HEAT & THERMODYNAMICS

1. A litre of dry air at STP expands adiabatically to a volume of 3 litres. If $\gamma = 1.40$, the work done by air is : ($3^{1.4} = 4.6555$) [Take air to be an ideal gas]

(1) 90.5 J (2) 48 J

(3) 60.7 J (4) 100.8 J

2. Two moles of an ideal gas with $\frac{C_P}{C_V} = \frac{5}{3}$ are mixed with 3 moles of another ideal gas with $\frac{C_P}{C_V} = \frac{4}{3}$. The value of $\frac{C_P}{C_V}$ for the mixture is:

(1) 1.50 (2) 1.42

(3) 1.45 (4) 1.47

3. A Carnot engine operates between two reservoirs of temperatures 900 K and 300 K. The engine performs 1200 J of work per cycle. The heat energy (in J) delivered by the engine to the low temperature reservoir, in a cycle, is____.

4. A non-isotropic solid metal cube has coefficients of linear expansion as : 5×10^{-5}/°C along the x-axis and 5×10^{-6}/°C along the y and the z-axis. If the coefficient of volume expansion of the solid is $C \times 10^{-16}$/°C then the value of C is ______.

5. Two ideal Carnot engines operate in cascade (all heat given up by one engine is used by the other engine to produce work) between temperatures, T_1 and T_2. The temperature of the hot reservoir of the first engine is T_1 and the temperature of the cold reservoir of the second engine is T_2. T is temperature of the sink of first engine which is also the source for the second engine. How is T related to T_1 and T_2, if both the engines perform equal amount of work ?

(1) $T = \frac{2T_1T_2}{T_1 + T_2}$ (2) $T = \sqrt{T_1T_2}$

(3) $T = \frac{T_1 + T_2}{2}$ (4) T = 0

6. Under an adiabatic process, the volume of an ideal gas gets doubled. Consequently the mean collision time between the gas molecule changes from τ_1 to τ_2. If $\frac{C_p}{C_v} = \gamma$ for this gas then a good estimate for $\frac{\tau_2}{\tau_1}$ is given by :

(1) $\left(\frac{1}{2}\right)^{\frac{\gamma+1}{2}}$ (2) 2

(3) $\frac{1}{2}$ (4) $\left(\frac{1}{2}\right)^{\gamma}$

7. M grams of steam at 100°C is mixed with 200 g of ice at its melting point in a thermally insulated container. If it produces liquid water at 40°C [heat of vaporization of water is 540 cal/ g and heat of fusion of ice is 80 cal/g], the value of M is______.

8. The plot that depicts the behavior of the mean free time t (time between two successive collisions) for the molecules of an ideal gas, as a function of temperature (T), qualitatively, is: (Graphs are schematic and not drawn to scale)

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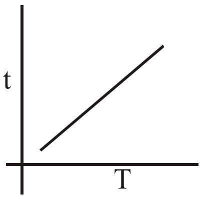

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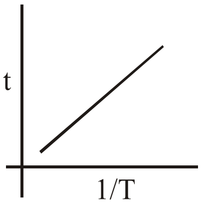

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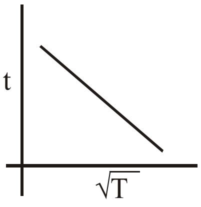

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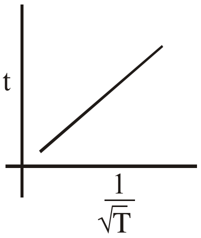
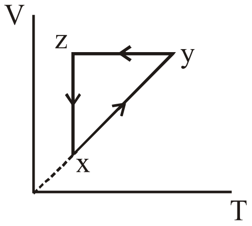
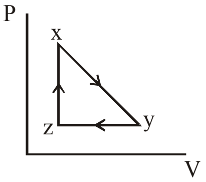


9. A thermodynamic cycle xyzx is shown on a V-T diagram.



The P-V diagram that best describes this cycle is : (Diagrams are schematic and not to scale)

(1)



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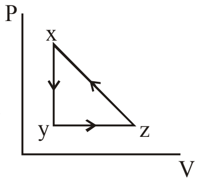

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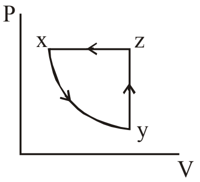

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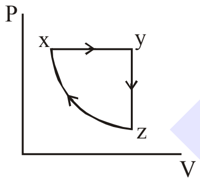


10. A leak proof cylinder of length 1m, made of a metal which has very low coefficient of expansion is floating vertically in water at 0°C such that its height above the water surface is 20 cm. When the temperature of water is increased to 4°C, the height of the cylinder above the water surface becomes 21 cm. The density of water at T = 4°C, relative to the density at T = 0°C is close to :

(1) 1.01 (2) 1.04 (3) 1.03 (4) 1.26

11. A carnot engine having an efficiency of $\frac{1}{10}$ is being used as a refrigerator. If the work done on the refrigerator is 10 J, the amount of heat absorbed from the reservoir at lower temperature is :

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

12. Consider a mixture of n moles of helium gas and 2 n moles of oxygen gas (molecules taken to be rigid) as an ideal gas. Its C_P/C_V value will be :

(1) 67/45 (2) 19/13 (3) 23/15 (4) 40/27

13. Three containers C_1, C_2 and C_3 have water at different temperatures. The table below shows the final temperature T when different amounts of water (given in litres) are taken from each containers and mixed (assume no loss of heat during the process)

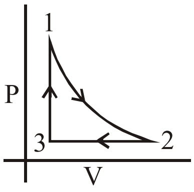
C_1	C_2	C_3	T
1*l*	2*l*	–	60°C
–	1*l*	2*l*	30°C
2*l*	–	1*l*	60°C
1*l*	1*l*	1*l*	θ

The value of θ (in °C to the nearest integer) is ....

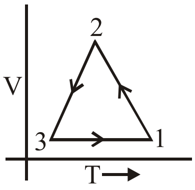
14. Consider two ideal diatomic gases A and B at some temperature T. Molecules of the gas A are rigid, and have a mass m. Molecules of the gas B have an additional vibrational mode, and have a mass $\frac{m}{4}$. The ratio of the specific heats $(C_V^A$ and $C_V^B)$ of gas A and B, respectively is :

(1) 7 : 9 (2) 5 : 7 (3) 3 : 5 (4) 5 : 9

15. Which of the following is an equivalent cyclic process corresponding to the thermodynamic cyclic given in the figure ? where, 1 → 2 is adiabatic. (Graphs are schematic and are not to scale)



(1)



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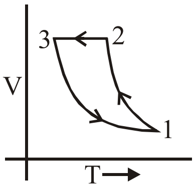

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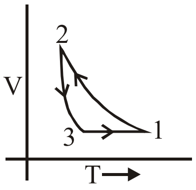

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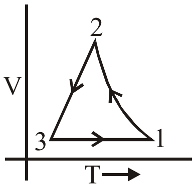


16. Two gases-argon (atomic radius 0.07 nm, atomic weight 40) and xenon (atomic radius 0.1 nm, atomic weight 140) have the same number density and are at the same temperature. The raito of their respective mean free times is closest to :

(1) 3.67 (2) 4.67 (3) 1.83 (4) 2.3

17. Starling at temperature 300 K, one mole of an ideal diatomic gas (γ = 1.4) is first compressed adiabatically from volume V_1 to $V_2 = \frac{V_1}{16}$. It is then allowed to expand isobarically to volume $2V_2$. If all the processes are the quasi-static then the final temperature of the gas (in °K) is (to the nearest integer) ________.

18. A gas mixture consists of 3 moles of oxygen and 5 moles of argon at temperature T. Assuming the gases to be ideal and the oxygen bond to be rigid, the total internal energy (in units of RT) of the mixture is :

(1) 11 (2) 15 (3) 20 (4) 13

19. An engine takes in 5 moles of air at 20°C and 1 atm, and compresses it adiabaticaly to 1/10th of the original volume. Assuming air to be a diatomic ideal gas made up of rigid molecules, the change in its internal energy during this process comes out to be X kJ. The value of X to the nearest integer is ________.

20. A heat engine is involved with exchange of heat of 1915 J, –40 J, +125 J and QJ, during one cycle achieving an efficiency of 50.0%. The value of Q is:

(1) 640 J (2) 400 J (3) 980 J (4) 40 J

21. An ideal gas in a closed container is slowly heated. As its temperature increases, which of the following statements are true ?

(A) the mean free path of the molecules decreases.

(B) the mean collision time between the molecules decreases.

(C) the mean free path remains unchanged.

(D) the mean collision time remains unchanged.

(1) (C) and (D) (2) (A) and (B)

(3) (A) and (D) (4) (B) and (C)

22. When the temperature of a metal wire is increased from 0°C to 10°C, its length increases by 0.02%. The percentage change in its mass density will be closest to :

(1) 0.008 (2) 0.06

(3) 0.8 (4) 2.3

23. A balloon filled with helium (32°C and 1.7 atm.) bursts. Immediately afterwards the expansion of helium can be considered as :

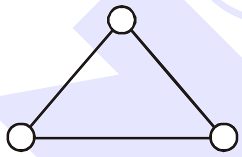
(1) Irreversible isothermal

(2) Irreversible adiabatic

(3) Reversible adiabatic

(4) Reversible isothermal

24.



Consider a gas of triatomic molecules. The molecules are assumed to the triangular and made of massless rigid rods whose vertices are occupied by atoms. The internal energy of a mole of the gas at temperature T is :

(1) $\frac{9}{2}RT$ (2) $\frac{3}{2}RT$

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

25. A bakelite beaker has volume capacity of 500 cc at 30°C. When it is partially filled with V_m volume (at 30°) of mercury, it is found that the unfilled volume of the beaker remains constant as temperature is varied. If $\gamma_{(beaker)} = 6 \times 10^{-6}$ °C^{-1} and $\gamma_{(mercury)} = 1.5 \times 10^{-4}$ °C^{-1}, where γ is the coefficient of volume expansion, then V_m (in cc) is close to__________.

26. To raise the temperature of a certain mass of gas by 50°C at a constant pressure, 160 calories of heat is required. When the same mass of gas is cooled by 100°C at constant volume, 240 calories of heat is released. How many degrees of freedom does each molecule of this gas have (assume gas to be ideal) ?

(1) 5 (2) 3 (3) 6 (4) 7

27. A metallic sphere cools from 50°C to 40°C in 300 s. If atmospheric temperature around is 20°C, then the sphere's temperature after the next 5 minutes will be close to :

(1) 33°C (2) 35°C (3) 31°C (4) 28°C

28. A calorimeter of water equivalent 20 g contains 180 g of water at 25°C. 'm' grams of steam at 100°C is mixed in it till the temperature of the mixure is 31°C. The value of 'm' is close to (Latent heat of water = 540 cal g^{-1}, specific heat of water = 1 cal g^{-1} $°C^{-1}$)

(1) 2.6 (2) 2 (3) 4 (4) 3.2

29. If minimum possible work is done by a refrigerator in converting 100 grams of water at 0°C to ice, how much heat (in calories) is released to the surrounding at temperature 27°C (Latent heat of ice = 80 Cal/gram) to the nearest integer?

30. Match the C_P/C_V ratio for ideal gases with different type of molecules :

Molecular type	C_P/C_V
(A) Monoatomic	(I) 7/5
(B) Diatomic rigid molecules	(II) 9/7
(C) Diatomic non-rigid molecules	(III) 4/3
(D) Triatomic rigid molecules	(IV) 5/3

(1) A-IV, B-I, C-II, D-III
(2) A-IV, B-II, C-I, D-III
(3) A-III, B-IV, C-II, D-I
(4) A-II, B-III, C-I, D-IV

31. Dimensional formula for thermal conductivity is (here K denotes the temperature)

(1) $MLT^{-3}K$ (2) $MLT^{-2}K$
(3) $MLT^{-2}K^{-2}$ (4) $MLT^{-3}K^{-1}$

32. The specific heat of water = 4200 J kg^{-1} K^{-1} and the latent heat of ice = 3.4×10^5 J kg^{-1}. 100 grams of ice at 0°C is placed in 200 g of water at 25°C. The amount of ice that will melt as the temperature of water reaches 0°C is close to (in grams) :

(1) 61.7 (2) 63.8 (3) 69.3 (4) 64.6

33. A closed vessel contains 0.1 mole of a monoatomic ideal gas at 200 K. If 0.05 mole of the same gas at 400 K is added to it, the final equilibrium temperature (in K) of the gas in the vessel will be closed to ______.

34. Match the thermodynamic processes taking place in a system with the correct conditions. In the table : ΔQ is the heat supplied, ΔW is the work done and ΔU is change in internal energy of the system :

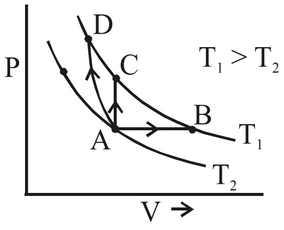
Process	**Condition**
(I) Adiabatic	(A) $\Delta W = 0$
(II) Isothermal	(B) $\Delta Q = 0$
(III) Isochoric	(C) $\Delta U \neq 0, \Delta W \neq 0, \Delta Q \neq 0$
(IV) Isobaric	(D) $\Delta U = 0$

(1) I-B, II-D, III-A, IV-C
(2) I-B, II-A, III-D, IV-C
(3) I-A, II-A, III-B, IV-C
(4) I-A, II-B, III-D, IV-D

35. The change in the magnitude of the volume of an ideal gas when a small additional pressure ΔP is applied at a constant temperature, is the same as the change when the temperature is reduced by a small quantity ΔT at constant pressure. The initial temperature and pressure of the gas were 300 K and 2 atm respectively. If $|\Delta T| = C|\Delta P|$ then value of C in (K/atm) is ______:

36. Three different processes that can occur in an ideal monoatomic gas are shown in the P vs V diagram. The paths are labelled as $A \rightarrow B$, $A \rightarrow C$ and $A \rightarrow D$. The change in internal energies during these process are taken as E_{AB}, E_{AC} and E_{AD} and the workdone as W_{AB}, W_{AC} and W_{AD}.

The correct relation between these parameters are :



(1) $E_{AB} = E_{AC} = E_{AD}$, $W_{AB} > 0$, $W_{AC} = 0$, $W_{AD} > 0$
(2) $E_{AB} < E_{AC} < E_{AD}$, $W_{AB} > 0$, $W_{AC} > W_{AD}$
(3) $E_{AB} = E_{AC} < E_{AD}$, $W_{AB} > 0$, $W_{AC} = 0$, $W_{AD} < 0$
(4) $E_{AB} > E_{AC} > E_{AD}$, $W_{AB} < W_{AC} < W_{AD}$

37. A bullet of mass 5g, travelling with a speed of 210 m/s, strikes a fixed wooden target. One half of its kinetic energy is converted into heat in the bullet while the other half is converted into heat in the wood. The rise of temperature of the bullet if the specific heat of its material is 0.030 cal/(g–°C) (1 cal = 4.2×10^7 ergs) close to :

(1) 83.3°C (2) 87.5°C

(3) 119.2°C (4) 38.4°C

38. Number of molecules in a volume of 4 cm^3 of a perfect monoatomic gas at some temperature T and at a pressure of 2 cm of mercury is close to ? (Given, mean kinetic energy of a molecule (at T) is 4×10^{-14} erg, g = 980 cm/s^2, density of mercury = 13.6 g/cm^3)

(1) 5.8×10^{18} (2) 5.8×10^{16}

(3) 4.0×10^{18} (4) 4.0×10^{16}

39. In an adiabatic process, the density of a diatomic gas becomes 32 times its initial value. The final pressure of the gas is found to be n times the initial pressure. The value of n is:

(1) 326 (2) $\frac{1}{32}$

(3) 32 (4) 128

40. Two different wires having lengths L_1 and L_2, and respective temperature coefficient of linear expansion α_1 and α_2, are joined end-to-end. Then the effective temperature coefficient of linear expansion is :

(1) $4\frac{\alpha_1\alpha_2}{\alpha_1+\alpha_2}\frac{L_2L_1}{(L_2+L_1)^2}$ (2) $2\sqrt{\alpha_1\alpha_2}$

(3) $\frac{\alpha_1+\alpha_2}{2}$ (4) $\frac{\alpha_1L_1+\alpha_2L_2}{L_1+L_2}$

41. Nitrogen gas is at 300°C temperature. The temperature (in K) at which the rms speed of a H_2 molecule would be equal to the rms speed of a nitrogen molecule, is _____.

(Molar mass of N_2 gas 28 g)

42. Molecules of an ideal gas are known to have three translational degrees of freedom and two rotational degrees of freedom. The gas is maintained at a temperature of T. The total internal energy, U of a mole of this gas, and the value of $\gamma\left(=\frac{C_P}{C_v}\right)$ given, respectively, by:

(1) $U=\frac{5}{2}RT$ and $\gamma=\frac{6}{5}$

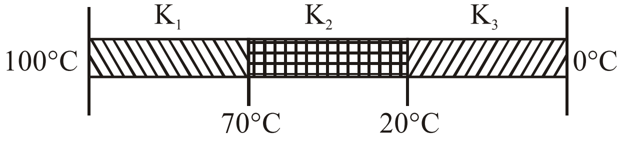
(2) U = 5RT and $\gamma=\frac{7}{5}$

(3) U = 5RT and $\gamma=\frac{6}{5}$

(4) $U=\frac{5}{2}RT$ and $\gamma=\frac{7}{5}$

43. Initially a gas of diatomic molecules is contained in a cylinder of volume V_1 at a pressure P_1 and temperature 250 K. Assuming that 25% of the molecules get dissociated causing a change in number of moles. The pressure of the resulting gas at temperature 2000 K, when contained in a volume $2V_1$ is given by P_2. The ratio P_2/P_1 is.

44. Three rods of identical cross-section and lengths are made of three different materials of thermal conductivity K_1, K_2, and K_3, respectively. They are joined together at their ends to make a long rod (see figure). One end of the long rod is maintained at 100°C and the other at 0°C (see figure). If the joints of the rod are at 70°C and 20°C in steady state and there is no loss of energy from the surface of the rod, the correct relationship between K_1, K_2 and K_3 is :



(1) $K_1 : K_3 = 2 : 3$; $K_2 : K_3 = 2 : 5$

(2) $K_1 < K_2 < K_3$

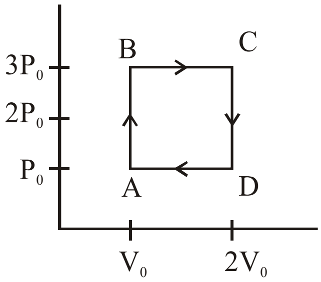
(3) $K_1 : K_2 = 5 : 2$; $K_1 : K_3 = 3 : 5$

(4) $K_1 > K_2 > K_3$

45. In a dilute gas at pressure P and temperature T, the mean time between successive collisions of a molecule varies with T as :

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

46. An engine operates by taking a monatomic ideal gas through the cycle shown in the figure. The percentage efficiency of the engine is close to _____



SOLUTION

1. NTA Ans. (1)

Sol. $$w = \frac{nR(T_1 - T_2)}{\gamma - 1} = \frac{P_1V_1 - P_2V_2}{0.4}$$

$$= \frac{100 - \frac{100}{4.6555} \times 3}{0.4} = 88.90 \cdot$$

2. NTA Ans. (2)

Sol. $$C_{P_{eq}} = \frac{n_1C_{P_1} + n_2C_{P_2}}{n_1 + n_2}$$

$$C_{V_{eq}} = \frac{n_1C_{V_1} + n_2C_{V_2}}{n_1 + n_2}$$

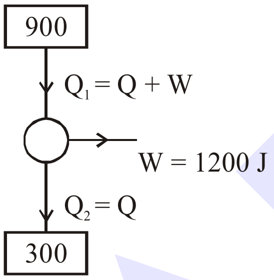
$$\gamma_{eq} = \frac{C_{P_{eq}}}{C_{V_{eq}}} = \frac{2 \times \frac{5R}{2} + 3 \times \frac{8R}{2}}{2 \times \frac{3R}{2} + 3 \times \frac{6R}{2}}$$

$$= \frac{5+12}{3+9} = \frac{17}{12} \simeq 1.42$$

Correct Answer : 2

3. NTA Ans. (600)

Sol.



for carnot engine

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

$$\frac{Q + 1200}{Q} = \frac{900}{300}$$

Q + 1200 = 3Q

Q = 600 J.

4. NTA Ans. (60)

Sol. $\gamma = \alpha_x + \alpha_y + \alpha_z$

$= 5 \times 10^{-5} + 5 \times 10^{-6} + 5 \times 10^{-6}$

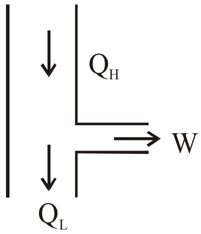
$= (50 + 5 + 5) \times 10^{-6}$

$\gamma = 60 \times 10^{-6}$

C = 60.

5. NTA Ans. (3)

Sol.



$$\frac{Q_H}{Q_L} = \frac{T_1}{T} \text{ and } W = Q_H - Q_L \quad ....(1)$$

$$\frac{Q_L}{Q'_L} = \frac{T}{T_2} \text{ and } W = Q_L - Q'_L \quad ....(2)$$

6. NTA Ans. (1)

Sol. $t \propto \frac{V}{\sqrt{T}}$ ....(1)

$TV^{\gamma-1}$ = constant ....(2)

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

7. NTA Ans. (40)

Sol. $M \times 540 + M + 60 = 200 \times 80 + 200 \times 1 \times (40 - 0)$

$\Rightarrow M = 40$

8. NTA Ans. (4)

Sol. Mean free time = $\frac{\text{Mean free path}}{\text{Average speed}}$

$$= \frac{\frac{1}{\sqrt{2}\pi D^2 n}}{\sqrt{\frac{8RT}{\pi M_w}}}$$

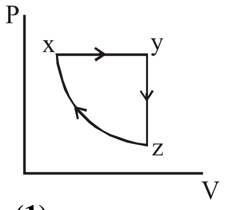
$$t \propto \frac{1}{\sqrt{T}}$$

9. NTA Ans. (4)

Sol. $x \rightarrow y \Rightarrow$ Isobaric

$y \rightarrow z \Rightarrow$ Isochoric

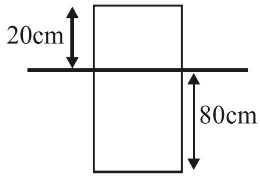
$z \rightarrow x \Rightarrow$ Isothermal



10. NTA Ans. (1)

Sol. $m = \rho_0 A\ (80)$ ....(i)

$m = \rho A\ (79)$ ....(ii)



11. NTA Ans. (3)

Sol. Refrigerator cycle is :

$$\eta = \frac{W}{Q_+} = \frac{W}{W+Q_-}$$

$$\frac{1}{10} = \frac{10}{10+Q_-}$$

$Q_- = 90$ J

Heat absorbed from the reservoir at lower temperature is 90 J

12. NTA Ans. (2)

Sol. $$\frac{C_P}{C_V}\text{mix} = \frac{n_1C_{P_1}+n_2C_{P_2}}{n_1C_{V_1}+n_2C_{V_2}}$$

$$\frac{C_P}{C_V}\text{mix} = \frac{n\times\left(\frac{5R}{2}\right)+2n\left(\frac{7R}{2}\right)}{n\times\frac{3R}{2}+2n\left(\frac{5R}{2}\right)}$$

$$\frac{C_P}{C_V} = \frac{19}{13}$$

13. NTA Ans. (50)

Sol. According to table and applying law of calorimetry

$1T_1 + 2T_2 = (1 + 2)60°$ ....(1)

$= 180$

$1T_2 + 2T_3 = (1 + 2)30°$ ....(2)

$= 90$

$2T_1 + 1T_3 = (1 + 2)60$

$= 180$ ....(3)

Adding (1) + (2) + (3)

$3\,(T_1 + T_2 + T_3) = 450$

$T_1 + T_2 + T_3 = 150°$

Hence,

$T_1 + T_2 + T_3 = (1 + 1 + 1)\theta$

$150 = 3\theta$

$\theta = 50°C$

14. NTA Ans. (2)

Sol. Degree of freedom of a diatomic molecule if vibration is absent = 5

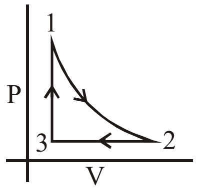
Degree of freedom of a diatomic molecule if vibration is present = 7

$$\therefore\ C_v^A = \frac{f_A}{2}R = \frac{5}{2}R \ \&\ C_v^B = \frac{f_B}{2}R = \frac{7}{2}R$$

$$\therefore\ \frac{C_v^A}{C_v^B} = \frac{5}{7}$$

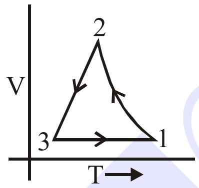
15. NTA Ans. (4)

Sol.



In process 2 to 3 pressure is constant & in process 3 to 1 volume is constant which is correct only in option 4.

Correct graph is



16. NTA Ans. (1)

ALLEN Ans. (3)

Sol. $$\lambda = \frac{1}{\sqrt{2}\pi n_v d^2}$$

$$\tau = \frac{\lambda}{v} = \frac{1}{\sqrt{2}\pi n_v d^2 v} = \frac{1}{\sqrt{2}\pi n_v d^2}\sqrt{\frac{M}{3RT}}$$

$$\frac{\tau_1}{\tau_2} = \sqrt{\frac{M_1}{M_2}}\frac{d_2^2}{d_1^2}$$

$$= \sqrt{\frac{40}{140}}\frac{(0.1)^2}{(0.07)^2}$$

$= 1.09$

$\therefore$ Nearest possible answer (3)

17. NTA Ans. (1816.00 to 1820)

Sol. PV^γ = constant

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

$$300\times V^{\frac{7}{5}-1} = T_2\left(\frac{V}{16}\right)^{\frac{7}{5}-1}$$

$$300\times 2^{4\times\frac{2}{5}} = T_2$$

Isobaric process

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

$V_2 = kT_2$ ... (1)

$2V_2 = KT_f$ ... (2)

$$\frac{1}{2} = \frac{T_2}{T_f} \Rightarrow T_f = 2T_2$$

$$T_f = 2\times300\times2^{\frac{8}{5}} = 1818.85$$

$\therefore$ Correct answer 1819

18. Official Ans. by NTA (2)

Sol. $$u=\frac{f_1n_1RT}{2}+\frac{f_2n_2RT}{2}$$

$$u=\frac{5}{2}\times 3RT+\frac{3\times 5RT}{2}=15RT$$

19. Official Ans. by NTA (46)

Official Ans. by ALLEN (46 Actual 45.78)

Sol. Diatomic :

$f = 5$

$\gamma = 7/5$

$T_i = T = 273 + 20 = 293$ K

$V_i = V$

$V_f = V/10$

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

$$T_1V_1^{\gamma-1}=T_2V_2^{\gamma-1}$$

$$T.V^{7/5-1}=T_2\left(\frac{V}{10}\right)^{7/5-1}$$

$\Rightarrow T_2 = T.\ 10^{2/5}$

$$\Delta U=\frac{nfR(T_2-T_1)}{2}=\frac{5\times 5\times\frac{25}{3}\times(T.10^{2/5}-T)}{2}$$

$$=\frac{25\times 25\times}{6}T\,(10^{2/5}-1)$$

$$=\frac{625\times 293\times(10^{2/5}-1)}{6}$$

$$=4.033\times 10^3\approx 4kJ$$

20. Official Ans. by NTA (3)

Sol. $$\eta=\frac{\text{Work done}}{\text{Heat supplied}}$$

$$\frac{1}{2}=\eta=\frac{1915-40+125-Q}{1915+125}$$

$$\frac{1}{2}=\frac{2000-Q}{2040}\qquad\Rightarrow 2040 = 4000 - 2Q$$

$2Q = 1960$

$Q = 980$ J

21. Official Ans. by NTA (4)

Sol. The mean free path of molecules of an ideal gas is given as:

$$\lambda=\frac{V}{\sqrt{2}\pi d^2N}$$

where : V = Volume of container

N = No of molecules

Hence with increasing temp since volume of container does not change (closed container), so mean free path is unchanged.

Average collision time

$$=\frac{\text{mean free path}}{V_{av}}=\frac{\lambda}{(\text{avg speed of molecules})}$$

$\because$ avg speed $\alpha\sqrt{T}$

$\therefore$ Avg coll. time $\alpha\frac{1}{\sqrt{T}}$

Hence with increase in temperature the average collision time decreases.

22. Official Ans. by NTA (2)

Sol. Given $\frac{\Delta L}{L}=0.02\%$

$$\therefore \Delta L=L\alpha\Delta T\Rightarrow\frac{\Delta L}{L}=\alpha\Delta T=0.02\%$$

$\therefore\ \beta = 2\alpha$ (Areal coefficient of expansion)

$\Rightarrow \beta\Delta T = 2\alpha\Delta T = 0.04\%$

Volume = Area × Length

$$\text{Density}(\rho)=\frac{\text{Mass}}{\text{Volume}}=\frac{\text{Mass}}{\text{Area}\times\text{Length}}=\frac{M}{AL}$$

$$\Rightarrow\frac{\Delta\rho}{\rho}=\cancelto{0}{\frac{\Delta M}{M}}-\frac{\Delta A}{A}-\frac{\Delta L}{L}\ \text{(Mass remains constant)}$$

$$\Rightarrow\left(\frac{\Delta\rho}{\rho}\right)=\frac{\Delta A}{A}+\frac{\Delta L}{L}=\beta\Delta T+\alpha\Delta T$$

$= 0.04\% + 0.02\%$

$= 0.06\%$

23. Official Ans. by NTA (2)

Sol. Bursting of helium balloon is irreversible & adiabatic.

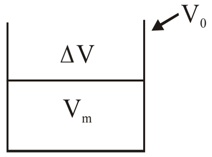
24. Official Ans. by NTA (4)

Sol. DOF = 3 + 3 = 6

$$U=\frac{f}{2}nRT=3RT$$

25. Official Ans. by NTA (20)

Sol.



$$\Rightarrow\boxed{\Delta V=(V_0-V_m)}$$

After increasing temperature

$\Delta V' = (V'_0 - V'_m)$

$\Delta V' = \Delta V$

$V_0 - V_m = V_0(1+\gamma_b\Delta T) - V_m\,(1+\gamma_M\Delta T)$

$V_0\gamma_b = V_m\gamma_m$

$$V_m=\frac{V_0\gamma_b}{\gamma_m}=\frac{(500)(6\times 10^{-6})}{(1.5\times 10^{-4})}$$

= 20 CC

26. Official Ans. by NTA (3)

Sol. $nC_p(50) = 160$

$nC_v\ (100) = 240$

$$\Rightarrow \frac{C_p}{2C_v} = \frac{160}{240} = \frac{\gamma}{2}$$

$$\therefore\ \gamma = \frac{4}{3} \text{ and } f = \frac{2}{\gamma - 1} = 6$$

27. Official Ans. by NTA (1)

Sol. $$\frac{50-40}{300} = \beta\left(\frac{50+40}{2} - 20\right)$$

$$\frac{40-T}{300} = \beta\left(\frac{40+T}{2} - 20\right)$$

$$\therefore\ T = \frac{100}{3}$$

28. Official Ans. by NTA (2)

Sol.

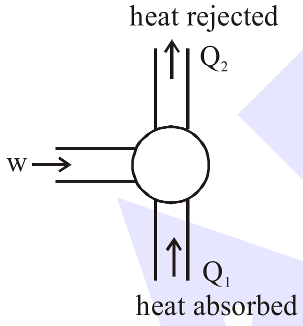
Cal	H_2O	Sterm
20gm	180gm	m
$25^\circ C$	$25^\circ C$	$100^\circ C$

$200 \times 1 \times (31 - 25)$

$= m \times 540 + m \times 1 \times (100 - 31)$

29. Official Ans. by NTA (8791)

Sol.



$w + Q_1 = Q_2$

$w = Q_2 - Q_1$

$$\text{C.O.P.} = \frac{Q_1}{w} = \frac{Q_1}{Q_2 - Q_1} = \frac{273}{300-273} = \frac{Q_1}{W}$$

$$w = \frac{27}{273} \times 80 \times 100 \times 4.2$$

$Q_2 = w + \theta_1$

$$Q_2 = \frac{27}{273} \times 80 \times 100 \times 4.2 + 80 \times 100 \times 4.2$$

$$Q_2 = \frac{300}{273} \times 80 \times 100 = 8791.2\ \text{cal}$$

30. Official Ans. by NTA (1)

Sol. $$\gamma = \frac{C_p}{C_v} = 1 + \frac{2}{f}$$

where 'f' is degree of freedom

(A) Monoatomic f = 3, $\gamma = 1 + \frac{2}{3} = \frac{5}{3}$

(B) Diatomic rigid molecules,

$f = 5, \gamma = 1 + \frac{2}{3} = \frac{7}{5}$

(C) Diatomic non-rigid molecules

$f = 7, \gamma = 1 + \frac{2}{7} = \frac{9}{7}$

(D) Triatomic rigid molecules

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

31. Official Ans. by NTA (4)

Sol. $$\because\ \frac{d\theta}{dt} = kA\frac{dT}{dx}$$

$$k = \frac{\left(\frac{d\theta}{dt}\right)}{A\left(\frac{dT}{dx}\right)}$$

$$[k] = \frac{[ML^2T^{-3}]}{[L^2][KL^{-1}]} = [MLT^{-3}K^{-1}]$$

32. Official Ans. by NTA (1)

Sol. Here the water will provide heat for ice to melt therefore

$m_w\, s_w\, \Delta\theta = m_{ice}\, L_{ice}$

$$m_{ice} = \frac{0.2 \times 4200 \times 25}{3.4 \times 10^5}$$

$= 0.0617$ kg

$= 61.7$ gm

Remaining ice will remain un-melted

so correct answer is 1

33. Official Ans. by NTA (266)

Official Ans. by ALLEN (266.67)

Sol. As work done on gas and heat supplied to the gas are zero,

total internal energy of gases remain same

$u_1 + u_2 = u_1' + u_2'$

$(0.1)\ C_v\ (200) + (0.05)\ C_v\ (400) = (0.15)C_v\,T$

$$T = \frac{800}{3}k = 266.67\,k$$

34. Official Ans. by NTA (1)

Sol. (I) Adiabatic process ⇒ $\Delta Q = 0$

No exchange of heat takes place with surroundings

(II) Isothermal proess ⇒ Temperature remains constant ($\Delta T = 0$)

$$\Delta u = \frac{F}{2} nR\Delta T \Rightarrow \Delta u = 0$$

No change in internal energy [$\Delta u = 0$]

(III) Isochoric process Volume remains constant $\Delta V = 0$

$$W = \int P.dV = 0$$

Hence work done is zero.

(IV) Isobaric process ⇒ Pressure remains constant

$$W = P.\ \Delta V \neq 0$$

$$\Delta u = \frac{F}{2} nR\Delta T = \frac{F}{2}[P\Delta V] \neq 0$$

$$\Delta Q = nC_P\Delta T \neq 0$$

35. Official Ans. by NTA (150)

Sol. $PV = nRT$

$P\Delta V + V\Delta P = 0$ (for constant temp.)

$P\Delta V = nR\Delta T$ (for constant pressure)

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

$$\Delta P = -\frac{P\Delta V}{V} \quad (\Delta V \text{ is same in both cases})$$

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

($PV = nRT$)

$$\left(\frac{V}{nR} = \frac{T}{P}\right) \qquad \left|\frac{\Delta T}{\Delta P}\right| = \left|\frac{-300}{2}\right| = 150$$

36. Official Ans. by NTA (1)

Sol. $\Delta U = nC_v\ \Delta T$ = same

AB → volume is increasing ⇒ $W > 0$

AD → volume is decreasing ⇒ $W < 0$

AC → volume is constant ⇒ $W = 0$

37. Official Ans. by NTA (2)

Sol. $$\frac{1}{2}mv^2 \times \frac{1}{2} = ms\Delta T$$

$$\Delta T = \frac{v^2}{4\times5} = \frac{210^2}{4\times30\times4.200}$$

$= 87.5°C$

38. Official Ans. by NTA (3)

Sol. $n = \frac{PV}{RT}, \frac{3}{2}kT = 4\times10^{-14}$

$$N = \frac{PV}{RT}\times Na$$

$$= \frac{2\times13.6\times980\times4}{\frac{8}{3}\times10^{-14}} = 3.99 \times 10^{18}$$

39. Official Ans. by NTA (4)

Sol. In adiabatic process

PV^{γ} = constant

$$P\left(\frac{m}{\rho}\right)^{\gamma} = \text{constant}$$

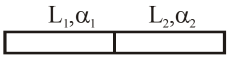
as mass is constant

$P \propto \rho^{\gamma}$

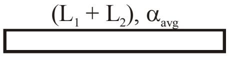
$$\frac{P_f}{P_i} = \left(\frac{\rho_f}{\rho_i}\right)^{\gamma} = (32)^{7/5} = 2^7 = 128$$

40. Official Ans. by NTA (4)

Sol. At T°C $\quad L = L_1 + L_2$



At T + ΔT $\quad L'_{eq} = L'_1 + L'_2$



where $L'_1 = L_1(1+\alpha_1\Delta T)$

$$L'_2 = L_2(1+\alpha_2\Delta T)$$

$$L'_{eq} = (L_1+L_2)\ (1+\alpha_{avg}\Delta T)$$

$$\Rightarrow (L_1+L_2)(1+\alpha_{avg}\Delta T) = L_1 + L_2 + L_1\alpha_1\Delta T + L_2\alpha_2\Delta T$$

$$\Rightarrow (L_1 + L_2)\ \alpha_{avg} = L_1\alpha_1 + L_2\alpha_2$$

$$\Rightarrow \alpha_{avg} = \frac{L_1\alpha_1 + L_2\alpha_2}{L_1 + L_2}$$

41. Official Ans. by NTA (41.00)

Official Ans. by ALLEN (40.93)

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

$$V_{N_2} = V_{H_2}$$

$$\sqrt{\frac{3RT_{N_2}}{M_{N_2}}} = \sqrt{\frac{3RT_{H_2}}{M_{H_2}}}$$

$$\frac{573}{28} = \frac{T_{H_2}}{2} \Rightarrow T_{H_2} = 40.928$$

42. Official Ans. by NTA (4)

Sol. Total degree of freedom = 3 + 2 = 5

$$U=\frac{nfRT}{2}\Rightarrow\frac{5RT}{2}$$

$$\gamma\Rightarrow\frac{C_P}{C_V}\Rightarrow 1+\frac{2}{f}\Rightarrow 1+\frac{2}{5}\Rightarrow\frac{7}{5}$$

Ans. (4)

43. Official Ans. by NTA (5.00)

Sol. PV = nRT

P_1V_1 = nR 250

$$P_2\left(2V_1\right)=\frac{5n}{4}R\times 2000$$

Divide

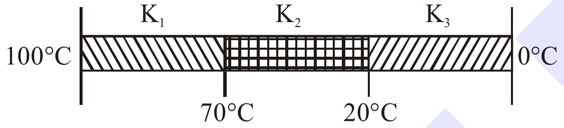
$$\frac{P_1}{2P_2}=\frac{4\times 250}{5\times 2000}$$

$$\frac{P_1}{P_2}=\frac{1}{5}\qquad\Rightarrow\frac{P_2}{P_1}=5$$

Ans. 5.00

44. Official Ans. by NTA (1)

Sol.



Rods are identical have same length (ℓ) and area of cross-section (A)

Combination are in series, so heat current is same for all Rods

$$\left(\frac{\Delta Q}{\Delta t}\right)_{AB}=\left(\frac{\Delta Q}{\Delta t}\right)_{BC}=\left(\frac{\Delta Q}{\Delta t}\right)_{CD}=\text{Heat current}$$

$$\frac{(100-70)K_1A}{\ell}=\frac{(70-20)K_2A}{\ell}=\frac{(20-0)K_3A}{\ell}$$

$30K_1 = 50K_2 = 20K_3$

$3K_1 = 2K_3$

$$\frac{K_1}{K_3}=\frac{2}{3}=2:3$$

$5K_2 = 2K_3$

$$\frac{K_2}{K_3}=\frac{2}{5}=2:5$$

45. Official Ans. by NTA (3)

Sol. $v_{avg}\propto\sqrt{T}$

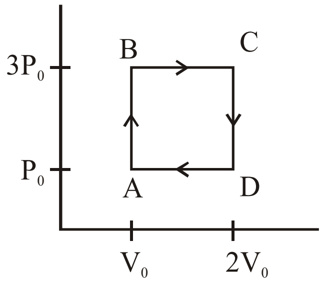
t_0 : mean time

λ : mean free path

$$t_0=\frac{\lambda}{v_{avg}}\propto\frac{1}{\sqrt{T}}$$

46. Official Ans. by NTA (19.00)

Sol.



$W_{ABCDA} = 2P_0V_0$

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

$Q_{AB} = nC(T_B - T_A)$

$$=\frac{n3R}{2}(T_B-T_A)$$

$$=\frac{3}{2}(P_BV_B-P_AV_A)$$

$$=\frac{3}{2}(3P_BV_0=P_0V_0)=3P_0V_0$$

$Q_{BC} = nC_P(T_C - T_B)$

$$=\frac{n5R}{2}(T_C-T_B)$$

$$=\frac{5}{2}(P_CV_C-P_BV_B)$$

$$=\frac{5}{2}(6P_0V_0-3P_0V_0)=\frac{15}{2}P_0V_0$$

$$\eta=\frac{W}{Q_{in}}\times 100=\frac{2P_0V_0}{3P_0V_0+\frac{15}{2}P_0V_0}\times 100$$

$$\eta=\frac{400}{21}=19.04\approx 19$$

$\eta = 19$