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CHAPTER 12

Kinetic Theory

1. Cooking gas containers are kept in a lorry moving with uniform speed. The temperature of the gas molecules inside will **[2002]**
   (a) increase
   (b) decrease
   (c) remain same
   (d) decrease for some, while increase for others

2. At what temperature is the r.m.s velocity of a hydrogen molecule equal to that of an oxygen molecule at 47°C? **[2002]**
   (a) 80 K (b) –73 K
   (c) 3 K (d) 20 K.

3. A gaseous mixture consists of 16 g of helium and 16 g of oxygen. The ratio $\frac{C_p}{C_v}$ of the mixture is **[2005]**
   (a) 1.62 (b) 1.59
   (c) 1.54 (d) 1.4

4. The speed of sound in oxygen (O_2) at a certain temperature is 460 ms^{-1}. The speed of sound in helium (*He*) at the same temperature will be (assume both gases to be ideal) **[2008]**
   (a) 1421 ms^{-1} (b) 500 ms^{-1}
   (c) 650 ms^{-1} (d) 330 ms^{-1}

5. One kg of a diatomic gas is at a pressure of $8 \times 10^4 N/m^2$. The density of the gas is $4 kg/m^3$. What is the energy of the gas due to its thermal motion? **[2009]**
   (a) 5×10^4 J (b) 6×10^4 J
   (c) 7×10^4 J (d) 3×10^4 J

6. A thermally insulated vessel contains an ideal gas of molecular mass *M* and ratio of specific heats γ. It is moving with speed *v* and it's suddenly brought to rest. Assuming no heat is lost to the surroundings, its temperature increases by: **[2011]**
   (a) $\frac{(\gamma-1)}{2\gamma R}Mv^2K$ (b) $\frac{\gamma M^2 v}{2R}K$
   (c) $\frac{(\gamma-1)}{2R}Mv^2K$ (d) $\frac{(\gamma-1)}{2(\gamma+1)R}Mv^2K$

7. Consider an ideal gas confined in an isolated closed chamber. As the gas undergoes an adiabatic expansion, the average time of collision between molecules increases as V^q, where V is the volume of the gas. The value of q is : $\left(\gamma = \frac{C_p}{C_v}\right)$ **[2015]**
   (a) $\frac{\gamma+1}{2}$ (b) $\frac{\gamma-1}{2}$
   (c) $\frac{3\gamma+5}{6}$ (d) $\frac{3\gamma-5}{6}$

8. The temperature of an open room of volume 30 m^3 increases from 17°C to 27°C due to sunshine. The atmospheric pressure in the room remains 1×10^5 Pa. If n_i and n_f are the number of molecules in the room before and after heating, then $n_f - n_i$ will be : **[2017]**
   (a) 2.5×10^{25} (b) -2.5×10^{25}
   (c) -1.61×10^{23} (d) 1.38×10^{23}

9. C_p and C_v are specific heats at constant pressure and constant volume respectively. It is observed that **[2017]**
   $C_p - C_v = a$ for hydrogen gas
   $C_p - C_v = b$ for nitrogen gas
   The correct relation between a and b is :
   (a) a = 14 b (b) a = 28 b
   (c) $a = \frac{1}{14}b$ (d) a = b

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Answer Key

1	2	3	4	5	6	7	8	9						
(c)	(d)	(a)	(a)	(a)	(c)	(a)	(b)	(a)						

SOLUTIONS

1. **(c)** Since P and V are not changing, so temperature remain same.

2. **(d)** $v_{rms} = \sqrt{\frac{8RT}{\pi M}}$

For v_{rms} to be equal $\frac{T_{H_2}}{M_{H_2}} = \frac{T_{O_2}}{M_{O_2}}$

Here $M_{H_2} = 2;\ M_{O_2} = 32$;

$T_{O_2} = 47 + 273 = 320\,\text{K}$

$\therefore \frac{T_{H_2}}{2} = \frac{320}{32} \Rightarrow T_{H_2} = 20\,\text{K}$

3. **(a)** For mixture of gas, $C_v = \frac{n_1C_{v_1} + n_2C_{v_2}}{n_1 + n_2}$

$$= \frac{4 \times \frac{3}{2}R + \frac{1}{2} \times \frac{5}{2}R}{\left(4 + \frac{1}{2}\right)} = \frac{6R + \frac{5}{4}R}{\frac{9}{2}}$$

$$= \frac{29R \times 23}{9 \times 4} = \frac{29R}{18} \quad \text{and}$$

$$C_p = \frac{n_1C_{p_1} + n_2C_{p_2}}{(n_1 + n_2)} = \frac{4 \times \frac{5R}{2} + \frac{1}{2} \times \frac{7R}{2}}{\left(4 + \frac{1}{2}\right)}$$

$$= \frac{10R + \frac{7}{4}R}{\frac{9}{2}} = \frac{47R}{18}$$

$$\therefore \frac{C_p}{C_v} = \frac{47R}{18} \times \frac{18}{29R} = 1.62$$

4. **(a)** The speed of sound in a gas is given by

$v = \sqrt{\frac{\gamma RT}{M}}$

$$\therefore \frac{v_{O_2}}{v_{He}} = \sqrt{\frac{\gamma_{O_2}}{M_{O_2}} \times \frac{M_{He}}{\gamma_{He}}}$$

$$= \sqrt{\frac{1.4}{32} \times \frac{4}{1.67}} = 0.3237$$

$$\therefore v_{He} = \frac{v_{O_2}}{0.3237} = \frac{460}{0.3237} = 1421\ \text{m/s}$$

5. **(a)** Volume $= \frac{\text{mass}}{\text{density}} = \frac{1}{4}\ \text{m}^3$

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

Alternatively:

$$\text{K.E} = \frac{5}{2}nRT = \frac{5}{2}\frac{m}{M}RT = \frac{5}{2}\frac{m}{M} \times \frac{PM}{d}$$

$[\because PM = dRT]$

$$= \frac{5}{2}\frac{mP}{d} = \frac{5}{2} \times \frac{1 \times 8 \times 10^4}{4} = 5 \times 10^4\,\text{J}$$

6. **(c)** Here, work done is zero.

So, loss in kinetic energy = change in internal energy of gas

$$\frac{1}{2}mv^2 = nC_v\Delta T = n\frac{R}{\gamma - 1}\Delta T$$

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

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

7. **(a)** $\tau = \frac{1}{\sqrt{2}\pi d^2 \left(\frac{N}{V}\right)\sqrt{\frac{3RT}{M}}}$

$\tau \propto \frac{V}{\sqrt{T}}$

As, $TV^{\gamma - 1} = K$ So, $\tau \propto V^{\gamma + 1/2}$

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

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8. **(b)** Given: Temperature $T_i = 17 + 273 = 290\,K$

Temperature $T_f = 27 + 273 = 300\,K$

Atmospheric pressure, $P_0 = 1 \times 10^5\,Pa$

Volume of room, $V_0 = 30\,m^3$

Difference in number of molecules, $n_f - n_i = ?$

Using ideal gas equation, $PV = nRT(N_0)$,

N_0 = Avogadro's number

$$\Rightarrow \quad n = \frac{PV}{RT}(N_0)$$

$$\therefore \quad n_f - n_i = \frac{P_0 V_0}{R}\left(\frac{1}{T_f} - \frac{1}{T_i}\right) N_0$$

$$= \frac{1 \times 10^5 \times 30}{8.314} \times 6.023 \times 10^{23}\left(\frac{1}{300} - \frac{1}{290}\right)$$

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

9. **(a)** As we know, $C_p - C_v = R$ where C_p and C_v are molar specific heat capacities

or, $\quad C_p - C_v = \frac{R}{M}$

For hydrogen $(M = 2)$ $C_p - C_v = a = \frac{R}{2}$

For nitrogen $(M = 28)$ $C_p - C_v = b = \frac{R}{28}$

$\therefore \quad \frac{a}{b} = 14 \quad$ or, $\quad a = 14b$