ P_0V_0$ |

**Codes :**

| | **P** | **Q** | **R** | **S** |
|---|---|---|---|---|
| (A) | 4 | 3 | 2 | 1 |
| (B) | 4 | 3 | 1 | 2 |
| (C) | 3 | 1 | 2 | 4 |
| (D) | 1 | 3 | 2 | 4 |

**Ans.** (A)

**Sol.**




In F→G work done in isothermal proces is $nRT \ln\left(\frac{V_f}{V_i}\right) = 32\ P_0\ V_0 \ln\left(\frac{32V_0}{V_0}\right)$

$= 32\ P_0V_0 \ln 2^5 = 160\ P_0\ V_0 \ln 2$

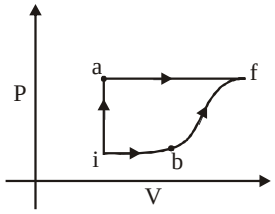
In $G \rightarrow E$, $\Delta W = P_0\ \Delta V = P_0\ (31\ V_0) = 31\ P_0V_0$

In $G \rightarrow H$ work done is less than $31\ P_0V_0$ i.e., $24\ P_0V_0$

In $F \rightarrow H$ work done is $36\ P_0V_0$

**26.** A thermodynamic system is taken from an initial state *i* with internal energy $U_i = 100$ J to the final state *f* along two different paths *iaf* and *ibf*, as schematically shown in the figure. The work done by the system along the paths *af*, *ib* and *bf* are Waf = 200 J, $W_{ib} = 50$ J and $W_{bf}$ =

100 J respectively. The heat supplied to the system along the path iaf, ib and bf are $Q_{iaf}$ ,$Q_{ib}$ and $Q_{bf}$ respectively. If the internal energy of the system in the state b is Ub = 200 J and Qiaf = 500 J, the ratio $\mathbf{Q_{bf} / Q_{ib}}$ is **[IIT JEE -2014]**




**Ans.** 2

**Sol.**

$w_{ibf} = 150$ J

$w_{iaf} = 200$ J

$Q_{iaf} = 500$ J So $U_{iaf} = 300$ J

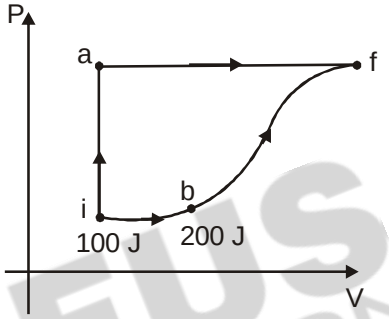
So vr% $U_f = 400$ J

$U_{ib} = 100$ J

$Q_{ib} = 100 + 50 = 150$ J

$Q_{ibf} = 300 + 150 = 450$ J

So the required ratio $\frac{Q_{bf}}{Q_{ib}} = \frac{450-150}{150} = 2$




**Paragraph for Questions 27 & 28**

In the figure a container is shown to have a movable (without friction) piston on top. The container and the piston are all made of perfectly insulating material allowing no heat transfer between outside and inside the container. The container is divided into two compartments by a rigid partition made of a thermally conducting material that allows slow transfer of heat. The lower compartment of the container is filled with 2 moles of an ideal monatomic gas at 700 K and the upper compartment is filled with 2 moles of an ideal diatomic gas at 400 K. The heat capacities per mole of an ideal monatomic gas are $C_v = \frac{3}{2}R$ , $C_P = \frac{5}{2}R$ , and those for an ideal diatomic gas are $C_V = \frac{5}{2}R$ , $C_P = \frac{7}{2}R$ . **[IIT JEE -2014]**



**27.** Consider the partition to be rigidly fixed so that it does not move. When equilibrium is achieved, the final temperature of the gases will be

(A) 550 K (B) 525 K (C) 513K (D) 490 K

**Ans.** (D)

**Sol.** Let final temperature of gases is T

Heat rejected by gas in lower compartment $(nC_v\Delta T) = 2\times\frac{3}{2}R(700-T)$

Heat received by gas in above compartment $(nC_P\Delta T) = 2\times\frac{7}{2}R(T-400)$

Equating above

$2100 - 3T = 7T - 2800$

$\Rightarrow \quad T = 490\ K$

**28.** Now consider the partition to be free to move without friction so that the pressure of gases in both compartments is the same. Then total work done by the gases till the time they achieve equilibrium will be

(A) 250 R (B) 200 R (C) 100 R (D) –100 R

**Ans.** (D)

**Sol.** $\Delta W_1 + \Delta U_1 = \Delta Q_1$

$\Delta W_2 + \Delta U_2 = \Delta Q_2$

$\Delta Q_1 + \Delta Q_2 = 0$

$\frac{7}{2}R\ (T-400) = \frac{5}{2}R\ (700-T)$

$\Rightarrow \quad T = \frac{6300}{12} = 525\ K$

So $\Delta W_1 + \Delta W_2 = 2\ .\ R.\ (525-400) + 2R(525-700)$

$= +250R - 350\ R$

$= -100R$

**29.** A container of fixed volume has a mixture of one mole of hydrogen and one mole of helium in equilibrium at temperature T. Assuming the gases are ideal, the correct statement(s) is(are) **[IIT JEE -2015]**

(A) The average energy per mole of the gas mixture is 2RT.

(B) The ratio of speed of sound in the gas mixture to that in helium gas is $\sqrt{6/5}$.

(C) The ratio of the rms speed of helium atoms to that of hydrogen molecules is 1/2.

(D) The ratio of the rms speed of helium atoms to that of hydrogen molecules is $1/\sqrt{2}$.

**Ans.** (ABD)

**Sol.** $U = nC_{V_1}T + nC_{V_2}T$

$= 1\times\frac{5}{2}RT + 1\times\frac{3}{2}RT = 4RT$

$\Rightarrow 2C_{V_{mix}}T = 4RT$

Average energy per mole $= 2RT \Rightarrow C_{V_{mix}} = 2R$

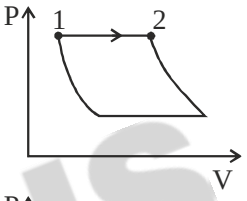
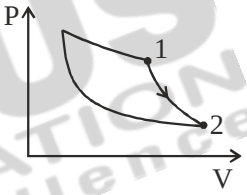
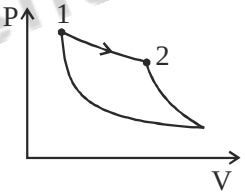
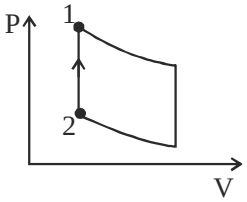
$$\frac{C_{mix}}{C_{He}} = \sqrt{\left(\frac{\gamma_{mix}}{\gamma_{He}}\right)\left(\frac{M_{He}}{M_{mix}}\right)} = \sqrt{\frac{3}{2}\times\frac{3}{5}\times\frac{4}{3}} = \sqrt{\frac{6}{5}}$$

$$\frac{V_{rms\ He}}{V_{rms\ H_2}} = \sqrt{\frac{M_{H_2}}{M_{He}}} = \frac{1}{\sqrt{2}}$$

**Answer Q.30, Q.31 and Q.32 by appropriately matching the information given in the three columns of the following table.**

An ideal gas is undergoing a cyclic thermodynamic process in different ways as shown in the corresponding P–V diagrams in column 3 of the table. Consider only the path from state 1 to 2. W denotes the corresponding work done on the system. The equations and plots in the table have standard notations as used in thermodynamic processes. Here $\gamma$ is the ratio of heat capacities at constant pressure and constant volume. The number of moles in the gas in n.

**[JEE-2017]**

| | **Column 1** | | **Column 2** | | **Column 3** |
|---|---|---|---|---|---|
| (I) | $W_{1\to2}=\frac{1}{\gamma-1}(P_2V_2-P_1V_1)$ | (i) | Isothermal | (P) |  |
| (II) | $W_{1\to2}=-PV_2+PV_1$ | (ii) | Isochoric | (Q) |  |
| (III) | $W_{1\to2}=0$ | (iii) | Isobaric | (R) |  |
| (IV) | $W_{1\to2}=-nRT\ln\left(\frac{V_2}{V_1}\right)$ | (iv) | Adiabatic | (S) |  |

**30.** Which of the following options is the only correct representation of a process in which $\Delta U = \Delta Q - P\Delta V$?

(A) (II) (iv) (R) (B) (II) (iii) (P) (C) (II) (iii) (S) (D) (III) (iii) (P)

**Ans.** (B)

**Sol.** The process must be isobaric.

**31.** Which one of the following options is the correct combination?

(A) (III) (ii) (S) (B) (II) (iv) (R) (C) (II) (iv) (P) (D) (IV) (ii) (S)

**Ans.** (A)

**Sol.** The correct combination is for isochoric process.

**32.** Which one of the following options correctly represents a thermodynamic process that is used as a correction in the determination of the speed of sound in an ideal gas?

(A) (III) (iv) (R) (B) (I) (ii) (Q) (C) (IV) (ii) (R) (D) (I) (iv) (Q)

**Ans.** (D)

**Sol.** The process must be adiabatic, which is used in Laplace correction over Newton's law for sound speed in air.

**33.** One mole of a monatomic ideal gas undergoes an adiabatic expansion in which its volume becomes eight times its initial value. If the initial temperature of the gas is 100 K and the universal gas constant R = 8.0 $mol^{-1}$ $K^{-1}$, the decrease in its internal energy, in Joule, is_____. **[JEE ADVANCED-2018]**

**Ans.** (900.00)

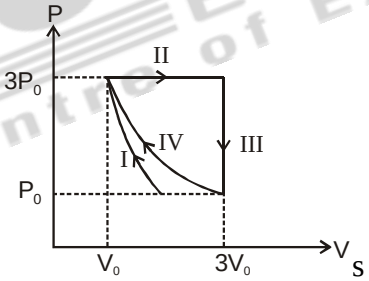
**Sol.** $\frac{T_f}{T_i} = \left(\frac{V_i}{V_f}\right)^{\gamma-1} = \left(\frac{1}{8}\right)^{2/3}$

$T_f = \frac{T_i}{4} = \frac{100}{4} = 25\ K$

$\therefore\ \Delta U = nC_V(T_f - T_i)$

$= 1\times\frac{3R}{2}(25-100) = \frac{3}{2}\times 8\times(-75) = -900$ Joule

**34.** One mole of a monatomic ideal gas undergoes four thermodynamic processes as shown schematically in the PV-diagram below. Among these four processes, one is isobaric, one is isochoric, one is isothermal and one is adiabatic. Match the processes mentioned in List-1 with the corresponding statements in List-II. **[JEE ADVANCED-2018]**




| LIST–I | LIST–II |
|---|---|
| P. In process I | 1. Work done by the gas is zero |
| Q. In process II | 2. Temperature of the gas remains unchanged |
| R. In process III | 3. No heat is exchanged between the gas and its surroundings |
| S. In process IV | 4. Work done by the gas is 6 $P_0V_0$ |

**Codes :**

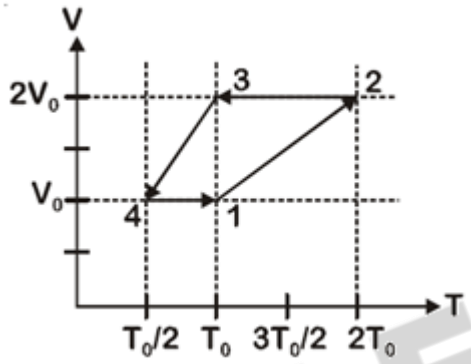
| | P | Q | R | S |
|---|---|---|---|---|
| (A) | 4 | 3 | 1 | 2 |
| (B) | 1 | 3 | 2 | 4 |
| (C) | 3 | 4 | 1 | 2 |
| (D) | 3 | 4 | 2 | 1 |

**Ans.** (C)

**Sol.** Process 1 is adiabatic process, hence Q = 0

Process 2 is isobaric, hence $W = P\cdot\Delta V = 6P_0V_0$
Process 3 is isochoric, hence $W = 0$
Process 4 is isothermal

**35.** One mole of a monatomic ideal gas goes through a thermodynamic cycle, as shown in the volume versus temperature (V-T) diagram. The correct statement(s) is/are:
[R is the gas constant] **[JEE ADVANCED-2019]**




(1) The ratio of heat transfer during processes $1 \to 2$ and $2 \to 3$ is $\left|\frac{Q_{1\to2}}{Q_{2\to3}}\right| = \frac{5}{3}$

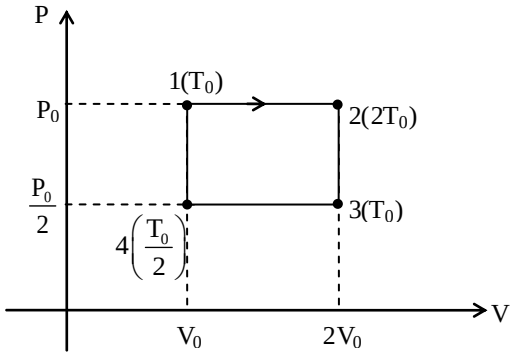
(2) The above thermodynamic cycle exhibits only isochoric and adiabatic processes.

(3) Work done in this thermodynamic cycle $(1 \to 2 \to 3 \to 4 \to 1)$ is $|W| = \frac{1}{2}RT_0$

(4) The ratio of heat transfer during processes $1 \to 2$ and $3 \to 4$ is $\left|\frac{Q_{1\to2}}{Q_{2\to4}}\right| = \frac{1}{2}$

**Ans. (1,3)**

**Sol.**



**1.** $\left|\frac{Q_{12}}{Q_{23}}\right| = \frac{nC_P(2T_0 - T_0)}{nC_V(2T_0 - T_0)} = \frac{C_P}{C_V} = \frac{5}{3}$ (Monatomic gas)

**3.** $W_{Total}$ = Area

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

$= \frac{P_0V_0}{2} = \frac{RT_0}{2}$ (As $P_0V_0 = 1\ RT_0$)

**4.** $\left|\frac{Q_{12}}{Q_{34}}\right| = \frac{nC_P(2T_0 - T_0)}{nC_P\left(T_0 - \frac{T_0}{2}\right)} = 2$

**36.** A mixture of ideal gas containing 5 moles of monatomic gas and 1 mole of rigid diatomic gas is initially at pressure $P_0$, volume $V_0$, and temperature $T_0$. If the gas mixture is adiabatically compressed to a volume $V_0/4$, then the correct statement(s) is/are.
(Given $2^{1.2} = 2.3$; $2^{3.2} = 9.2$; R is gas constant) **[JEE ADVANCED-2019]**
(1) The work |W| done during the process is $13RT_0$
(2) The final pressure of the gas mixture after compression is in between $9P_0$ and $10P_0$
(3) Adiabatic constant of the gas mixture is 1.6
(4) The average kinetic energy of the gas mixture after compression is in between $18RT_0$ and $19RT_0$

**Ans.** **(1,2,3)**

**Sol.** $\gamma_{mix} = \frac{5\times\frac{5}{2}R + 1\times\frac{7}{2}R}{5\times\frac{3}{2}R + 1\times\frac{5}{2}R} = \frac{8}{5} = 1.6$

$P_iV_i = P_f V_f \Rightarrow P_f = P_0\left(\frac{V}{V/4}\right)^{1.6} = 9.2\ P_0$

$W = \frac{P_iV_i - P_fV_f}{\gamma - 1} = \frac{P_0V_0 - 9.2P_0\cdot\frac{V_0}{4}}{1.6 - 1} = \frac{-1.3P_0V_0}{0.6} = -13RT_0$

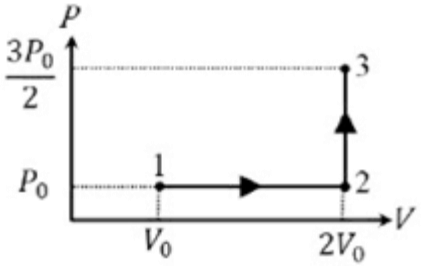
$(K.E.)_{Avg} = \frac{3}{2}RT = \frac{3}{2}\times\frac{9.2\ P_0\times V_0/4}{n} = \frac{3}{2}\times\frac{2.3}{n}\times nRT_0 = 3.45RT_0$

**Answer the question 37 and 38 by appropriately matching the lists based on the information given in the paragraph**

In a thermo dynamic process on an ideal monatomic gas. the infinitesimal heat absorbed by the gas is given by $T\Delta X$. where T is temperature of the system and $\Delta X$ is the infinitesimal change in a thermodynamic quantity X of the system. For a mole of monatomic ideal gas $X = \frac{3}{2}R\ln\left(\frac{T}{T_A}\right)+R\ln\left(\frac{v}{v_A}\right)$. Here R is gas constant. V is volume of gas. $T_A$ and $V_A$ are constants. The List-I below gives some quantities involved in a process and List-II gives some possible values of these quantities. **[JEE ADVANCED-2019]**

| | **List-I** | | **List-II** |
|---|---|---|---|
| (I) | Work done by the system in process $1 \to 2 \to 3$ | (P) | $\frac{1}{3}RT_0 \ln 2$ |
| (II) | Change in internal energy in process $1 \to 2 \to 3$ | (Q) | $\frac{1}{3}RT_0$ |
| (III) | Heat absorbed by the system in process $1 \to 2 \to 3$ | (R) | $RT_0$ |
| (IV) | Heat absorbed by the system in process $1 \to 2$ | (S) | $\frac{4}{3}RT_0$ |
| | | (T) | $\frac{1}{3}RT_0(3+\ln 2)$ |
| | | (U) | $\frac{5}{6}RT_0$ |

**37.** If the process carried out on one mole of monatomic ideal PV-diagram with $P_0V_0 = \frac{1}{3}RT_0$, the correct match is.




(1) I $\to$ Q. II $\to$ R. III $\to$ P. IV $\to$ U

(2) I $\to$ S. II $\to$ R. III $\to$ Q. IV $\to$ T

(3) I $\rightarrow$ Q. II $\rightarrow$ R. III $\rightarrow$ S. IV $\rightarrow$ U

(4) I $\rightarrow$ Q. II $\rightarrow$ S. III $\rightarrow$ R, IV$\rightarrow$ U

**Ans. (3)**

**Sol.** $P_0V_0 = \frac{1}{3}RT_0$

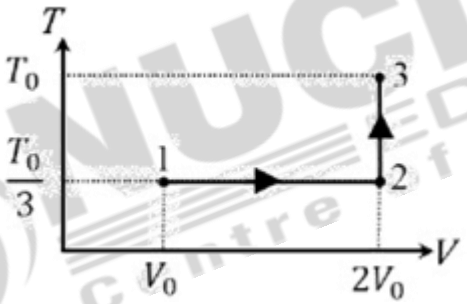
Work done = $P_0V_0 = \frac{1}{3}RT_0$

$\Delta U = \frac{f}{2}nR\Delta T = \frac{f}{2}\left(P_fV_f - P_iV_i\right) = \frac{3}{2}\cdot\left(3P_0V_0 - P_0V_0\right) = 3P_0V_0 = RT_0$

Total heat absorbed = $\frac{1}{3}RT_0 + RT_0 = \frac{4}{3}RT_0$

Heat absorbed in $1 \rightarrow 2$ = $\frac{1}{3}RT_0 + \frac{3}{2}\left(2P_0V_0 - P_0V_0\right) = \frac{1}{3}RT_0 + \frac{3}{2}\cdot\frac{1}{3}RT_0 = \frac{5}{6}RT_0$

**38.** If the process on one mole of monatomic ideal gas is as shown in the TV-diagram with $P_0V_0 = \frac{1}{3}RT_0$. The correct match is.




(1) I $\rightarrow$ P. II $\rightarrow$ T. III $\rightarrow$ Q. IV $\rightarrow$ T (2) I $\rightarrow$ P. II $\rightarrow$ R. III $\rightarrow$ T. IV $\rightarrow$ P

(3) I $\rightarrow$ P. II $\rightarrow$ R. III $\rightarrow$ T. IV $\rightarrow$ S (4) I $\rightarrow$ S. II $\rightarrow$ T. III $\rightarrow$ Q, IV$\rightarrow$ U

**Ans. (2)**

**Sol.** $P_0V_0 = \frac{1}{3}RT_0$

Work done = $nRT\ ln\left(\frac{V_f}{V_i}\right) = \frac{RT_0}{3}ln\,2$

$\Delta U = \frac{f}{2}nR\Delta T = \frac{3}{2}R\left(T_0 - \frac{T_0}{3}\right) = RT_0$

Total Heat absorbed = $RT_0 + \frac{RT_0}{3}ln\,2$

$= \frac{1}{3}RT_0\left(3 + ln2\right)$

Heat absorbed in $1 \rightarrow 2$ = $W = \frac{RT_0}{3}ln\,2$