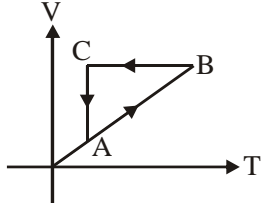
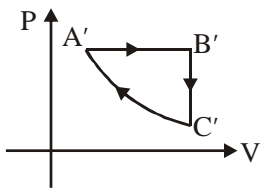
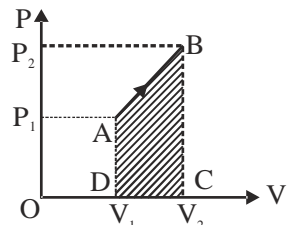


SOLVED EXAMPLES

Example 1.	<p>70 calorie of heat is required to raise the temperature of a diatomic gas at constant pressure from 30 to 35°C. The amount of heat required (in calorie) to raise the temperature of the same gas through the same range (30 to 35°C) at constant volume is</p> <p>(1) 30 (2) 60 (3) 50 (4) 70.</p>
Solution :	<p>(3) $\frac{C_p}{C_v} = \gamma = 1.4$ [$\because \gamma = 1.4$ for diatomic gas]</p> $\frac{(\Delta Q)_p}{(\Delta Q)_v} = \frac{nC_p\Delta T}{nC_v\Delta T} = \frac{C_p}{C_v} = 1.4 \quad \therefore (\Delta Q)_v = \frac{(\Delta Q)_p}{1.4} = 50 \text{ cal .}$
Example 2.	<p>A vessel contains 1 mole of O₂ and 1 mole of He. The value of γ for the mixture is</p> <p>(1) 1.4 (2) 1.50 (3) 1.53 (4) None of these.</p>
Solution :	<p>(2) $C_{v_{\text{mix}}} = \frac{\frac{3}{2}R + \frac{5}{2}R}{2} = 2R$; $C_{p_{\text{mix}}} = 2R + R = 3R$</p> $\gamma_{\text{mix}} = \frac{C_p}{C_v} = \frac{3}{2} .$
Example 3.	<p>The temperature of an ideal gas is increased from 120 K to 480 K. If at 120 K the rms velocity of the gas molecules is v, at 480 K it becomes</p> <p>(1) $4v$ (2) $2v$ (3) $\frac{v}{2}$ (4) $\frac{v}{4}$.</p>
Solution :	<p>(2) $\frac{v_1}{v_2} = \frac{\sqrt{\frac{3RT_1}{M}}}{\sqrt{\frac{3RT_2}{M}}} = \sqrt{\frac{T_1}{T_2}} \quad \therefore v_2 = 2v .$</p>
Example 4.	<p>A and B are two gases. $\frac{T_A}{M_A} = 4 \frac{T_B}{M_B}$ where T is the temperature and M is the molecular mass. If C_A and C_B are rms speeds, then $\frac{C_A}{C_B}$ will be</p> <p>(1) 2 (2) 4 (3) 0.5 (4) 0.25.</p>
Solution :	<p>(1)</p> $\frac{C_A}{C_B} = \frac{\sqrt{\frac{3RT_A}{M_A}}}{\sqrt{\frac{3RT_B}{M_B}}} = 2 .$

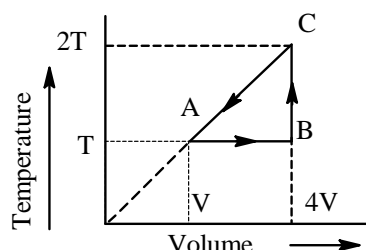
<p>Example 5.</p>	<p>3 mole of H_2 is mixed with 1 mole of Ne. The specific heat of mixture at constant pressure is</p> <p>(1) $\frac{9}{4}R$ (2) $\frac{13}{4}R$ (3) $\frac{9R}{2}$ (4) $\frac{13R}{2}$.</p> <p>Solution :</p> $(2) C_{V_{\text{mix}}} = \frac{n_1 C_{V_1} + n_2 C_{V_2}}{n_1 + n_2} = \frac{\frac{5}{2}R \times 3 + \frac{3}{2}R \times 1}{4} = \frac{18R}{8} = \frac{9R}{4}$ $C_{P_{\text{mix}}} = C_{V_{\text{mix}}} + R = \frac{13R}{4}.$
<p>Example 6.</p>	<p>Figure shows a V–T diagram for an ideal gas. Convert it to PV diagram.</p>  <p>Solution :</p> <p>In process AB, $V \propto T$. That is, P is constant. In BC volume is constant.</p> <p>$\therefore P \propto T$</p> <p>In C to A, T is constant.</p> <p>$\therefore P \propto \frac{1}{V}$ (Boyle's law).</p> 
<p>Example 7.</p>	<p>The pressure in monoatomic gas increases linearly from $4 \times 10^5 \text{ N-m}^{-2}$ to $8 \times 10^5 \text{ N-m}^{-2}$, when its volume increases from 0.2 m^3 to 0.5 m^3. Calculate the following :</p> <p>(1) Work done by the gas</p> <p>(2) Increase in the internal energy</p> <p>(3) Amount of heat supplied</p> <p>(4) Molar specific heat capacity of gas</p>  <p>Solution :</p> <p>$\Delta W = \text{work done by the gas} = \text{area of trapezium ABCD}$</p> $\Delta W = \frac{1}{2}(P_1 + P_2)(V_2 - V_1) = \frac{1}{2}[4 \times 10^5 + 8 \times 10^5][0.5 - 0.2] = 1.8 \times 10^5 \text{ J.}$ <p>(2) Increase in internal energy</p> $\Delta U = \mu C_V \Delta T = (m/M)C_V(T_2 - T_1) = \frac{C_V(P_2 V_2 - P_1 V_1)}{R}$ <p>for monoatomic gas, $C_V = \frac{f}{2}R = \frac{3}{2}R$</p> $\therefore \Delta U = \frac{3}{2}R(8 \times 10^5 \times 0.5 - 4 \times 10^5 \times 0.2) = 4.8 \times 10^5 \text{ J.}$ <p>(3) Heat supplied = $dQ = dU + dW = 1.8 \times 10^5 + 4.8 \times 10^5 = 6.6 \times 10^5 \text{ J.}$</p> <p>(4) Molar specific heat</p> $C = \frac{\Delta Q}{\mu \Delta T} = \frac{\Delta Q \cdot R}{(P_2 V_2 - P_1 V_1)} = \frac{6.6 \times 10^5 \times 8.3}{[8 \times 10^5 \times 0.5 - 4 \times 10^5 \times 0.2]} = 17.12$

Example 8.

The figure shows a V–T graph of the thermodynamic process ABCA of an ideal gas. During process ABCA. Find

- (1) Total change in internal energy (2) Total work done by the gas
 (3) Heat supplied to the system

Assume number of moles of the gas = μ .

**Solution :**

- (1) Because the process is cyclic; hence $\Delta U = 0$
 (2) During the process AB temperature remains constant; process AB is isothermal. Work done during isothermal process AB

$$W_{AB} = \mu RT_1 \log_e (V_2/V_1) = \mu RT \log_e (4V/V) = 2\mu RT \log_e 2$$

During the process BC, volume remains constant. $W_{BC} = 0$

During the process CA, $V \propto T$ i.e., $(V/T) = \text{constant}$

$$\therefore PV = \mu RT \quad \text{or} \quad P = \frac{\mu RT}{V} = \text{constant}$$

Hence, AC is the isobaric process

$$\therefore W_{AC} = P(V_1 - V_2) = PV_1 - PV_2 = \mu RT_1 - \mu RT_2$$

$$= \mu R(T - 2T) = -\mu RT$$

Total work done by the gas during the process ABCA

$$\Delta W = W_{AB} + W_{CA} = 2\mu RT \log_e 2 + 0 - \mu RT_2$$

$$= \mu RT(2\log_e 2 - 1) = 0.386 \mu RT$$

- (3) $\Delta Q = \Delta U + \Delta W = 0 + 0.386 \mu RT$

Heat supplied to the gas = $0.386 \mu RT$.

Example 9.

A tyre pumped to a pressure 3.375 atm at 27°C suddenly bursts. Then the final temperature will be ($\gamma = 1.5$) ?

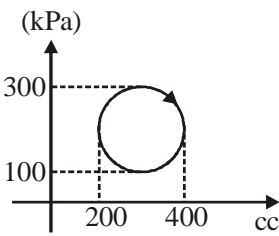
- (1) 27°C (2) -27°C (3) 0°C (4) -73°C.

Solution :

$$(4) T_1^\gamma P_1^{1-\gamma} = T_2^\gamma P_2^{1-\gamma}$$

$$\text{or} \quad \left(\frac{T_1}{T_2}\right)^\gamma = \left(\frac{P_1}{P_2}\right)^{\gamma-1} = \left(\frac{300}{T_2}\right)^{3/2} = \left(\frac{3.375}{1}\right)^{3/2-1}$$

$$\text{or} \quad T_2 = \frac{300}{(3.375)^{1/3}} = 200\text{K} = -73^\circ\text{C}.$$

<p>Example 10.</p> <p>Solution :</p>	<p>The ratio of work done by an ideal diatomic gas to the heat supplied by the gas in an isobaric process is</p> <p>(1) $\frac{5}{7}$ (2) $\frac{3}{5}$ (3) $\frac{2}{7}$ (4) $\frac{5}{3}$</p> <p>(3) $\Delta U = nC_v\Delta T = n\frac{5}{2}R\Delta T$</p> <p>$\Delta Q = nC_p\Delta T = n\frac{7}{2}R\Delta T$</p> <p>$W = \Delta Q - \Delta U = \frac{7n}{2}R\Delta T - \frac{5n}{2}R\Delta T = nR\Delta T, \frac{W}{Q} = \frac{2}{7}$.</p>
<p>Example 11.</p> <p>Solution :</p>	<p>One mole of Argon is heated using $PV^{3/2} = \text{constant}$. Find the amount of heat obtained by the process when the temperature changes by $\Delta T = -26$ K.</p> <p>Let μ be the number of moles where $\mu = 1$</p> <p>Then $C = \frac{R}{\gamma-1} - \frac{R}{\eta-1} = \frac{R}{\frac{5}{3}-1} - \frac{R}{\frac{3}{2}-1}$ ($C \Rightarrow$ molar heat capacity for polytropic process, $PV^n = \text{constant}$)</p> <p>$\Delta Q = \mu C \Delta T = 1 \left(\frac{3}{2}R - 2R \right) (-26)$ (μ is number of mole)</p> <p>$= +26 \left(\frac{8.314}{2} \right) = 108$ J.</p>
<p>Example 12.</p> <p>Solution :</p>	<p>Calculate the heat absorbed the system in going through the process shown in figure.</p>  <p>Heat absorbed = work done in the cyclic process = πr^2</p> <p>$= \pi (P_r) (V_r)$</p> <p>$= 3.14 (100 \times 10^3) (100 \times 10^{-6})$</p> <p>$= 31.4$ J.</p>

Example 13.

How much heat energy should be added to the gaseous mixture consisting of one gram of hydrogen and one gram of helium to raise its temperature from 0°C to 100°C (a) at constant volume (b) at constant pressure? ($R = 2 \text{ cal/mol K}$)

Solution :

As hydrogen is diatomic and has molecular weight 2.

$$(C_V)_{\text{H}_2} = \frac{5}{2} \quad \text{and} \quad \mu_{\text{H}_2} = \frac{1}{2}$$

while He is monatomic and has molecular weight 4.

$$(C_V)_{\text{He}} = \frac{3}{2} R \quad \text{and} \quad \mu_{\text{He}} = \frac{1}{4}$$

So by conservation of energy.

$$(C_V)_{\text{mix}} = \frac{\mu_1(C_V)_1 + \mu_2(C_V)_2}{\mu_1 + \mu_2}$$

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

$$\text{i.e. } (C_V)_{\text{mix}} = \frac{13}{8} \times \frac{4}{3} R = \frac{13}{6} R$$

(a) So $(\Delta Q)_V = \mu C_V \Delta T$

$$= \left(\frac{1}{2} + \frac{1}{4} \right) \times \frac{13}{6} \times 2 \times (100 - 0) = 325 \text{ cal.}$$

(b) Now as $(C_p)_{\text{mix}} = (C_V)_{\text{mix}} + R = \frac{13}{6} R + R = \frac{19}{6} R$

So, $(\Delta Q)_P = \mu C_p \Delta T$

$$= \left(\frac{1}{2} + \frac{1}{4} \right) \times \frac{19}{6} \times 2 \times (100 - 0)$$

$$= 475 \text{ cal}$$

Alternative of part (b)

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

$$\text{but } \Delta W = P \Delta V = \mu R \Delta T = \left(\frac{3}{4} \right) \times 2 \times 100$$

$$= 150 \text{ cal}$$

$$\text{So } (\Delta Q)_P = 325 + 150 = 475 \text{ cal}$$

<p>Example 14.</p> <p>Solution :</p>	<p>0.014 kg of nitrogen is enclosed in a vessel at a temperature of 27°C. How much heat has to be transferred to the gas to double the rms speed of its molecules ? (R = 2 cal/mol K)</p> <p>As gas is enclosed in the cylinder, V = constant,</p> $\therefore (\Delta Q)_V = \mu C_V \Delta T$ <p>Here $\mu = (0.014 \times 10^3) / 28 = (1/2) \text{ mol}$</p> <p>and nitrogen is diatomic, $C_V = (5/2)R$</p> <p>Further as according to given problem.</p> $\frac{(v_{\text{rms}})_2}{(v_{\text{rms}})_1} = \sqrt{\frac{T_2}{T_1}} = 2, \quad T_2 = 4T_1 \quad \text{or} \quad \Delta T = 4T_1 - T_1 = 3T_1 = 3 \times 300 = 900$ $\therefore (\Delta Q)_V = \frac{1}{2} \times \frac{5}{2} \times 2 \times 900 = 2250 \text{ caloric}$
<p>Example 15.</p> <p>Solution :</p>	<p>If 70 caloric of heat is required to raise the temperature of 2 mole of an ideal gas at constant pressure from 30 to 35°C, calculate (a) the work done by the gas (b) increase in internal energy of the gas and (c) degrees of freedom of the gas molecule. (R = 2 cal/mol K).</p> <p>(a) At constant pressure $\Delta W = P \Delta V = \mu R \Delta T$ [as $PV = \mu RT$]</p> <p>i.e. $\Delta W = \mu R \Delta T = 2 \times 2 \times (35 - 30) = 20 \text{ cal.}$</p> <p>(b) $\Delta U = (\Delta Q)_V = (\Delta Q)_P - \Delta W$</p> <p>So $\Delta U = 70 - 20 = 50 \text{ cal}$</p> $\gamma = \frac{C_P}{C_V} = \frac{(\Delta Q)_P}{(\Delta Q)_V} = \frac{70}{50} = \frac{7}{5}$ <p>Now as $\gamma = 1 + \frac{2}{F}$ so $\frac{7}{5} = 1 + \frac{2}{F}$</p> <p>i.e. $F = 5$ (and so gas is diatomic)</p>
<p>Example 16.</p> <p>Solution :</p>	<p>An insulated container is divided into two equal portions. One portion contains an ideal gas at pressure P and temperature T, while the other portion is a perfect vacuum. If a hole is opened between the two portions. Find the change in internal energy and temperature of the gas.</p> <p>As the system is thermally insulated,</p> $\Delta Q = 0$ <p>Further as here the gas is expanding against vacuum (surroundings), the process is called free expansion and for it.</p> $\Delta W = \int P dV = 0 \quad [\text{as for vacuum } P = 0]$

So in accordance with first law of thermodynamics, i.e. $\Delta Q = \Delta U + \Delta W$ we have

$$0 = \Delta U + 0 \text{ i.e. } \Delta U = 0 \text{ or } U = \text{constant}$$

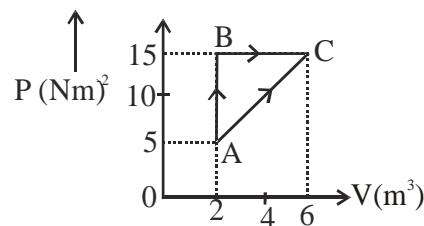
So in this problem internal energy of the gas remains constant. i.e. $\Delta U = 0$
Now as for an ideal gas.

$$U = \frac{3}{2}\mu RT \text{ i.e. } U \propto T$$

So temperature of the gas will also remain constant, i.e. $\Delta T = 0$

Example 17.

In the given figure, an ideal gas changes its state from state A to state C by two paths ABC and AC.



- (i) Find the path along which work done is the least.
- (ii) The internal energy of gas at A is 10 J and amount of heat supplied to change its state to C through the path AC is 200 J. Calculate the internal energy at C.
- (iii) The internal energy of gas at state B is 20 J. Find the amount of heat supplied to the gas to go from A to B.

Solution :

As work done $W = \int P dV = \text{area under P-V curve,}$

So, (i) $W_{ABC} = W_{AB} + W_{AC}$

i.e. $W_{ABC} = 0 + 15 \times 4 = 60\text{J}$

and $W_{AC} = \frac{1}{2}[5 + 15] \times (6 - 2) = 40\text{ J}$

So work done along AC is least.

- (ii) As according to first law of thermodynamics,

$$dQ = dU + dW$$

So for path AC

$$(U_C - U_A) = dQ - dW = 200 - 40 = 160\text{ J}$$

$$\text{So } U_C = 160 + U_A = 160 + 10 = 170\text{ J}$$

- (iii) For path AB, first law of thermodynamics yields

$$dQ = (U_B - U_A) + 0 = 20 - 10 = 10\text{ J}$$

MULTIPLE CHOICE QUESTIONS

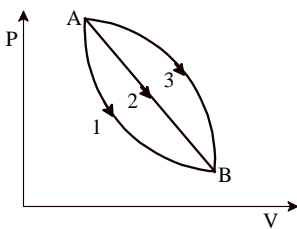
LEVEL - I

1. One mole of a monatomic gas is mixed with one mol of a diatomic gas. The molar specific heat of mixture at constant volume will be
 - (1) $R/2$
 - (2) R
 - (3) $2R$
 - (4) $3R$.
2. The value of internal energy for 1 mol of polyatomic gas is (f = number of degrees of freedom)
 - (1) $\frac{fR}{2T}$
 - (2) $\frac{fR}{2}$
 - (3) $\frac{fRT}{2}$
 - (4) $2fRT$.
3. The amount of heat required to increase the temperature of 1 mol of a triatomic gas (non-linear) at constant volume is n times the amount of heat required for 1 mol of monoatomic gas. The value of n will be
 - (1) 1
 - (2) 1.3
 - (3) 2
 - (4) 2.5
4. The temperature at which the rms speed of gas molecules becomes double its value at 0°C is
 - (1) 819°C
 - (2) 760°C
 - (3) 273°C
 - (4) 224°C .
5. Which of the following expression is not correct for rms velocity ?
 - (1) $\sqrt{\frac{3p}{P}}$
 - (2) $\sqrt{\frac{3RT}{M}}$
 - (3) $\sqrt{\frac{3PV}{M}}$
 - (4) $\sqrt{\frac{2E_k}{M}}$.
6. If the mean kinetic energy per unit volume of a gas is n times its pressure, then the value of n is
 - (1) 4.5
 - (2) 3.5
 - (3) 2.5
 - (4) 1.5
7. When a molecule moving with velocity u collides normally with the wall of the container, then the change in its velocity and momentum will be
 - (1) $-u$ and mu
 - (2) $2u$ and $2mu$
 - (3) $2u$ and mu
 - (4) u and $-mu$.
8. A man is climbing up a spiral type staircase. His degrees of freedom are
 - (1) 1
 - (2) 2
 - (3) 3
 - (4) More than 3
9. N balls, each of mass M kg, strike per second per unit area a surface normally with velocity V . The pressure exerted by them on the surface will be
 - (1) $2MNV^2$
 - (2) $2MNV$
 - (3) MNV^2
 - (4) MNV .
10. The specific heat at constant pressure of mixture of N_2 and He ($N_2 : \text{He} :: 3 \text{ mole} : 2 \text{ mole}$) will be
 - (1) $3.1 R$
 - (2) $1.5 R$
 - (3) $1.9 R$
 - (4) $2.1 R$
11. Which of the following is correct in terms of increasing work done for the same initial and final volume for expansion
 - (1) Adiabatic < isothermal < isobaric
 - (2) Isobaric < Adiabatic < Isothermal
 - (3) Adiabatic < Isobaric < Isothermal
 - (4) None of these
12. When an ideal diatomic gas is heated at constant pressure, the fraction of the heat energy supplied which increases the internal energy of the gas, is
 - (1) $\frac{2}{5}$
 - (2) $\frac{3}{5}$
 - (3) $\frac{3}{7}$
 - (4) $\frac{5}{7}$
13. A mono atomic gas is supplied the heat Q very slowly keeping the pressure constant. The work done by the gas will be
 - (1) $\frac{2}{3}Q$
 - (2) $\frac{3}{5}Q$
 - (3) $\frac{2}{5}Q$
 - (4) $\frac{1}{5}Q$

14. The temperature of a hypothetical gas increases to $\sqrt{2}$ times when compressed adiabatically to half the volume. Its equation can be written as

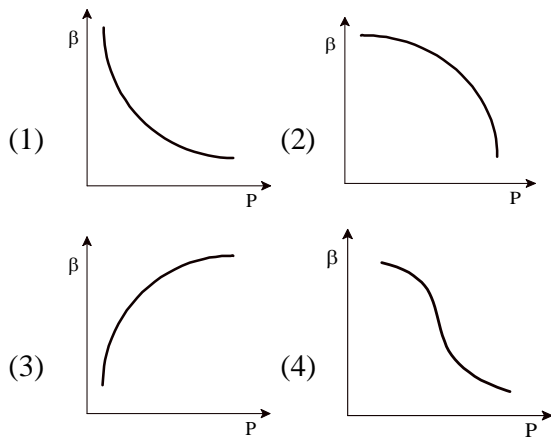
- (1) $PV^{3/2} = \text{constant}$ (2) $PV^{5/2} = \text{constant}$
 (3) $PV^{7/3} = \text{constant}$ (4) $PV^{4/3} = \text{constant}$

15. An ideal gas of mass m in a state A goes to another state B via three different processes as shown in figure. If Q_1, Q_2 and Q_3 denote the heat absorbed by the gas along the three paths, then



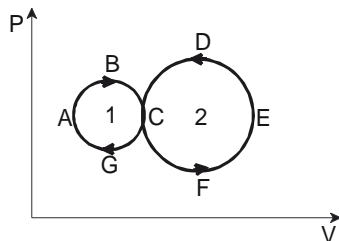
- (1) $Q_1 < Q_2 < Q_3$ (2) $Q_1 < Q_2 = Q_3$
 (3) $Q_1 = Q_2 > Q_3$ (4) $Q_1 > Q_2 > Q_3$

16. Which of the following graphs correctly represents the variation of $\beta = -(dV/dP)V$ with P for an ideal gas at constant temperature



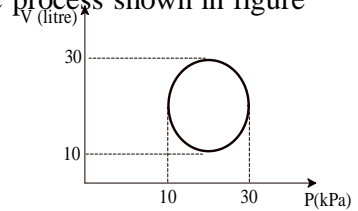
17. In the following indicator diagram, the net amount of work done in process

$A \rightarrow B \rightarrow C \rightarrow F \rightarrow E \rightarrow D \rightarrow C \rightarrow G \rightarrow A$



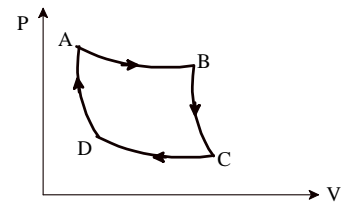
- (1) Positive (2) Negative
 (3) Zero (4) Infinity

18. Heat energy absorbed by a system in going through a cyclic process shown in figure



- (1) $10^7 \pi J$
 (2) $10^4 \pi J$
 (3) $10^2 \pi J$
 (4) $10^{-3} \pi J$

19. The P-V graph of an ideal gas cycle is shown here as below. The adiabatic process is described by

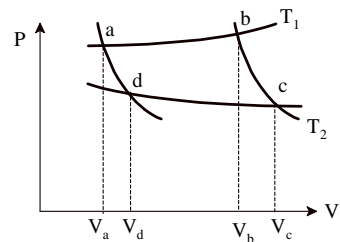


- (1) AB and BC (2) AB and CD
 (3) BC and DA (4) BC and CD

20. In the following P-V diagram two adiabatics cut two isothermals at temperature T_1 and T_2

(fig.). The value of $\frac{V_a}{V_d}$ will be

- (1) $\frac{V_b}{V_c}$
 (2) $\frac{V_c}{V_b}$
 (3) $\frac{V_d}{V_a}$
 (4) $V_b V_c$

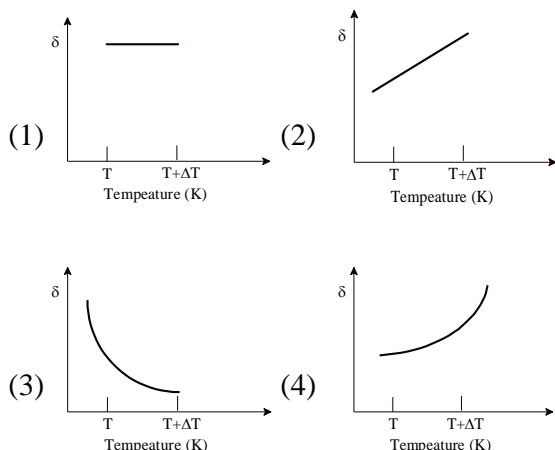


LEVEL - II

1. If C_p and C_v are the molar specific heats of a gas at constant pressure and volume respectively then the ratio of adiabatic and isothermal moduli of elasticity will be

- (1) $\frac{C_p - C_v}{C_p}$ (2) $C_p C_v$
 (3) $\frac{C_v}{C_p}$ (4) $\frac{C_p}{C_v}$

12. An ideal gas is initially at temperature T and volume V . Its volume is increased by ΔV due to an increase in temperature ΔT , pressure remaining constant. The quantity $\delta = \Delta V / (V\Delta T)$ varies with temperature as



13. 110J of heat is added to a gaseous system, whose internal energy increases by 40J, then the amount of work done by the system is
 (1) 150J (2) 70J
 (3) 110J (4) 40J
14. For free expansion of the gas which of the following is true
 (1) $Q = W = 0$ and $\Delta E_{\text{int}} = 0$
 (2) $Q = 0, W > 0$ and $\Delta E_{\text{int}} = 0$
 (3) $W = 0, Q > 0,$ and $\Delta E_{\text{int}} = Q$
 (4) $W > 0, Q < 0$ and $\Delta E_{\text{int}} = 0$
15. The specific heat of hydrogen gas at constant pressure is $C_p = 3.4 \times 10^{-3} \text{ cal/kg}^\circ\text{C}$ and at constant volume is $C_v = 2.4 \times 10^{-3} \text{ cal/kg}^\circ\text{C}$. If one kilogram hydrogen gas is heated from 10°C to 20°C at constant pressure, the external work done on the gas to maintain it at constant pressure is
 (1) 10^5 cal (2) 10^4 cal
 (3) 10^3 cal (4) $5 \times 10^3 \text{ cal}$
16. If a cylinder containing a gas at high pressure explodes, the gas undergoes

- (1) Reversible adiabatic change and fall of temperature
 (2) Reversible adiabatic change and rise of temperature
 (3) Irreversible adiabatic change and fall of temperature
 (4) Irreversible adiabatic change and rise of temperature

17. An ideal gas at 27°C is compressed adiabatically to $\frac{8}{27}$ of its original volume. If

$$\gamma = \frac{5}{3}, \text{ then the rise in temperature is}$$

- (1) 450K (2) 375K
 (3) 225K (4) 405K

18. Which is the correct statement

- (1) For an Isothermal change $P = \text{Bulk Modulus}$
 (2) In an isothermal process the change in internal energy must be equal to the work done

(3) For an adiabatic change $\frac{P_2}{P_1} = \left(\frac{V_2}{V_1}\right)^\gamma,$

where γ is the ratio of specific heats

- (4) In an adiabatic process work done must be equal to the heat entering the system

19. The amount of work done by a mole of a gas in an adiabatic expansion from temperature T to T_1 is

- (1) $R(T - T_1)$
 (2) $\frac{R}{\gamma - 1}(T - T_1)$
 (3) RT
 (4) $R(T - T_1)(\gamma - 1)$

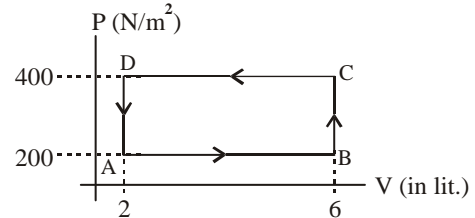
20. A monoatomic ideal gas does work of amount 2 Joules isobarically then what is the heat supply

- (1) 7 joule (2) 5 joule
 (3) 3 joule (4) 2 joule

LEVEL - III

- The specific heat of argon at constant volume is $c_V = 75 \text{ cal kg}^{-1} \text{ }^\circ\text{C}^{-1}$. The molecular weight of argon is ($R = 8.3 \text{ KJ kg. mole}^{-1}\text{ }^\circ\text{C}^{-1}$).
 (1) 20 (2) 25
 (3) 30 (4) 40
- For a process $PV^3 = K = \text{constant}$. The value of specific heat if the gas is diatomic is
 (1) R (2) 2R
 (3) 3R (4) 4R
- For one mole of a monoatomic gas $TP^{-2/5} = \text{constant}$, find work done in the process if temperature increases from 300 K to 400 K ($R = 2 \text{ cal/mol/k}$) and name the process is
 (1) 5/3, adiabatic (2) 5/3, isothermal
 (3) 2/3, adiabatic (4) 2/3, isothermal
- 1 gram mole of oxygen is trapped at 0°C in a cylinder under a smooth light piston inside the cylinder. The outside atmospheric pressure is $1.013 \times 10^5 \text{ Nm}^{-2}$ and the initial volume of the gas is $2.24 \times 10^{-2} \text{ m}^3$. If it is heated till its volume increases by 10%, the heat absorbed by the gas is
 (1) 780 J (2) 783 J
 (3) 793 J (4) 790 J
- The coefficient of volume expansion for an ideal gas at constant pressure is
 (1) $1/T$ (2) $1/T^2$
 (3) T (4) T^2
- A monoatomic ideal gas undergoes a process defined by $\frac{T^{3/2}}{P} = \text{constant}$ where P = absolute pressure and T = absolute temperature. Bulk modulus of the gas for the process is
 (1) 2P (2) 3P
 (3) P (4) 4P

- An ideal gas is taken through a cycle ABCDA as shown in the diagram. The heat supplied to the gas in the process AB and BC are respectively 10^6 J and $2 \times 10^5 \text{ J}$ and that released by the gas during CD is 10^5 J . Find the heat being absorbed or released during DA.



- 0.8×10^5 (2) 0.08×10^5
 - 8×10^6 (4) 0.8×10^6
- An ideal gas of $\gamma = 1.5$ has 10 litre volume at a pressure of 1 atmosphere and temperature 300 K. It is adiabatically expanded to twice its original volume. Work done in expansion is (1 atmosphere = $1.01 \times 10^5 \text{ Nm}^{-2}$, $R = 8.3 \text{ J mole}^{-1} \text{ K}^{-1}$)
 (1) 14.59 J
 (2) 145.9 J
 (3) 1459 J
 (4) 14590 J
- A Carnot engine whose sink is at 290 K has an efficiency of 30%. By how much should the temperature of the source be increased to have its efficiency equal to 50%, while keeping sink temperature constant.
 (1) 66 K (2) 60 K
 (3) 56 K (4) 50 K
- A refrigerator freezes 5 kg of water at 0°C into ice at 0°C in a time interval of 30 minutes. The room temperature is 20°C . Calculate the minimum power needed to accomplish it.
 (1) 67.38 W (2) 68 W
 (3) 68.58 W (4) 68.38 W

ANSWERS (HEAT AND THERMODYNAMICS - II)

LEVEL - I

- | | | | | |
|--------|--------|---------|---------|---------|
| 1. (3) | 5. (1) | 9. (2) | 13. (3) | 17. (2) |
| 2. (3) | 6. (4) | 10. (1) | 14. (1) | 18. (3) |
| 3. (3) | 7. (2) | 11. (1) | 15. (1) | 19. (3) |
| 4. (1) | 8. (3) | 12. (4) | 16. (1) | 20. (1) |

LEVEL - II

- | | | | | |
|--------|--------|---------|---------|---------|
| 1. (4) | 5. (3) | 9. (2) | 13. (2) | 17. (2) |
| 2. (1) | 6. (3) | 10. (2) | 14. (1) | 18. (1) |
| 3. (2) | 7. (3) | 11. (3) | 15. (2) | 19. (2) |
| 4. (3) | 8. (2) | 12. (3) | 16. (3) | 20. (2) |

LEVEL - III

- | | | | | |
|--------|--------|--------|--------|---------|
| 1. (4) | 3. (1) | 5. (1) | 7. (4) | 9. (1) |
| 2. (2) | 4. (3) | 6. (2) | 8. (3) | 10. (4) |

SOLUTIONS (LEVEL - III)

1. Principal $c_V = 75 \text{ cal kg}^{-1}\text{°C}^{-1}$
 $= 75 \times 4.2 \text{ J kg}^{-1}\text{°C}^{-1}$

$$= \frac{3}{2} \frac{R}{M_0} \quad (\because \text{argon is monoatomic})$$

$$\therefore M_0 = \frac{3}{2} \frac{R}{c_V} = \frac{3}{2} \left(\frac{8.3 \times 10^3}{75 \times 4.2} \right)$$

$$= 39.52 \approx 40 \text{ (whole number)}$$

2. Given,

$$\gamma = \frac{7}{5} \quad \text{and} \quad N = 3$$

$$C = \frac{R}{\frac{7}{5} - 1} + \frac{R}{1 - 3} = \frac{5}{2}R + \left(-\frac{R}{2} \right) = 2R$$

3. Given, $T \propto P^{2/5}$... (1)

Now, if $T^N P^{1-N} = \text{constant}$

$$T \propto P^{\frac{N-1}{N}} \quad \dots (2)$$

Comparing (1) and (2)

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

$$\text{Therefore, } W = \frac{nR(-100)}{N-1} = -150R$$

Since, $N = \frac{5}{3}$, process is adiabatic.

4. The process is isobaric because the piston is free to move so that pressure is maintained constant.

i.e. $V \propto T$

$$\frac{T_1}{T_2} = \frac{V_1}{V_2} = \frac{100}{110} = \frac{1}{1.1}$$

$$\therefore T_2 = (1.1)(T_1) = (1.1)(273) = 300.3 \text{ K} = 27.3^\circ\text{C}$$

ΔW = work done by the gas at constant pressure

$$= P (V_2 - V_1)$$

$$= (1.013 \times 10^5) \left(2.24 \times 10^{-2} \times \frac{10}{100} \right)$$

$$= 226.9 \text{ J}$$

$$R = 8.3 \text{ J mole}^{-1} \text{ K}^{-1}$$

$$C_V = \frac{R}{\gamma - 1} = \frac{8.3}{1.4 - 1} = 20.75 \text{ J mole}^{-1} \text{ K}^{-1}$$

$$\Delta U = (n) (C_V) (\Delta T)$$

$$= (1) (20.75) (300.3 - 273) = 566.5 \text{ J}$$

ΔQ = total heat absorbed by the gas

$$= \Delta U + \Delta W = (566.5 + 226.9) \text{ J} = 793 \text{ J}$$

Alternative solution

$$\Delta Q = (n) (C_P) (\Delta T) = (1) (C_V + R)$$

$$= (1) (20.75 + 8.3)(27.3) (300.3 - 273)$$

$$= 793 \text{ J}$$

5. For an ideal gas

$$PV = nRT$$

As P is constant, we have

$$P \cdot dV = nRdT$$

$$\therefore \frac{dV}{dT} = \frac{nR}{P}$$

$$\text{or } \gamma = \frac{1}{V} \cdot \frac{dV}{dT} = \frac{nR}{PV} = \frac{nR}{nRT} = \frac{1}{T}$$

$$\therefore \gamma = \frac{1}{T}$$

$$6. \frac{T^{3/2}}{P} = \text{constant} \Rightarrow \frac{(PV)^{3/2}}{P} = \text{constt}$$

$$\Rightarrow P^{1/2} V^{3/2} = \text{constt}$$

$$\text{or } PV^3 = \text{constt}$$

Now for a process $PV = \text{constant}$,

$$\text{Workdone} = \frac{nR(T_1 - T_2)}{N-1}$$

$$\therefore \text{Here } W = \frac{nR(T_1 - T_2)}{2} = \frac{-nR\Delta T}{2}$$

$$\text{Now } \Delta Q = \Delta U + W \quad (1\text{st law})$$

$$\therefore nC\Delta T = nC_V\Delta T + \left(\frac{-nR\Delta T}{2} \right) \Rightarrow C = \frac{R}{\gamma-1} - \frac{R}{2}$$

$$\text{or } C = \frac{R}{5/3-1} - R/2 = \frac{3R}{2} - \frac{R}{2} = R$$

$$\therefore \boxed{C = R = 2(\text{cal / mole k})}$$

$$\boxed{\text{Bulk modulus} = \frac{\Delta P}{(-\Delta V/V)} = NP = 3P}$$

7. For a cyclic process

$$\Delta U = 0$$

$$\therefore W = \Delta Q$$

$$\therefore W_{AB} + W_{BC} + W_{CD} + W_{DA}$$

$$= \Delta Q_{AB} + \Delta Q_{BC} + \Delta Q_{CD} + \Delta Q_{DA}$$

$$\Rightarrow 200(6-2) \times 10^3 + 0 + 400(2-6) \times 10^3 + 0$$

$$= 10^6 + 2 \times 10^6 - 10^5 + \Delta Q_{DA} - 8 \times 10^5 = \Delta Q_{DA}$$

$$\therefore \boxed{\Delta Q_{DA} = -0.8 \times 10^6 \text{ J}}$$

$0.8 \times 10^6 \text{ J}$ of heat is realised in DA.

8. For adiabatic expansion

$$\frac{T_1}{T_2} = \left(\frac{V_2}{V_1} \right)^{\gamma-1} = \left(\frac{2}{1} \right)^{1/2} = \sqrt{2}$$

$$\therefore T_2 = \frac{T_1}{\sqrt{2}} = \frac{300}{\sqrt{2}} = 212.1 \text{ K}$$

Work done during adiabatic process

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

$$= \left(\frac{1}{1.5-1} \right) (1)(8.3)(300 - 212.1) = 1459 \text{ J}$$

$$9. \quad \eta = 1 - \frac{T_2}{T_1}$$

$$0.3 = 1 - \frac{290}{T_1}$$

$$T_1 = \frac{290}{0.7} = \frac{2900}{7} = 414 \text{ K}.$$

Hence source temperature = 414 K

Let new source temperature = T_1^1

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

$$0.5 = 1 - \frac{290}{T_1^1}$$

$$T_1^1 = \frac{290}{0.5} = \frac{2900}{5} = 480 \text{ K}.$$

Hence new source temperature is 480 K.

So increase in temperature of source

$$= 480 \text{ K} - 414 = 66 \text{ K}.$$

10. Amount of heat required to convert water into ice at 0°C ,

$$Q_2 = mL = (5 \text{ kg}) \times (80 \text{ kcal/kg}) = 400 \text{ kcal}$$

$$\text{Now } T_1 = 20^\circ\text{C} = 293 \text{ K}$$

$$T_2 = 0^\circ\text{C} = 273 \text{ K}$$

Minimum power will be needed only when the refrigerator cycle is based on Carnot cycle.

$$\text{Then, } \frac{Q_2}{W} = \frac{T_2}{T_1 - T_2}$$

$$W = Q_2 \times \frac{T_1 - T_2}{T_2} = 400 \text{ kcal} \times \frac{293 - 273}{273}$$

$$= 29.3 \times 4.2 \times 10^3 \text{ J} = 1.23 \times 10^5 \text{ J}$$

$$\therefore \text{ Power needed, } P = \frac{W}{t} = \frac{1.23 \times 10^5}{1800} \text{ watt}$$

$$= 68.3 \text{ watt}.$$