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16/ENG07/024 C/O

PETROLEUM ENGINEERING

PTE 314. HEAT AND MASS TRANSFER

Question

In order to avoid pressure build up gas at atmospheric pressure in a pipe, is vented to atmosphere through a pipe of 3mm diameter and 20m length. Determine the mass of the gas diffusing out and mass of air diffusing in per hour. Assume $D = 0.28 \times 10^{-4}$ m^2/s, $M = 17 kg/kg\ mole$

Solution.

$$Na = \frac{Ma}{M} \quad \ldots\ldots (i)$$

$P_{a_1} = 1 atm = 1.013 \times 10^{-5}\ Nm^{-2}$

$P_{a_2} = 0$ {Since the gas is vented to the atmosphere}

$L = 20m$

$d = 3m \simeq \frac{3}{1000} = 0.003m$

$A = \frac{\pi}{4d^2} \text{ and } \Rightarrow \frac{\pi}{4.(0.003)^2} = 7.068 \times 10^{-6} m^2$

Molar Mass, $M = 17 kg/kg\ mol$

$R = 8315\ J/kg\ mol\ K$

$D = 0.28 \times 10^{-4}\ m^2/s$

Using the equimolar counter diffusion equation;

$$\frac{Na}{A} = \frac{D}{R\bar{T}} \cdot \frac{P_{a_1} - P_{a_2}}{L} \Rightarrow Na = \frac{DA}{R\bar{T}} \cdot P_{a_1} - P_{a_2}$$

Where $\bar{T}$ is the temperature in absolute unit i.e $0^\circ K$

$$\therefore Na = \frac{DA}{R} \cdot \frac{P_{a_1} - P_{a_2}}{L}$$

Substituting equation (i)

$$\frac{Ma}{M} = \frac{DA}{R} \cdot \frac{P_{a_1} - P_{a_2}}{L}$$

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$$M_a = \frac{D \cdot A}{R} \cdot \frac{P_{a_1} - P_{a_2}}{L} \times M$$

where Ma is the mass of gas diffusing out in kg/s

$$m_a = \frac{DA}{R} \cdot \frac{P_{a_1} - P_{a_2}}{L} \times m\,(3000) \text{ ..... kg/hr}$$

$$M_a = \frac{(0.28 \times 10^{-4}) \times (7.068 \times 10^{-6})}{8315} \times \frac{(1.013 \times 10^{-5} - 0)}{20} \times (17 \times 3000)$$

$$= 7.38 \times 10^{-6} \text{ kg/hr}$$

b Mass of air diffusing in (M_{air})

Recall $\frac{N_a}{A} = \frac{-N_b}{A}$

$\therefore N_a = -N_b$

$N_b = -N_a$

$= -7.38 \times 10^{-6}$

Mole of air $= \frac{-7.38 \times 10^{-6}}{17}$

$= -4.34 \times 10^{-7}$

Mass of air $= -4.34 \times 10^{-7} \times 28.97$

$= -1.26 \times 10^{-5}$ kg/hr