The following question given below consist of an "Assertion" (A) and "Reason" (R) Type questions. Use the following Key to choose the appropriate answer.

(A) If both (A) and (R) are true, and (R) is the correct explanation of (A).
(B) If both (A) and (R) are true but (R) is not the correct explanation of (A).
(C) If (A) is true but (R) is false.
(D) If (A) is false but (R) is true.

Q.1 **Assertion :** Total internal energy of a particle is given as $\frac{7}{2}K_B T$

Reason : No. of degrees of freedom of particle is $\frac{7}{2}$ **[C]**

Q.2 **Assertion :** The rms speed of helium gas is equal to rms speed of hydrogen gas when temperature of helium is twice that of hydrogen gas.

Reason : rms speed of gas depends only on the temperature of gas. **[C]**

Q.3 **Assertion :** Average translation kinetic energy per molecule of Helium and Oxygen gas are equal if temperature of both gases are equal.

Reason : Average translation kinetic energy per molecule of gas does not depend on the mass of molecule of the gas. **[A]**

Sol.

$$\left[(K.E_{av})_{per\ molecule}\right]_{translation} = \frac{3}{2}K_B T$$

K_B : Boltzmann's constant
T : absolute temperature

Q.4 **Assertion :** .The rms speed of helium gas is equal to rms speed of hydrogen gas when temperature of helium gas is twice that of hydrogen gas.

Reason : rms speed of a gas depends only on the temperature of gas. **[C]**

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

Q.5 **Assertion :** Most of planets do not have proper atmosphere.

Reason : Escape velocity of gas molecules is inversely proportional to $\sqrt{T}$, where T is absolute temperature. **[C]**

Q.6 **Assertion :** At constant pressure equal moles of helium and oxygen gases are given equal quantities of heat then rise in temperature of helium gas is greater than oxygen gas.

Reason : Molecular mass of oxygen is more than that of helium. **[B]**

Sol. C_P for helium gas is small than that of oxygen gas.

Q.7 **Assertion** : The value of pV/T for one gram mole of an ideal gas is 8.4 J mole^{-1}K^{-1}.

Reason : = R = universal gas constant for 1 gram mole of the gas ; whose standard value is 8.4 J mole^{-1}K^{-1}. **[A]**

Q.8 **Assertion** : The root mean square velocity of molecules of a gas having Maxwellian distribution of velocities is higher than their most probable velocity, at any temperature.

Reason : A very small number of molecules of a gas which possess very large velocities, increase the root mean square velocity, without affecting the most probable velocity. **[A]**

Q.9 **Assertion :** 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. **[IIT - 2007]**

because

Reason : The molecules of a gas collide with each other and the velocities of then molecules change due to the collision. **[B]**

Statements based Question : 10

This section contains Statement-1 and Statement-2. Of the four choices given here, choose the one that best describes the two Statement.

(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.

Q.10 **Statement-1**

The specific heat at constant pressure is greater than the specific heat at constant volume i.e., $C_P > C_V$.

Statement-2

In case of specific heat at constant volume, the whole of heat supplied is used to raise the temperature of one mole of the gas through 1°C while in case of specific of heat at constant pressure, heat is to be supplied not only for heating 1 mole of gas through 1°C but also for doing work during expansion of the gas. **[A]**

Q.11 **Statement I :** For an ideal gas at constant temperature, the product of pressure and volume is constant.

Statement II : The mean square velocity is inversely proportional to mass. **[B]**

Q.12 **Statement I :** The ratio $\frac{C_P}{C_V}$ for a diatomic gas is more than that for a monoatomic gas.

Statement II : The molecules of a monoatomic gas have less degree of freedom than those of diatomic gas. **[D]**

Q.13 **Statement I :** The rms velocity of gas molecules having Maxwellian distribution of speeds is greater than their most probable speed.

Statement II : The asymmetry of the Maxwellian distribution curve reveals that the number of molecules having speed greater than most probable speed is more than the number of molecules having speed less than the most probable speed. **[A]**

Q.14 **Statement I :** The average translational kinetic energy per molecule of a gas for various gases at the same temperature is the same.

Statement II : A given temperature, all molecules move with nearly the same speed. **[C]**

Q.15 **Statement I :** To liquefy a gas by pressure alone it must first be cooled below its critical temperature.

Statement II : The critical temperature for a gas is the temperature below which it behaves like an ideal gas. **[C]**

Q.16 **Statement I :** The average kinetic energy of the molecules of 1 mole of all ideal gases at the same temperature is the same.

Statement II : Two different gases at the same temperature have equal rms velocities. **[C]**

Q.17 **Statement I :** The potential energy of ideal gas is zero.

Statement II : At low pressure or high temperature the molecules are far apart and molecular interactions are negligible. **[A]**

Q.18 **Statement I :** At constant temperature, the average translational kinetic energy of gas molecule does not depends upon pressure and volume.

Statement II : Internal energy is only the function of temperature. **[A]**

Q.19 **Statement I :** Absolute zero degree temperature is not the zero energy temperature.

Statement II : At absolute zero temperature the gas may posses potential energy **[A]**

Q.20 **Statement - I**

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.

Statement - II

The molecules of a gas collide with each other and the velocities of them molecules change due to the collision. **[IIT - 2007]**

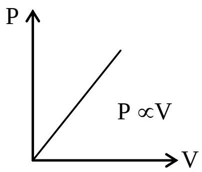
[B]

PHYSICS

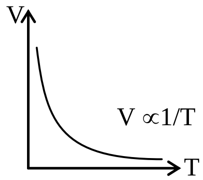
Q.1 One mole of ideal monoatomic gas is taken through following process. Match the molar heat capacity of gas in the column –II with process in column I –

Column-I	**Column-II**
(Process)	**(**Molar Heat capacity)
(A)	(P) $\frac{R}{2}$
(B)	(Q) $\frac{7R}{2}$
(C)	(R) $\frac{5R}{2}$
(D)	(S) 2 R

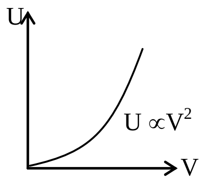
(A)



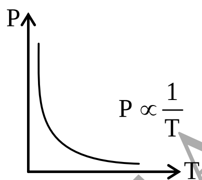
(B)



(C)



(D)



(A) $\rightarrow$ S **(B)** $\rightarrow$ P **(C)** $\rightarrow$ S **(D)** $\rightarrow$ Q

Q.2

Column I	**Column II**
(A) The coefficient of volume expansion at constant pressure is	(P) with decrease in pressure
(B) Mean free path of molecule increases	(Q) at all temperatures
(C) An ideal gas obeys Boyle's and Charle's Law	(R) Same for all gases
(D) A real as behaves as an ideal gas at low pressure and	(S)At high temperature

Ans. **(A)** $\rightarrow$ R **(B)** $\rightarrow$ P, S **(C)** $\rightarrow$ Q **(D)** $\rightarrow$ S

Q.3

Column I	**Column II**
(A) The coefficient of volume expansion at constant pressure is	(P) with decrease in pressure
(B) Mean free path of molecule increases	(Q) at all temperatures
(C) An ideal gas obeys Boyle's and Charle's Law	(R) Same for all gases
(D) A real gas behaves as an ideal gas at low pressure and	(S)At high temperature

Sol. **A $\rightarrow$ R, B $\rightarrow$ P,S, C $\rightarrow$ Q, D $\rightarrow$ S**

(A) $\left(\frac{dV}{V}\right)_P = \frac{dT}{T} \Rightarrow \frac{1}{dT}\left[\frac{dV}{V}\right]_P = \frac{1}{T}$

(B) $\bar{\lambda} = \frac{kT}{\sqrt{2}\pi d^2 \rho}$

(C) Ideal gas law are valid at all temperatures.

(D) conceptual

Q.4

Column I	**Column II**
(A) Adiabatic bulk modulus of a gas	(P) $-\frac{P}{V}$
(B) Slope of P-V curve for isothermal process	(Q) $\frac{2}{\gamma-1}$
(C) Degree of freedom	(R) γP
(D) Ratio of molar heat capacity at constant pressure to R (gas constant)	(S) $\frac{\gamma}{\gamma-1}$

Ans. **A $\rightarrow$ R ; B $\rightarrow$ P ; C $\rightarrow$ Q ; D $\rightarrow$ S**

Q.5 **Column-I** | **Column-II**

Column-I	Column-II
(A) Diatomic molecule	(P) Internal energy $= \frac{f}{2}$ RT
(B) f degree of freedom	(Q) Work done is maximum
(C) Adiabatic process	(R) $C_p = 3.5$ R
(D) Isobaric expansion	(S) Fast and isolated system
	(T) Constraints = 3 N – f

Sol. **(A) → (R),** **(B) → (P) & (T),**

(C) → (S), **(D) → (Q)**

Any diatomic molecule has 5 degrees of freedom

$\therefore C_V = \frac{5}{2} R$

and $C_p = C_V + R = \frac{7}{2} R = 3.5 R$

So, (A) → (R).

If there are f degree of freedom, internal energy will be $\frac{f}{2}$RT since each degree of freedom contributes $\frac{1}{2}$RT of energy per mole to the internal energy.

So, (B) → (P)

Since f = 3N – K where K represents constraints.

K = 3N – f

So, (B) → (T)

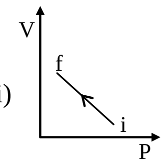
Adiabatic processes are fast and do not allow exchange of heat energy ($\Delta Q = 0$)

So, (C) → (S)

In an isobaric process from certain situation, work done will be maximum.

So, (D) → (Q).

Q.6 The diagrams below shows different processes for a given amount of an ideal gas. Match columns I & II –

(i)


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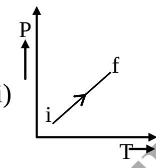
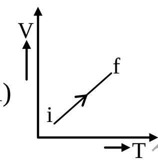
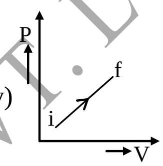


(iii)


(iv)


Column I	Column II
(A) In fig. (i)	(P) Temperature must increase
(B) In fig. (ii)	(Q) Pressure must increase
(C) In fig. (iii)	(R) Volume must increase
(D) In fig. (iv)	(S) Temperature may increase

Ans. **A → Q ; B → R ; C → S ; D → P**

Q.7 For a monoatomic gas at temp T, match the following.

Column I	Column II
(A) Mean square speed	(P) $\sqrt{\frac{2RT}{M_0}}$
(B) RMS speed of gas molecule	(Q) $\sqrt{\frac{8RT}{\pi M_0}}$
(C) Average speed of gas molecule	(R) $\sqrt{\frac{3RT}{M_0}}$
(D) Most probable speed of gas molecule	(S) $\frac{v_1^2 + v_2^2 + ... + v_N^2}{N}$

Ans. **A → S ; B → R ; C → Q ; D → P**

Q.8 Column-I contains different processes undergone by a diatomic ideal gas. Column-II change in different parameter of ideal gas.

Column I	Column II
(A) PV^{-1} = constant and volume is increased twice	(P) Heat is given to gas
(B) P^2V = constant and pressure is increased twice	(Q) Heat is rejected by gas
(C) $PV^{6/5}$ = constant and volume is reduced to half the initial volume	(R) Work done by gas is negative
(D) PV^2 = constant and pressure is increased 3 times	(S) Internal energy increase

Sol. **A → P,S ; B → Q,R; C → Q,R,S ; D → P,Q,R**

<u>For process PV^n = constant</u>

Molar heat capacity of gas

$$C = R\left(\frac{1}{\gamma-1}-\frac{1}{n-1}\right) \quad \text{... (i)}$$

Here, $\gamma = 7/5$

$$PV = nRT = \frac{\text{costant}}{V^{n-1}}$$

$$= \text{Constant} \times P^{\left(1-\frac{1}{n}\right)}$$

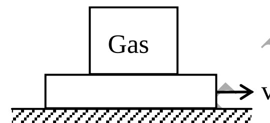
For n = 1 : Temperature with increase in volume work done positive
Hence heat is absorbed by system.

For $n = \frac{1}{2}$: Temperature and volume decrease with increase in pressure
∴ Work done negative
Hence heat is rejected

For $n = \frac{6}{5}$: Temperature increases with decrease in volume work done negative

For n = 2 : Temperature increase with increase in pressure work done negative
Hence heat is absorbed.

Q.9 Consider the situation shown in the diagram. Temperature of gas is T. The gas contained in insulated container has been placed on the block. The container is in the state of rest with respect to block. Now match the column. (Total number of molecules as N and mass of each molecule as m, M is molecular weight of gas)



Column -I	Column-II
(A) Average linear momentum w.r.t. block	(P) $\left[v^2+\frac{3RT}{M}\right]^{1/2}$
(B) v_{rms} of the gas w.r.t. earth	(Q) zero
(C) Average linear momentum w.r.t. earth	(R) N mv
(D) v_{rms} w.r.t. block	(S) $\sqrt{\frac{3RT}{M}}$

Sol. **A→ Q ; B → P ; C → R ; D → S**

$$\vec{v}_{total} = \vec{v}_{block} + \vec{v}_{M,block}$$

Q.10 An ideal gas (monoatomic) undergoing a process VT = constant. If pressure of gas changes from P_0 to $4P_0$. Then match the following :

Column-I	Column-II
(A) Temperature of gas will become	(P) Positive
(B) Volume of gas will become	(Q) Two times
(C) Work done by the gas	(R) Negative
(D) Molar specific heat for the given process	(S) 3R/2
	(T) None

Sol. (A) → Q; (B) → T;
(C) → R; (D) → T

Q.11 In gases the particles are free to move about randomly moving in straight line between any two successive collisions. The velocity of particles in a gas is stated under different names and different conditions in column I and its values are given in column II. Match the correct values.

Column I	**Column II**
(A) Mean velocity	(1) $\sqrt{\frac{2RT}{M}}$
(B) Mean speed	(2) $\sqrt{\frac{3RT}{M}}$
(C) Most probable speed	(3) $\sqrt{\frac{8RT}{\pi M}}$
(D) Root mean square velocity	(4) 0

(1) A-4, B-3, C-1, D-2 (2) A-3, B-2, C-1, D-4
(3) A-1, B-2, C-3, D-4 (4) A-2, B-1, C-4, D-3

Sol.[1]

Q.12 Compare the dimensional formula mentioned in column II with the physical constants for gas mentioned in column I.

Column I	**Column II**
(A) Boltzmann constant	(1) $[M^0L^0T^0]$ mole^{-1}
(B) Avogadro constant	(2) $[M^1L^2T^{-2}K^{-1}]$mole^{-1}
(C) Gas constant	(3) $[M^1L^5T^{-2}]$
(D) van der Waals constant	(4) $[M^1L^2T^{-2}K^{-1}]$

(1) A-1, B-2, C-3, D-4 (2) A-4, B-1, C-2, D-3
(3) A-4, B-3, C-2, D-4 (4) A-3, B-2, C-1, D-4

Sol.[2]

PHYSICS

Q.1 Case-I : The temperature of the walls of a vessel containing a gas at temperature T, is T_{wall}. It is known that $T_{wall} > T$. –

Case-II : same gas fill in an another vessel has temperature $T_{wall} < T$ (All other conditions are keeping same), Then

(A) Pressure exerted by gas on wall is higher in case I than in case II

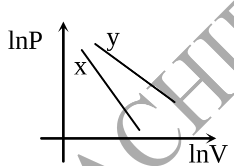
(B) Average kinetic energy of gas molecules after collision is higher in case I than in case II

(C) Pressure exerted by gas on wall is lower in case I than in case II

(D) Average kinetic energy of gas molecules after collision is lower in case I than in case II

[A,B]

Q.2 For two different gases x and y, having degrees of freedom f_1 and f_2 and molar heat capacities at constant volume C_{V_1} and C_{V_2} respectively, the lnP versus lnV graph is plotted for adiabatic process as shown, then –



(A) $f_1 > f_2$ (B) $f_2 > f_1$

(C) $C_{V_2} < C_{V_1}$ (D) $C_{V_1} > C_{V_2}$ **[B,C]**

Q.3 According to kinetic theory of gases, 0 K is that temperature at which–

(A) pressure of ideal gas is zero

(B) volume of ideal gas is zero

(C) internal energy of ideal gas is zero

(D) ideal gas liquefies **[A,B,C]**

Q.4 One gram molecule of nitrogen occupies 2×10^4 cm^3 at a pressure of 10^6 dyne cm^{-2}. Given : $N_A = 6 \times 10^{23}$. Which of the following is correct ?

(A) The value of kT is $\frac{1}{3} \times 10^{-13}$ erg

(B) The value of kT is $\frac{1}{4} \times 10^{-13}$ erg

(C) Mean kinetic energy per molecule is 5×10^{-14} erg

(D) Mean kinetic energy per molecule is 9.8 erg

[A,C]

Q.5 The mean kinetic energy of the molecules of a gas is $\frac{1}{4}$th of its value at 127ºC. The temperature of the gas is–

(A) 100 K (B) –173ºC

(C) 8ºF (D) 9ºR **[A,B]**

Q.6 Which of the following quantities is the same for all ideal gases at the same temperature?

(A) the translational kinetic energy of 1 mole

(B) the translational kinetic energy of 1 g

(C) the number of molecules in 1 mole

(D) the number of molecules in 1 g **[A,C]**

Q.7 A vessel contains 6×10^{26} molecules m^{-3}. Mass of each molecule is 6×10^{-27} kg. Assume that, on an average, one-sixth of the molecules move with a velocity 10^3 m/s perpendicularly towards each wall. If the collisions with the walls are perfectly elastic, then which of the following is correct?

(A) Change in momentum of each molecule is 12 $\times 10^{-24}$ kg m/s in each collision

(B) The number of molecules hitting normally to1 m^2 of the wall per second is 10^{29}

(C) Total change in momentum of all molecules per second is 10^{31} SI units

(D) The number of molecules hitting one square metre of the surface is 6×10^{29} **[A,B]**

Q.8 Let $\bar{v}$, v_{rms} and v_p respectively denote the mean speed, root mean square speed and most probable speed of the molecules in an ideal monoatomic gas at absolute temperature T. The mass of a molecule is m. Then – **[IIT – 98]**

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

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

(C) $v_p < v < \bar{v}_{rms}$

(D) The average kinetic energy of a molecule is $(3/4)\, m v_p^2$ **[C,D]**

Q.9 C_v and C_p denote the molar specific heat capacities of a gas at constant volume and constant pressure, respectively. Then **[IIT - 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) $C_p \cdot C_v$ is larger for a diatomic ideal gas than for a monoatomic ideal gas **[B,D]**

Q.10 The total translational kinetic energy of all molecules of 5 litres of nitrogen exerting a pressure P is 3000 J. Then -

(A) The total kinetic energy of 10 litres of N_2 at pressure of 2 P is 3000 J

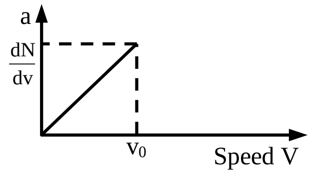
(B) The total kinetic energy of 10 litres of He at pressure of 2 P is 3000 J

(C) The total kinetic energy of 10 litres of O_2 at pressure of 2 P is 20000 J

(D) The total kinetic energy of 10 litres of Ne at pressure of 2 P is 12000 J **[C,D]**

Sol. $K_T = \frac{3}{2} nRT = \frac{3}{2} PV$

Q.11 Graph shows a hypothetical speed distribution for a sample of N gas particle (for $v > v_0$, $\frac{dN}{dv} = c$)



(A) The value of av_0 is 2N

(B) The ratio v_{avg}/v_0 is equal to $\frac{2}{3}$.

(C) The ratio v_{rms}/v_0 is equal to $\frac{1}{\sqrt{2}}$

(D) Three fourth of the total particle has a speed between $0.5\, v_0$ and v_0 **[A,B,C,D]**

Q.12 Pick the correct statements(s) –

(A) the rms translational speed for all ideal-gas molecules at the same temperature is not the same but it depends on the mass of a molecule

(B) Each particle in a gas has average translational kinetic energy and the equation $\frac{1}{2} m v_{rms}^2 = \frac{3}{2} kT$ establishes the relationship between the average translational kinetic energy per particle and temperature of an ideal gas. It can be concluded that single particle has a temperature

(C) Temperature of an ideal gas is doubled from 100ºC to 200ºC. The average kinetic energy of each particle is also doubled

(D) It is possible for both the pressure and volume of a mono-atomic ideal gas to change simultaneously without causing the internal energy of the gas to change **[A,D]**

Q. 13 One mole of an ideal monoatomic gas is taken from temperature T_0 to $2T_0$ by the process PT^{-4} = constant, then -

(A) Molar heat capacity of gas is $-\frac{3R}{2}$ in the process

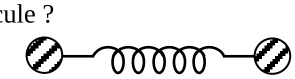
(B) Molar heat capacity of gas is $\frac{3R}{2}$ in the process

(C) Work done is $-3RT_0$ in the process

(D) Work done is $3RT_0$ in the process **[A,C]**

Sol. Polytropic process.

Q. 14 Consider the model of linear diatomic molecule. Which of following results is/are true regarding the gas sample composed of such linear diatomic molecule ?



(A) At high temperature the molecule can have more than five degrees of freedom

(B) If all the molecules dissociate into atoms, internal energy of gas sample decreases (assuming same temperature)

(C) If all the molecules dissociate into atoms, internal energy of gas sample increases (assuming same temperature)

(D) Internal energy of gas sample will remain unchanged and unaffected due to dissociation (assuming same temperature)

[A,C]

Sol. Conceptual

Q.15 Number of collisions of molecules of a gas on the wall of a container per m^2 will -

(A) Increase if temperature and volume both are doubled

(B) Increase if temperature and volume both are halved

(C) Increase if pressure and temperature both are doubled

(D) Increase if pressure and temperature both are halved

[B,C]

Sol. Number of collisions per unit area $\propto$.

$$\frac{1}{\text{time between two collision} \times \text{area}}$$

$$\Rightarrow n/A \propto \frac{V_{rms}}{\text{distance between walls} \times A}$$

$V_{rms} \propto \sqrt{T}$ distance between walls × A = volume

So $\frac{n}{A} \propto \frac{T^{1/2}}{V}$ if both T and V are halved, $\frac{n}{A}$ increases.

Q.16 The root-mean-square (rms) speed of oxygen molecules (O_2) at a certain absolute temperature is v. The temperature is doubled and the oxygen gas completely dissociates into atomic oxygen -

(A) the rms speed would be 2v

(B) the average kinetic energy per particle is doubled

(C) the average translational kinetic energy per particle is doubled

(D) the average rotational kinetic energy per particle is doubled

Sol. **[A,C]**

Q.17 One mole of an ideal gas undergoes a process $P = \frac{P_0}{1+(3V_0/V)^2}$. Here P_0 and V_0 are constants. Volume is changed from $V = V_0$ to $V = 3V_0$ -

(A) temperature of gas when its volume is $3V_0$ is $\frac{3P_0V_0}{2R}$

(B) temperature of gas when its volume is V_0 is $\frac{P_0V_0}{10R}$

(C) change in temperature is $5P_0V_0/8R$

(D) temperature remains constant

Sol. **[A,B]**

$PV = nRT$ …(i)

$$P = \frac{P_0}{1+\left(\frac{3V_0}{V}\right)^2}$$

at $V = 3V_0$

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

Equation (i)

$$\frac{P_0}{2} . 3V_0 = nRT$$

$$\boxed{T = \frac{3P_0V_0}{2R}}$$

when $V = V_0$

$$P = \frac{P_0}{2+\left(\frac{3V_0}{V_0}\right)^2} = \frac{P_0}{10}$$

$$\frac{P_0}{10} V_0 = 1 \times RT$$

$$\boxed{T = \frac{P_0V_0}{10R}}$$

Q. 18 An ideal gas of one mole is found to obey the law $P = P_0 \left[1+\left(\frac{V-V_0}{V_0}\right)^2\right]$. The initial absolute temperature of gas is T_0 and pressure is P_0. Select the correct statements -

(A) The absolute temperature of gas at $V = 2V_0$ is $\frac{4P_0V_0}{R}$

(B) The change in internal energy of gas when its temperature increases from T_0 to $2T_0$ can be calculated

(C) The change in internal energy of gas when its temperature increase from T_0 to $2T_0$ cannot be calculated

(D) Heat supplied to gas when its temperature change from T_0 to $2T_0$ is $\frac{P_0V_0}{2R}$ **[A,C]**

Q.19 An ideal monoatomic gas obeys the law PT^{-2} = constant. The initial temperature and volume are T_0 and V_0. If the volume of gas increase to $2V_0$ then -

(A) Internal energy of the gas increases

(B) Internal energy of the gas decreases

(C) For μ mole of gas work done by the gas is $\frac{\mu RT_0}{2}$

(D) Heat supplied to the gas $\frac{\mu R T_0}{2}$

Sol.[B,C] PT^{-2} = constant, PV^2 = constant

$$W = \frac{\mu RT_0}{2}, \; Q = -\frac{\mu RT_0}{2}$$

Q.20 A gas is kept in a closed container at temperature T. If temperature of gas is increased then according to Maxwell theory of molecular speed distribution, choose the correct alternatives :

(A) Number of molecular moving with v_{rms} must increase

(B) Number of molecules moving with v_{mp} must decrease

(C) Number of molecular moving with v_{av} may decrease

(D) Number of molecules moving with $2v_{rms}$ may increase

Sol. [B,C,D] Conceptual.

Q.1 Under standard conditions the gas density is ρ = 1.3 mg/cm^3 and the velocity of sound propagation in it is v = 330 m/s then what will be the no. of degrees of freedom of gas molcules ?

Sol. [0005]

Q.2 A diatomic molecule can be modelled as two rigid ball connected with spring such that the ball can vibrate with respect to centre of mass of the system (spring + balls). Consider a diatomic gas contain such diatomic molecule. If gas performs 20 Joule work under isobaric condition, then heat given to the gas (in Joule) is.

Sol. [0140J]

$$\frac{\Delta Q}{W} = \frac{nC_P\Delta T}{nR\Delta T}$$

$$\Rightarrow \Delta Q = \frac{C_P}{R} . W$$

$$= \frac{7}{2} \times 20$$

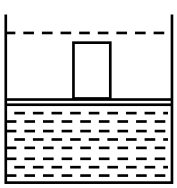
$$= 140 \text{ J}$$

Q.3 Under standard conditions the gas density is 1.3 mg/cm^3 and the velocity of sound propagation in it is 330 m/s, then the number of degrees of freedom of gas is. **[0005]**

Sol. $v_{sound} = \sqrt{\frac{\gamma P}{\rho}}$ and $\gamma = 1 + \frac{2}{f}$

$$\therefore \quad 1 + \frac{2}{f} = \frac{v_{sound}^2 \times \rho}{P}$$

Q.4 A cylinder contains 0.15 kg of hydrogen. The cylinder is closed by a piston supporting a weight of 74 kg (see fig.), n × 10^3 J amount of heat is given to lift the weight by 1.2 m ? The process should be assumed isobaric, the heat capacity of the vessel and the external pressure should be neglected. Find n (n is single digit.)



Sol.[3] $w = m_w gh$

$$Q = \frac{7}{2} \times m_w gh$$

$$= \frac{7}{2} \times 74 \times 9.8 \times 1.2 \approx 3 \times 10^3 \text{ J}$$

$\therefore$ n = 3

Q.5 Air separated from the atmosphere by a column of mercury of length h = 15 cm is present in a narrow cylindrical two soldered at one end. When the tube is placed horizontally the air occupies a volume V_1 = 240 mm^3. When it is set vertically with its open end upwards the volume of the air is V_2 = 200 mm^3. The atmospheric pressure during the experiment is 7n cm of Hg where n is single digit number. Find n.

Sol. [5]

$$P = \frac{hV_2}{V_1 - V_2}$$

n = 5

Q.6 Two balloons of the same volume are filled with gases at the same pressure, one with hydrogen and the other with helium. The ratio of buoyancies (including the weight of the bag) acts on hydrogen to buoyancy acts on balloon filled with helium. Give answer in single digit.

Sol. [1]

$$F = \frac{PVg}{RT} (M_{air} - M_{gas})$$

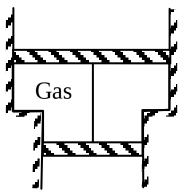
$$\frac{F_{H_2}}{F_{He}} = \frac{M_{air} - M_{H_2}}{M_{air} - M_{He}}$$

$$= 1.08$$

Q.7 Gas at pressure P_0 is contained in a vessel. If the mass of all the molecules are halved and their speed is doubled then the resulting pressure becomes nP_0. What is the value of 'n'.

Sol. [2]

Q.8 A smooth vertical tube having two different sections is open from both ends and equipped with 2 pistons of different areas. Each piston can slide. One mole of ideal gas is enclosed between the pistons tied with a non-stretchable thread. The cross-sectional area of the upper piston is $\Delta S = 10\ cm^2$ greater than that of the lower one. The combined mass of the two pistons is equal to 5 kg. The outside air pressure is 1 atm. If gas between the pistons be heated by $(n \times 10^{-1})$ Kelvin so that pistons shift through 5 cm, then what is the value of 'n' ?



Sol. **[9]**

Q.9 An ideal gas is trapped between a mercury column and the closed end of a narrow vertical tube of uniform base containing the column. The upper end of the tube is open to the atmosphere. The atmospheric pressure equals 76 cm of mercury. The lengths of the mercury column and the trapped air column are 20 cm and 43 cm respectively. What will be the length of the air column in cm when the tube is tilted slowly in a vertical plane through an angle of 60º? Assume the temperature to remain constant.

Sol. **[0048]**

Q.10 A cubical box of side 1 meter contains helium gas (atomic weight 4) at a pressure of 100 N/m^2. During an observation time of 1 second, an atom travelling with the root-mean-square speed parallel to one of the edges of the cube, was found to make 500 hits with a particular wall, without any collision with other atoms.
(Take R = 25/3 J/mol-K and $k = 1.38 \times 10^{-23}$ J/K.)
Evaluate the temperature of the gas. (in Kelvin)

Sol. **[0160]**

Q.11 Gas at pressure P_0 is contained in a vessel. If the mass of all the molecules are halved and their rms speed is doubled then the resulting pressure becomes nP_0. What is the value of 'n' ?
(Assuming same no. of molecules)

Sol.[2] $P = \frac{1}{3}\rho v^2_{rms}$

Q.12 The mass of a molecule of a gas is 4×10^{-30} kg. If 10^{23} molecules strike the area of 4 square meter with the velocity 10^7 m/sec, then what is the pressure exerted on the surface ?
(Assuming perfectly elastic collision and they are hitting perpendicularly) (Ans. in N/m^2)

Sol.[2] 2 N/m^2

Q.13 Calculate the root mean square velocity of a gas of density 1.5 gram per litre at a pressure of $2\times 10^6\ Nm^{-2}$. (Give answer in km/sec)

Sol.[2] 2×10^3 m/s

Q.1 A vessel is filled with a gas at a pressure of 76 cm of mercury at a certain temperature. The mass of the gas is increased by 50 % by introducing more gas in the vessel at the same temperature. The resultant pressure, in cm of Hg, is -

(A) 76 (B) 152 (C) 114 (D) 1117 **[C]**

Sol. $P \propto m$

Since m is increased by a factor of $\frac{3}{2}$,

therefore, P will increase by a factor of $\frac{3}{2}$.

$\therefore$ New pressure = $\frac{3}{2} \times 76$ cm of Hg

= 114 cm of Hg.

Q.2 One mole of ideal monoatomic gas (γ = 5/3) is mixed with two mole of diatomic gas (γ = 7/5). What is γ for mixture ?

(A) 3/2 (B) $\frac{23}{15}$

(C) $\frac{19}{13}$ (D) 4/3 **[C]**

Sol. $\gamma_{mix} = \dfrac{\mu_1 C_{p_1} + \mu_2 C_{p_2}}{\mu_1 C_{v_1} + \mu_2 C_{v_2}}$

$$= \frac{\left(1\times\frac{5}{2}R\right)+\left(2\times\frac{7}{2}R\right)}{\left(1\times\frac{3}{2}R\right)+\left(2\times\frac{5}{2}R\right)} = \frac{19}{13}$$

Q. 3 RMS velocity of an ideal gas at 27°C is 500 m/s. Temperature is increased four times, rms velocity will become -

(A) 1000 m/s (B) 560 m/s

(C) 2000 m/s (D) None of these **[B]**

Sol. $v_{rms} \propto \sqrt{T}$ [T = temperature in Kelvin]

$T_1 = 27 + 273 = 300$ K

$T_2 = 4 \times 27 + 273 = 381$ K

$\therefore v_2 = \sqrt{\frac{381}{300}} \times 500 \simeq 560$ m/s

Q. 4 One kg of a diatomic gas is at a pressure of 8×10^4 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]**

(A) 3×10^4 J (B) 5×10^4 J

(C) 6×10^4 J (D) 7×10^4 J **[B]**

Sol. $E = \frac{f}{2} RTn.$

Since gas is diatomic hence f = 5

$E = \frac{5}{2} RTn$ ($\because PV = nRT$)

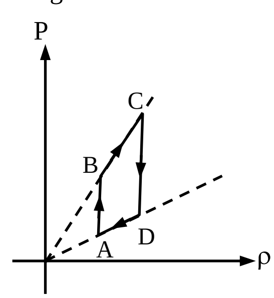
$E = \frac{5}{2} PV$

$E = \frac{5}{2}\frac{PM}{D}\begin{pmatrix} M = \text{Mass} \\ D = \text{Density}\end{pmatrix}$

$E = \frac{5}{2} \times \frac{8\times 10^4 \times 1}{4} = 5 \times 10^4$ J.

So option (2) is correct.

Q. 5 Pressure versus density graph of an ideal gas is shown in figure -



(A) during the process AB work done by the gas is positive

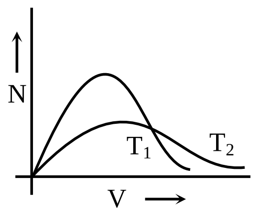
(B) during the process AB work done by the gas is negative

(C) during the process BC internal energy of the gas is increasing

(D) none of these **[D]**

Sol. As density increases, work done is – ve.

Q. 6 Maxwell's velocity distribution curve is given for two different temperatures. For the given curves -

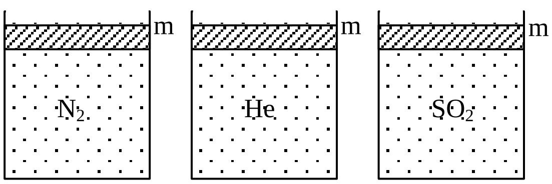


(A) $T_1 > T_2$ (B) $T_1 < T_2$

(C) $T_1 \leq T_2$ (D) $T_1 = T_2$ **[B]**

Sol. Higher is the temperature greater is the most probable velocity.

Q.7 Container below are filled with three different gases as shown. Piston is made to oscillate in below three cases. Time Period of oscillation is T_A, T_B, T_C. Then-



(A) $T_A > T_B > T_C$ (B) $T_C > T_A > T_B$

(C) $T_C > T_B > T_A$ (D) $T_B > T_A > T_C$

Sol. **[B]**

Time period of oscillation of piston is $T \propto \frac{1}{\sqrt{r}}$

where $\gamma = C_p/C_v$ adiabatic exponent

$\gamma_{mono} = 5/3$; $\gamma_{di} = 7/5$; $\gamma_{poly} = 4/3$

$\therefore \quad \gamma_{mono} > \gamma_{di} > \gamma_{poly}$

Q. 8 An ideal gas is held in a container of volume V at pressure P. The average speed of a gas molecule under these conditions is v. If now the volume and pressure are changed to 2V and 2P, the average speed of a molecule will be

(A) 1/2 v (B) v

(C) 2v (D) 4v

Sol. **[C]**

$PV = \frac{1}{3} m_o N v_{rms}^2$

$(2P)\,(2V) = \frac{1}{3} m_o N v'^2_{rms}$

$\varpi'_{rms} = 2v_{rms} = 2v$

Q.9 At NTP the density of a gas is 1.3 kg/m^3 and the velocity of sound propagation in the gas is 330 m/s. The degree of freedom of gas molecule is-

(A) 3 (B) 5

(C) 6 (D) 7 **[B]**

Sol.

$V = \sqrt{\gamma P/\rho}$

$330 = \sqrt{\gamma \times \frac{1\times10^5}{1.3}}$

$\frac{(33)^2 \times 100 \times 1.3}{1\times10^5} = \gamma$

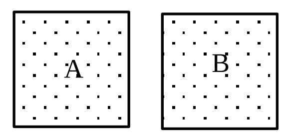
$\frac{1.089\times10^3 \times 10^2 \times 1.3}{1\times10^5} = \gamma$

$\frac{2}{f} + 1 = \gamma = 1.4 = 7/5$

$\frac{2}{f} = 2/5$

$f = 5$

Q.10



Two containers A & B contain ideal gases helium and oxygen respectively. Volume of both containers are equal and pressure is also equal. Container A has twice the number of molecules than container B then if v_A & v_B represent the rms speed of gases in containers A & B respectively, then -

(A) $\frac{v_A}{v_B} = \sqrt{2}$

(B) $\frac{v_A}{v_B} = 4$

(C) $\frac{v_A}{v_B} = 2$

(D) $\frac{v_A}{v_B} = \sqrt{8}$

Sol. **[C]**

$T_A = \frac{P_A V_A}{n_A R}$ and $T_B = \frac{P_B V_B}{n_B R}$

Given, $P_A = P_B$, $V_A = V_B$ and $n_A = 2n_B$

$\therefore \quad T_A = \frac{T_B}{2}$

Now, $\frac{V_A}{V_B} = \sqrt{\frac{T_A}{T_B} \times \frac{M_B}{M_A}} = 2$

Q.11 P-V diagram of a diatomic gas is a straight line passing through origin. The molar heat capacity of the gas in the process will be -

(A) 4R (B) 2.5 R

(C) 3 R (D) $\frac{4R}{3}$ **[A]**

Sol. P = KV

PV = nRT

$KV^2 = nRT$

2KVdV = nRdT

$W = \int KVdV = \frac{nR}{2}\int dT = \frac{nR}{2}\Delta T$

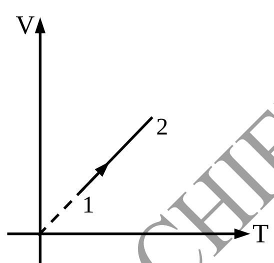
from first law of thermodynamics

$Q = W + \Delta U$

$nC\Delta T = \frac{nR}{2}\Delta T + nC_V\Delta T$

$C = \frac{R}{2} + C_V = \frac{R}{2} + \frac{7R}{2} = 4R$

Q.12 Volume versus temperature graph of two moles of helium gas is as shown in figure. The ratio of heat absorbed and the work done by the gas in process 1-2 is -



(A) 3 (B) 5/2

(C) 5/3 (D) 7/2 **[B]**

Sol. $\frac{Q}{W} = \frac{nC_p\Delta T}{nR\Delta T}$

Q.13 2 mole of an ideal monoatomic gas mix with 1 mole of a ideal diatomic gas. The $\frac{C_P}{C_V}$ for the mixture is -

(A) $\frac{15}{11}$ (B) $\frac{17}{11}$

(C) $\frac{13}{11}$ (D) None **[B]**

Sol. $\frac{2+3}{\gamma_{min}-1} = \frac{2}{\frac{5}{3}-1} + \frac{1}{\frac{7}{5}-1}$

$\frac{3}{\gamma_{min}-1} = 3 + \frac{5}{2}$

$\frac{3}{\gamma_{min}-1} = \frac{11}{2}$

$\gamma_{min}-1 = \frac{6}{11}$

$\gamma_{min} = \frac{6}{11} + 1 = \frac{17}{11}$

Q.14 Molecule of a gas can be modelled as three sphere connected through three rigid rods as to make triangle like structure. A gas containing such molecules performs 25 J of work when it expands at constant pressure. Heat given to gas is –

(A) 75 J (B) 100 J

(C) 150 J (D) 125 J **[B]**

Sol. For isobaric process

$\frac{Q}{W} = \frac{K+2}{K}$ [K = degree of freedom]

$Q = \frac{6+2}{2} \times 25 = 100$ J

Q.15 Choose the incorrect statement regarding the energy of gas molecules -

(A) Average KE of a diatomic gas molecule at normal temp is $\frac{5}{2}$ kT.

(B) Average translational KE of a molecule is $\frac{1}{2}\ m'v_{av}^2$ where m′ is the mass of molecules and v_{av} is the average speed of the molecules

(C) Average translational KE of all the gas molecules is the same as $\frac{3}{2}$ kT

(D) Rotational KE of all the diatomic gas molecules is the same as kT **[B]**

Sol. It is $\frac{1}{2}\ m'v_{rms}^2$.

Q.16 The absolute temperature of a gas increases 3 times. The root mean square velocity of the molecules will become:

(A) 3 times (B) 9 times

(C) (1/3) times (D) $\sqrt{3}$ times **[D]**

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

So, $\sqrt{3}$ times

Q.17 A triatomic molecule can be modelled as three rigid sphere joined by three rigid rods forming an triangle. Consider a triatomic gas consisting such molecule. If gas performs 30 J work when it expands under constant pressure the heat given to gas is -

(A) 60 J (B) 30 J

(C) 45 J (D) 120 J **[D]**

Sol. $\frac{\Delta Q}{W} = \frac{C_P}{R}$

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

(f = degree of produce)

$= 4R$

$\therefore \Delta Q = 4W = 120$ J

Q.18 An ideal diatomic gas occupies a volume V_1 at a pressure P_1. The gas undergoes a process in which the pressure is proportional to the volume. At the end of process the rms speed of the gas molecules has doubled from its initial value then the heat supplied to the gas in the given process is -

(A) 7 P_1V_1 (B) 8 P_1V_1

(C) 9 P_1V_1 (D) 10 P_1V_1 **[C]**

Sol. As $P \propto V$

$\therefore PV^{-1}$ = constant

Also, $C = C_V - \frac{R}{x-1} = \frac{5}{2}R - \frac{R}{-1-1} = 3R$

But as rms speed is doubled therefore temperature becomes four times.

Hence, $Q = nC\Delta T = n \times 3R \times 3T_i = 9\, nRT_i$

$= 9\, P_1V_1$

Q.19 The molar heat capacity in a process of a diatomic gas if it does a work of $\frac{Q}{4}$ when a heat of Q is supplied to it is -

(A) $\frac{2}{5}$ R (B) $\frac{5}{2}$ R

(C) $\frac{10}{3}$ R (D) $\frac{6}{7}$ R **[C]**

Sol. From first law of thermodynamics

$Q = W + \Delta U$

$Q = \frac{Q}{4} + nC_V\Delta T$

$\frac{3Q}{4} = nC_V\Delta T$

$\frac{3}{4}\, nC\Delta T = nC_V\Delta T$

Q.20 The root mean square velocity of the molecules in a sample of helium is 5/7th that of the molecules in a sample of hydrogen. If the temperature of the hydrogen sample is 0ºC, that of helium samples is about:

(A) 0ºC (B) 0 K

(C) 273ºC (D) 100ºC **[A]**

Sol. $v_{H_e} = \frac{5}{7} v_{H_2}$

$\sqrt{\frac{3RT}{4}} = \frac{5}{7}\sqrt{\frac{3R\times 273}{2}}$

Q.21 If the rms velocity of oxygen molecule at certain temperature is 0.5 km/s, the rms velocity for hydrogen molecule at the same temperature will be:

(A) 2 km/s (B) 4 km/s

(C) 9 km/s (D) 16 km/s **[A]**

Sol. $\frac{v_{O_2}}{v_{H_2}} = \sqrt{\frac{M_{H_2}}{M_{O_2}}} = \sqrt{\frac{2}{32}}$

$\frac{0.5}{v_{H_2}} = \sqrt{\frac{1}{16}} = \frac{1}{4}$

Q.22 The speeds of three molecules of a gas are 3v, 4v and 5v respectively. Their rms speed will be-

(A) $\sqrt{\frac{50}{3}}$ v

(B) $\sqrt{\frac{3}{50}}$ v

(C) $\frac{\sqrt{50}}{3}$ v

(D) 4 v **[A]**

Sol. $v_{rms}^2 = \frac{(3v)^2+(4v)^2+(5v)^2}{3}$

Q.23 For a gas, $\gamma = 1.4$, then atomicity of gas, C_P and C_V are respectively -

(A) monoatomic] $\frac{5}{2}R$, $\frac{3}{2}R$

(B) monoatomic] $\frac{7}{2}R$, $\frac{5}{2}R$

(C) diatomic] $\frac{7}{2}R$, $\frac{5}{2}R$

(D) triatomic] $\frac{7}{2}R$, $\frac{5}{2}R$ **[C]**

Sol. $\gamma = 1.4$

$\therefore C_P = \frac{7}{2}R$ and $C_V = \frac{5}{2}R$

Q.24 1 mole of a monoatomic and 2 mole of diatomic gas are mixed, Now the resulting gas is taken through a process in which molar heat capacity was found 3R. Polytropic constant in the process is -

(A) $-\frac{1}{5}$ (B) $\frac{1}{5}$

(C) $\frac{2}{5}$ (D) None of these **[A]**

Sol. $C = Cv_{mix} + \frac{R}{1-n}$; $Cv_{mix} = \frac{n_1Cv_1 + n_2Cv_2}{n_1 + n_2}$

Q.25 One mole of an ideal monoatomic gas is mixed with one mole of an ideal diatomic gas. The molar specific heat of this mixture at constant volume is-

(A) R (B) $\frac{3}{2}R$

(C) 2 R (D) 2.5 R **[C]**

Sol. $\because (C_V)_{mix} = \frac{n_1C_{V_1} + n_2C_{V_2}}{n_1 + n_2}$

For monoatomic $C_{V_1} = \frac{3}{2}R$

For diatomic $C_{V_2} = \frac{5}{2}R$

$(C_V)_{mix} = \frac{1\times\frac{3}{2}R + 1\times\frac{5}{2}R}{1+1} = 2R$

Q.26 In a diatomic gas translatory, rotatory and vibratory degrees of freedom are present. Then C_P/C_V value is-

(A) 1.66 (B) 1.4

(C) 1.29 (D) 1.33 **[B]**

Sol. For diatomic

$\gamma = 1.4$

Q.27 The ratio of diameters of two spheres made of same materials is 1 : 2. Then ratio of their heat capacities is -

(A) 1 : 2 (B) 1 : 8

(C) 1 : 4 (D) 2 : 1 **[B]**

Sol. $\frac{(H.C)_1}{(H.C.)_2} = \frac{m_1C_{gm_1}}{m_2C_{gm_2}} = \frac{r_1^3}{r_2^3} = \left(\frac{1}{2}\right)^3 = \frac{1}{8}$

$\because m = \rho V = \rho \times \frac{4}{3}\pi r^3$ and

$\rho_1 = \rho_2$, $C_{gm_1} = C_{gm_2}$

Q.28 The ratio of specific heats of an ideal gas is -

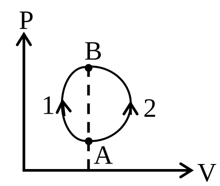
(A) $\frac{1}{1-\frac{R}{C_P}}$ (B) $1+\frac{R}{C_V}$

(C) $\frac{1}{1-\frac{C_V}{R}}$ (D) $\frac{C_V}{C_P}+R$ **[B]**

Sol. $\because C_P - C_V = R$, $\frac{C_P}{C_V} - 1 = \frac{R}{C_V}$

$\therefore \frac{C_P}{C_V} = \gamma = 1 + \frac{R}{C_V}$

Q.29 A certain amount of an ideal gas is taken from state A to state B first along process 1 and then along process 2. If the amount of heat absorbed by the gas is Q_1 and Q_2 respectively then -



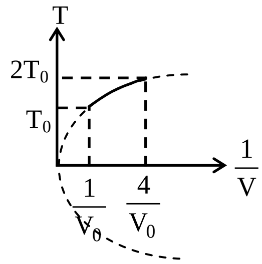
(A) $Q_1 > Q_2$ (B) $Q_1 < Q_2$

(C) $Q_1 = Q_2$ (D) data insufficient **[A]**

Sol. $W_1 > W_2$

$\Delta U_1 = \Delta U_{2ff}$

Q.30 Figure shows a parabolic graph between T and $\frac{1}{V}$ for a mixture of a gas undergoing an adiabatic process. What is the ratio of V_{rms} of molecules and speed of sound in mixture -



(A) $\sqrt{\frac{3}{2}}$ (B) $\sqrt{2}$

(C) $\sqrt{\frac{2}{3}}$ (D) $\sqrt{3}$ **[B]**

Sol. $T_0^2 V_0$ = constant

$\Rightarrow \gamma = 3/2$

$$\frac{V_{rms}}{V_{sound}} = \sqrt{\frac{3}{\gamma}} = \sqrt{2}$$

Q.31 N moles of monoatomic gas having translational KE 2U per molecule are mixed adiabatically inside a rigid boundry container with N moles of diatomic gas having translational KE U per molecule. What is final temperature of mixture ?

(A) $\frac{3N_AU}{8R}$ (B) $\frac{11N_AU}{12R}$

(C) $\frac{3N_AU}{12R}$ (D) None **[B]**

Sol. $(n_1 Cv_1 + n_2 Cv_2) T_f = n_1 Cv_1 T_1 + n_2 Cv_2 T_2$

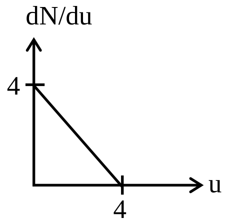
Q.32 Total K.E. per molecules of O_2 gas at 0ºC is -

(A) 0 (B) 273 K

(C) $\frac{3}{2} \times 273$ K (D) $\frac{5}{2} \times 273$ K **[D]**

Sol. $K_{total} = \frac{5}{2}$ K T

Q.33 Consider a hypothetical dN/du Vs u graph for an ideal gas particles. The root mean square speed of given distribution is -



(A) $\sqrt{\frac{8}{3}}$ (B) $\frac{2}{\sqrt{3}}$

(C) $\frac{4}{\sqrt{3}}$ (D) None **[A]**

Sol. $$V_{rms} = \frac{\int_0^4 u^2 dN}{\int_0^4 dN}$$

Q.34 The rotational K.E. of 2 gm H_2 gas at 27ºC is -

(A) RT (B) 2RT

(C) 1.5 RT (D) 2.5 RT

(R $\rightarrow$ Universal gas constant) **[A]**

Sol. $K_{rotational} = \frac{2}{2} \times 1 \times R\,T$

$= RT$

Q.35 The ratio of total K.E. per molecule of O_2 and He at same temperature is -

(A) 1 : 1 (B) 5 : 3

(C) 8 : 1 (D) 2 : 3 **[B]**

Sol. $$\frac{KE_{O_2}}{KE_{He}} = \frac{\frac{5}{2}kT}{\frac{3}{2}kT} = \frac{5}{3}$$

Q.36 The root mean square velocity of the molecules in a sample of helium is 5/7th that of the molecules in a sample of hydrogen. If the temperature of the hydrogen sample is 0°C, that of helium samples is about -

(A) 0°C (B) 0 K

(C) 273°C (D) 100°C **[A]**

Q.37 The rms velocity of a gas at a given temperature is 300 m/s. What will be the rms velocity of a gas having twice the molecular weight and half the temperature in K ?

(A) 300 m/s (B) 600 m/s

(C) 75 m/s (D) 150 m/s **[D]**

Q.38 It takes for an electric kettle to heat a certain quantity of water from 0°C to boiling point

(100°C) in 15 minutes. It requires 80 minutes to turn all the water at 100°C into steam. The latent heat of steam is -

(A) 513.3 cal/g (B) 493.6 cal/g

(C) 533.3 cal/g (D) 425.4 cal/g **[C]**

Q.39 A calorimeter contains 70.2 g of water at 15.3°C. If 143.7 g of water at 36.5°C in mixed with it the common temperature is 28.7°C. The water equivalent of the calorimeter is -

(A) 15.6 g (B) 9.4 g

(C) 6.3 g (D) 13.4 g **[D]**

Q.40 Calculate the time required to heat 20 kg of water from 10°C to 35°C using an immersion heater rated 1000 W. Assume that 80% of the power input is used to heat the water. Specific heat capacity of water = 4200 J/kg-K.

(A) 24 min (B) 34 min

(C) 44 min (D) 54 min **[C]**

Q.41 The root mean square (rms) speed of oxygen molecules (O_2) at a certain absolute temperature is v. If the temperature is doubled and the oxygen gas dissociates into atomic oxygen, the rms speed would be -

(A) v (B) $\sqrt{2}$v

(C) 2v (D) $2\sqrt{2}$v **[C]**

Q.42 A gas has volume V and pressure P. The total translational kinetic energy of all the molecules of the gas is -

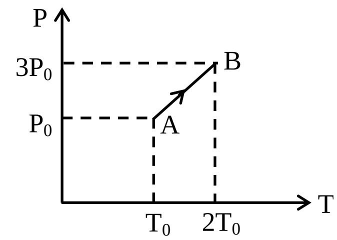
(A) $\frac{3}{2}$ PV only if the gas is monoatomic

(B) $\frac{3}{2}$ PV only if the gas is diatomic

(C) > $\frac{3}{2}$ PV if the gas is diatomic

(D) $\frac{3}{2}$ PV in all cases **[D]**

Q.43 Pressure versus temperature graph of an ideal gas is as shown in figure. Density of the gas at point A is ρ_0. Density at B will be –



(A) $\frac{3}{4}\rho_0$ (B) $\frac{3}{2}\rho_0$

(C) $\frac{4}{3}\rho_0$ (D) $2\rho_0$ **[B]**

Q.44 A vessel contains a mixture of one mole of oxygen and two moles of nitrogen at 300 K. The ratio of the average rotational kinetic energy per O_2 molecule to per N_2 molecule is -

(A) 1 : 1

(B) 1 : 2

(C) 2 : 1

(D) Depends on the moment of inertia of the two molecules **[A]**

Q.45 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 **[D]**

Q.46 The ratio of average translational kinetic energy to rotational kinetic energy of a diatomic molecule at temperature T is -

(A) 3 (B) 7/5

(C) 5/3 (D) 3/2 **[D]**

Q.47 One mole of an ideal gas at STP is heated in an insulated closed container until the average velocity of its molecules is doubled. Its pressure would therefore increases by factor -

(A) 1·5 (B) $\sqrt{2}$

(C) 2 (D) 4 **[D]**

Q.48 Two vessels of the same volume contain the same gas at same temperature. If the pressure in the vessels be in the ratio of 1 : 2, then –

(A) The ratio of the average kinetic energy is 1 : 2

(B) The ratio of the root mean square velocity is

1 : 1

(C) The ratio of the average velocity is 1 : 2

(D) The ratio of number of molecules is 1: 2

[D]

Q.49 At 0°C, the value of the density of a fixed mass of an ideal gas divided by its pressure is x. At 100°C, this quotient is -

(A) $\frac{100}{273}x$ (B) $\frac{273}{100}x$

(C) $\frac{273}{373}x$ (D) $\frac{373}{273}x$ **[C]**

Sol. $P = \rho \frac{RT}{M_w}$

$$\frac{\rho}{P} = \frac{M_w}{RT}$$

$$\left(\frac{\rho}{P}\right)_{0°C} = \frac{M_w}{R \times 273} = x$$

$$\left(\frac{\rho}{P}\right)_{100°C} = \frac{M_w}{R \times 373} = \frac{273}{373}x$$

Q.50 Jar A filled with gas characterized by parameter P,V and T and another jar B filled with a gas with parameter 2P, V/4 and 2T. The ratio of the number of molecules in jar A to those in jar B is-

(A) 1 : 1 (B) 1 : 2

(C) 2 : 1 (D) 4 : 1 **[D]**

Sol. $N = \frac{PV}{KT}$

$$\frac{N_A}{N_B} = \frac{PV}{KT} \times \frac{K2T}{2P(V/4)} = \frac{4}{1}$$

Q.1 The mass of a molecule of a gas is 4×10^{-30} kg. If 10^{23} molecules strike the area of 4 square meter with the velocity 10^7 m/sec, then what is the pressure exerted on the surface ?

Ans. 2 N/m^2

Q.2 The mass of a hydrogen molecules is 3.32×10^{-24} gm. If 10^5 hydrogen molecules strikes the wall of area 2 square cm with the velocity 10^5 cm/sec at an angle 45º with the normal on the wall then calculate the pressure exerted on the wall by the molecules.

Ans. 2347N/m^2

Q.3 A cubical box of side 1 metre contains helium gas (atomic weight 4) at a pressure of 100 Nm^{-2}. During an observation time of 1 second, an atom traveling with the root-mean-square speed parallel to one of the edges of the cube was found to make 500 hits with a particular wall, without any collision with other atoms. Take R = 25/3J/mol-K and k = 1.38×10^{-23}JK^{-1}

(a) Evaluate the temperature of the gas.

(b) Evaluate the average kinetic energy per atom.

(c) Evaluate the total mass of helium gas in the box.

Ans. (a) 160 K (b) 3.312×10^{-21}J (c) 3×10^{-4} kg

Q.4 Calculate the root mean square velocity of a gas of density 1.5 gram per litre at a pressure of 2×10^6 Nm^{-2}.

Ans. 2×10^3 m/s

Q.5 At what temperature average speed of oxygen gas molecule is equal to rms velocity of the same gas at 27ºC ?

Ans. 353.2 K

Q.6 A cylinder 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 gas at a temperature $\mathbf{t_0}$ = 27ºC and a pressure P_0 = 1 atm.

What distance from the middle of the cylinder will the piston be displaced if the gas in one of the parts is heated to **t** = 57ºC? What will be the pressure in this case in each part of the cylinder? The length of half the cylinder is $\boldsymbol{l}$ = 42 cm.

Sol. Knowing that the masses of the gas are equal and taking into account that after the piston is displaced by an amount x the pressures will be the piston is displaced by an amount **x** the **pressures will be the same in both parts of the cylinder**, we may apply Gay-Lussac's law and obtain the ratio

$$\frac{l-x}{T_0} = \frac{l+x}{T}$$

from which

$$x = l\,\frac{T-T_0}{T+T_0}.$$

$$x = l\,\frac{T-T_0}{T+T_0} = 2 \text{ cm}; \quad P = \frac{l}{l-x}P_0 = 1.05 \text{ atm.}$$

Ans.

Q.7 Calculate the value of the constant in the combined law of Boyle and Gay-Lussac for one gram-molecule of gas in calories and in CGS units.

Sol. One gram-molecule of any gas at T_0 = 273º abs and a pressure of P_0 = 1 atm occupies a volume of V_0 = 22.4 litres. Therefore,

$$R = \frac{P_0 - V_0}{T_0} = \frac{22.4}{273}\,l.\text{atm/deg} = 0.82\ l.\text{atm/deg}$$

The answer can be obtained by simply changing the dimensions for the different systems of units.

$R \approx 1.9$ cal/deg = 8.3×10^7 erg/deg. **Ans.**

Q.8 One gram-molecule of oxygen is heated at a constant pressure from 0ºC.

What amount of heat should be imparted to the gas to double its volume? The heat capacity of oxygen in these conditions is C_p = 0.218 cal/g.deg.

Sol. The final temperature of the gas is determined from Gay-Lussac's law

$$\frac{V_0}{T_0} = \frac{V}{T}$$

and the quantity of heat from the equation

$Q = C_{P\mu} (T - T_0)$

where μ is the molecular weight of oxygen.

Q = 1,904 cal. **Ans.**

Q.9 A gas is heated by 1ºC in a cylinder fitted with a piston. The weight of the piston is G and its area S. During heating the gas does work to lift the piston. Express this work: **(a)** in terms of the pressure and the change in volume of the gas; **(b)** in terms of the constant R in the combined equation of Boyle and Gay-Lussac. Disregard the pressure of the outside atmosphere.

Sol. The pressure acting on the gas is $P = \frac{G}{S}$. If heating the gas by 1º raises the piston to a height **h** the work done by the gas will be

A = Gh = PSh

But Sh is equal to the increment in the gas volume $(V - V_0)$ caused by the rising piston.

Hence,

$A = P (V - V_0)$

The equation of state of an ideal gas gives us the following equations:

$PV_0 = RT_0$ and $PV = R (T_0 + 1)$

whence $A\ PV - PV_0 = R$.

$A = P (V - V_0) = R$. **Ans.**

Q.10 A vertical cylinder with a base of area S = 10 cm^2 is filled with gas. The cylinder is fitted with a piston weighing G = 20 kgf which can move without friction. The original volume of the gas is V_0 = 11.21 and the temperature t_0 = 0ºC.

What quantity of heat is needed to raise the temperature of the gas in these conditions by 10ºC if the thermal capacity of this mass of gas with the piston secured in the initial position is C_V = 5 cal/deg? Disregard the pressure of the outside atmosphere.

Sol. The heat taken from the heater will be expended on increasing the temperature of the gas and doing work to raise the piston.

The heating will increase the volume of the gas to

$$V = \frac{T}{T_0} V_0 = 11.651$$

The work done by the gas in this expansion (see the previous problem) will be

$A = P (V - V_0) = 20 \times 0.45$ litre-atm = 9 kgf-m ≈ 21 cal

The quantity of heat used to heat the gas will be

$Q = C_V (T - T_0) + A = 71$ cal.

Q = 71 cal. **Ans.**

Q.11 During an experiment, an ideal gas is found to obey an additional law PV^2 = constant. The gas is initially at a temperature T and volume V. Find the temperature when it expands to a volume 2 V.

Ans. T/2

Q.12 A gas in a vessel is at a pressure of 10 atmosphere and temperature of 27 ºC. If $\frac{1}{4}$ th of the amount of gas be released from the vessel and temperature of the remaining gas is increased to 77 ºC, what is the pressure of the gas ?

Ans. 8.75 atm

Q.13 Air is pumped into an automobile tyre's tube upto a pressure of 200 kPa in the morning when the air temperature is 20 ºC. During the day the temperature rises to 40 ºC and the tube expands by 2%. Calculate the pressure of the air in the tube at this temperature.

Ans. 209 kPa

Q.14 Assume that the temperature remains essentially constant in the upper part of the atmosphere. Obtain an expression for the variation in pressure in the upper atmosphere with height. The mean molecular weight of air is M. Acceleration due to gravity is constant and is equal to g.

Ans. $P = P_0 e^{-\frac{Mgh}{RT}}$

Q.15 One mole of an ideal gas undergoes a process $p = \frac{p_0}{1 + (V/V_0)^2}$

where p_0 and V_0 are constants. Find the temperature of the gas when $V = V_0$.

Ans. $\frac{p_0 V_0}{2R}$ mol–1

Q.16 A vessel of volume V = 5.0 liters contains 1.4 g of nitrogen at a temperature T = 1800 K. Find the pressure of the gas if 30% of its molecules are dissociated into atoms at this temperature.

Ans. 1.94×10^5 N/m^2

Q.17 6.4 g of oxygen, 7 g of nitrogen, 5 g of Argon and 2.2 g of carbon dioxide are mixed together in a closed vessel of volume 20 litre. Calculate the pressure at 27 ºC. The molecular weight of O_2 , N_2, Ar, and CO_2 are 32 , 28, 40 and 44 respectively.

Ans. 0.78×10^5 N/m^2

Q.18 Find the average magnitude of linear momentum of a helium molecule in a sample of helium gas at 0 ºC. Mass of a helium molecule = 6.64×10^{-27} kg and Boltzmann constant = 1.38×10^{-23} J/K.

Ans. 8.0×10^{-24} kgm/s

Q.19 The temperature of a gas consisting of rigid diatomic molecules is T = 300 K. Calculate the angular root mean square velocity of a rotating molecule if its moment of inertia is $I = 2.0 \times 10^{-40}$ kg m^2.

Ans. 6.43×10^9 rad s^{-1}

Q.20 The mass of an oxygen molecule is 5.28×10^{-26} kg .Calculate the translatory K.E. of oxygen molecule at 50 ºC.

Ans. 6.65×10^{-21} J