Answer on Question #56577, Engineering / Mechanical Engineering

A vessel of 3 m^3 capacity contains a mixture of nitrogen and carbon dioxide, the analysis by volume showing equal quantities of each. The temperature is 15°C and the total pressure is 3.5 bar. Determine the mass of each constituent.

Solution:

An ideal gas can be characterized by three state variables: absolute pressure (P), volume (V), and absolute temperature (T). The relationship between them may be deduced from kinetic theory and is called the *ideal gas law*:

$$PV = nRT$$

where n = number of moles,

$$n = \frac{m}{M}$$

R = universal gas constant = 8.3145 J/mol K

In our case,

$$P_1 = \frac{nRT}{V}$$

and

$$P_2 = \frac{nRT}{V}$$

Dalton's law of partial pressures states that the total pressure exerted by a mixture of gases is the sum of partial pressure of each individual gas present. Each gas is assumed to be an ideal gas.

$$P_{total} = P_1 + P_2$$

Hence,

$$P_{total} = P_1 + P_1 = 2P_1$$

$$P_1 = \frac{P_{total}}{2} = \frac{3.5}{2} = 1.75 \text{ bar} = 1.75 \cdot 10^5 \text{ Pa}$$

Thus,

$$\frac{m_{N_2}}{M_{N_2}} = \frac{P_1 V}{RT}$$

$$m_{N_2} = \frac{P_1 V}{RT} M_{N_2}$$

M_{N_2} =molar mass of nitrogen is 28.0134 g/mol.

$$m_{N_2} = \frac{1.75 \cdot 10^5 \cdot 3 \cdot 28.0134 \cdot 10^{-3}}{8.315 \cdot 288} = 6.14 \text{ kg}$$

For carbon dioxide:

Molar mass of CO_2 = 44.0095 g/mol

$$m_{CO_2} = \frac{P_1 V}{RT} M_{CO_2}$$

$$m_{CO_2} = \frac{1.75 \cdot 10^5 \cdot 3 \cdot 44.0095 \cdot 10^{-3}}{8.315 \cdot 288} = 9.65 \text{ kg}$$

Answer: $m_{N_2} = 6.14 \text{ kg};\ m_{CO_2} = 9.65 \text{ kg}.$