Chapter 5 - States Of Matter

Question 5.1:

What will be the minimum pressure required to compress 500 dm^3 of air at 1 bar to 200 dm^3 at 30°C?

Answer:

Given,

Initial pressure, p_1 = 1 bar

Initial volume, V_1 = 500 dm^3

Final volume, V_2 = 200 dm^3

Since the temperature remains constant, the final pressure (p_2) can be calculated using Boyle's law.

According to Boyle's law,

$$p_1V_1 = p_2V_2$$

$$\Rightarrow p_2 = \frac{p_1V_1}{V_2}$$

$$= \frac{1 \times 500}{200} \text{ bar}$$

$$= 2.5 \text{ bar}$$

Therefore, the minimum pressure required is 2.5 bar.

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Question 5.2:

A vessel of 120 mL capacity contains a certain amount of gas at 35 °C and 1.2 bar pressure. The gas is transferred to another vessel of volume 180 mL at 35 °C. What would be its pressure?

Answer:

Given,

Initial pressure, p_1 = 1.2 bar

Initial volume, V_1 = 120 mL

Final volume, V_2 = 180 mL

Since the temperature remains constant, the final pressure (p_2) can be calculated using Boyle's law.

According to Boyle's law,

$$p_1V_1 = p_2V_2$$

$$p_2 = \frac{p_1V_1}{V_2}$$

$$= \frac{1.2 \times 120}{180} \text{ bar}$$

$$= 0.8 \text{ bar}$$

Therefore, the pressure would be 0.8 bar.

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Question 5.3:

Using the equation of state $pV = nRT$; show that at a given temperature density of a gas is proportional to gas pressure$p$.

Answer:

The equation of state is given by,

$pV = nRT$ ……….. (i)

Where,

p → Pressure of gas

V → Volume of gas

n → Number of moles of gas

R → Gas constant

T → Temperature of gas

From equation (i) we have,

$$\frac{n}{V} = \frac{p}{RT}$$

Replacing n with $\frac{m}{M}$, we have

$$\frac{m}{MV} = \frac{p}{RT} \quad \text{..........(ii)}$$

Where,

m → Mass of gas

M → Molar mass of gas

But, m/V = d (d = density of gas)

Thus, from equation (ii), we have

$$\frac{d}{M} = \frac{p}{RT}$$
$$\Rightarrow d = \left(\frac{M}{RT}\right)p$$

Molar mass (M) of a gas is always constant and therefore, at constant temperature (T), $\frac{M}{RT}$ = constant.

$$d = (\text{constant})\, p$$
$$\Rightarrow d \propto p$$

Hence, at a given temperature, the density (d) of gas is proportional to its pressure (p)

Question 5.4:

At 0°C, the density of a certain oxide of a gas at 2 bar is same as that of dinitrogen at 5 bar. What is the molecular mass of the oxide?

Answer:

Density (d) of the substance at temperature (T) can be given by the expression,

$d = \frac{M_1 p_1}{RT}$

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Now, density of oxide (d_1) is given by,

$$d_1 = \frac{M_1 p_1}{RT}$$

Where, M_1 and p_1 are the mass and pressure of the oxide respectively.

Density of dinitrogen gas (d_2) is given by,

$$d_2 = \frac{M_2 p_2}{RT}$$

Where, M_2 and p_2 are the mass and pressure of the oxide respectively.

According to the given question,

$$d_1 = d_2$$
$$\therefore M_1 p_1 = M_2 p_2$$

Given,

$$p_1 = 2\,bar$$
$$p_2 = 5\,\text{bar}$$

Molecular mass of nitrogen, M_2 = 28 g/mol

$$\text{Now}, M_1 = \frac{M_2 p_2}{p_1} \quad = \frac{28 \times 5}{2} \quad = 70 \text{ g/mol}$$

Hence, the molecular mass of the oxide is 70 g/mol.

Question 5.5:

Pressure of 1 g of an ideal gas A at 27 °C is found to be 2 bar. When 2 g of another ideal gas B is introduced in the same flask at same temperature the pressure becomes 3 bar. Find a relationship between their molecular masses.

Answer:

For ideal gas A, the ideal gas equation is given by,

$$p_A V = n_A RT \text{ ....(i)}$$

Where, p_A and n_A represent the pressure and number of moles of gas A.

For ideal gas B, the ideal gas equation is given by,

$$p_B V = n_B RT \text{ ....(ii)}$$

Where, p_B and n_B represent the pressure and number of moles of gas B.

[V and T are constants for gases A and B]

From equation (i), we have

$$p_B V = \frac{m_B}{M_B} RT \Rightarrow \frac{p_B M_B}{m_B} = \frac{RT}{V} \text{ ....(iv)}$$

From equation (ii), we have

$$p_B V = \frac{m_B}{M_B} RT \Rightarrow \frac{p_B M_B}{m_B} = \frac{RT}{V} \text{ ....(iv)}$$

Where, M_A and M_B are the molecular masses of gases A and B respectively.

Now, from equations (iii) and (iv), we have

$$\frac{p_A M_A}{m_A} = \frac{p_B M_B}{m_B} \text{..........}(v)$$

Given,

$$m_A = 1\text{ g}$$
$$p_A = 2\text{ bar}$$
$$m_B = 2\text{g}$$
$$p_B = (3-2) = 1\text{ bar}$$

(Since total pressure is 3 bar)

Substituting these values in equation (v), we have

$$\frac{2 \times M_A}{1} = \frac{1 \times M_B}{2}$$
$$\Rightarrow 4M_A = M_B$$

Thus, a relationship between the molecular masses of A and B is given by

$$4M_A = M_B$$ ..

Question 5.6:

The drain cleaner, Drainex contains small bits of aluminum which react with caustic soda to produce dihydrogen. What volume of dihydrogen at 20 °C and one bar will be released when 0.15g of aluminum reacts?

Answer:

The reaction of aluminium with caustic soda can be represented as:

$$\underset{2\times 27\text{g}}{2Al} + 2NaOH + 2H_2O \longrightarrow 2NaAlO_2 + \underset{3\times 22400\text{ mL}}{3H_2}$$

At STP (273.15 K and 1 atm),

∵ 54 g (2 × 27 g) of Al gives 3 × 22400 mL of H_2..

∴ 0.15 g Al gives $\frac{3 \times 22400 \times 0.15}{54}$ mL of H_2 i.e., 186.67 mL of H_2.

At STP,

$$p_1 = 1\text{ atm}$$
$$V_1 = 186.67\text{ mL}$$
$$T_1 = 273.15\text{ K}$$

Let the volume of dihydrogen be V_2 at p_2 = 0.987 atm (since 1 bar = 0.987 atm) and

T_2 = 20°C = (273.15 + 20) K = 293.15 K..

Now,

$$\frac{p_1 V_1}{T_1} = \frac{p_2 V_2}{T_2}$$
$$\Rightarrow V_2 = \frac{p_1 V_1 T_2}{p_2 T_1}$$
$$= \frac{1 \times 186.67 \times 293.15}{0.987 \times 273.15}$$
$$= 202.98\text{ mL}$$

Therefore, 203 mL of dihydrogen will be released.

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