CL201 : TUTORIAL5

Name: RIYA GUPTA Roll No.: 200107070

Branch: Chemical Engineering TUTORIAL NO: 5

Q1 (a) Dry ice amount added to the tank = 15.7 kg CO_2

$$= 15.7 \text{ kg} \times \frac{1 \text{ Kmol}}{44.01 \text{ kg}}$$

$$= 0.357 \text{ Kmol } CO_2$$

Assume gas to be ideal:

$\Rightarrow PV = nRT$

(let initial moles of air be n_1)

$$\frac{P_1 V}{P_2 V} = \frac{n_1 RT}{(n_1 + 0.357) RT}$$

$$\Rightarrow \frac{P_1}{P_2} = \frac{n_1}{n_1 + 0.357} = \frac{102 \text{ KPa}}{3.27 \times 10^3 \text{ KPa}} = 0.031$$

$$\Rightarrow \frac{n_1}{n_1 + 0.357} = 0.031$$

$$\Rightarrow n_1 (1 - 0.031) = 0.0111$$

$$\Rightarrow n_1 = \frac{0.0111}{0.969} = \underline{0.0115} \text{ Kmol of air in tank}$$

(b) $$V_{tank} = \frac{n_1 RT}{P_1} = 0.0115 \text{ Kmol} \times \frac{8.314 \text{ m}^3 \cdot \text{KPa}}{\text{Kmol} \cdot \text{K}} \times \frac{292.2 \text{ K}}{1} \times$$

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$$\frac{1}{102\,kPa} \quad \frac{\times 10^3 L}{m^3}$$

$= 273.89\ L \simeq 274L.$

$$P_{total} = \frac{\text{total mass}}{\text{Volume}}$$

$$= \frac{m_{CO_2} + m_{air}}{V_{tank}} = \frac{15700\,g\,CO_2 + 115\text{ mol air} \times 29\,g\,\frac{air}{mol}}{274\,L}$$

$= \underline{58.52\,g/L}$

(c) (a) Due to phase change., CO_2 sublimates causes large volume change. Volume of the tank is fixed. So the pressure increases rapidly.

(b) Temperature would drop due to sublimation and then temp. will rise back to the room temp. Here temperature will increase at constant volume, so pressure will slowly rise.

Q2. (a) Volume fractions equal to mol fractions in case of an ideal gas.

$\Rightarrow y_A = v_A$

$p_{He} = y_{He} \times P = 0.35 \times 2\text{atm} = 0.70\text{atm}$
$p_{CH_4} = y_{CH_4} \times P = 0.20 \times 2\text{atm} = 0.40\text{atm}$
$p_{N_2} = y_{N_2} \times P = 0.45 \times 2\text{atm} = 0.90\text{ atm}$

(b) Basis : assume 1 mole gas
$0.20 \text{ mol } CH_4 = 0.20 \times 16.05 = 3.21 g\, CH_4$
$0.35 \text{ mol } He = 0.35 \times 4.004 = 1.40 g\, He$
$0.45 \text{ mol } N_2 = 0.45 \times 28.02 = 12.61 g\, N_2$

$\therefore$ total mass $= 3.21 + 1.40 + 12.61$
$= 17.22\, g$

$\therefore$ mass fraction of $CH_4 = \dfrac{3.21}{17.22}$
$= \underline{0.186}$

(c) Avg molecular weight of gas $= \dfrac{g \text{ of gas}}{mol}$
$= 17.22 g / 1 \text{ mol}$
$= 17.22\, g/mol.$

(d). $\rho_{gas} = \dfrac{mass}{Vol^m} = \dfrac{n(\text{Avg molecular weight})}{V}$
$= \dfrac{P}{RT}(17.22\, kg/Kmol)$
$= \dfrac{(2\text{ atm}) \times (17.22\, kg/Kmol)}{0.08206 \frac{m^3 atm}{Kmol \cdot K} \times (273.2 + 90) K}$
$= 1.15\, kg/m^3$

Q3. (a) Truncated form upto 2nd virial coefficient is given by:

$$\frac{P\hat{V}}{RT} = 1 + \frac{B}{\hat{V}} \quad \text{--- (1)}$$

where B is given by

$$B = \frac{RT_c}{P_c}(B_0 + \omega B_1)$$

Now, $B_0 = 0.083 - \frac{0.422}{T_r^{1.6}}$

$$= 0.083 - \frac{0.422}{\left(\frac{T}{T_c}\right)^{1.6}} = \frac{0.422}{\left(\frac{273.2+35}{305.4}\right)^{1.6}}$$

$$= -0.333$$

& $B_1 = 0.139 - \frac{0.172}{\left(\frac{T}{T_c}\right)^{4.2}} = 0.139 - \frac{0.0172}{\left(\frac{308.2}{305.4}\right)^{4.9}}$

$$= -0.0270$$

$$B = \frac{RT_c}{P_c}(B_0 + \omega B_1)$$

$$= 0.08206 \frac{L.atm}{mol \cdot K} \times \frac{305.4K}{48.2atm} \times (-0.335 + (0.098)(-0.0270))$$

$= 0.5199 \times (-0.3357)$ L/mol

$= -0.1745$ L/mol

from (1) $\longrightarrow$

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$$\frac{P\hat{V}}{RT} = \frac{\hat{V}+B}{\hat{V}}$$

$$\Rightarrow \frac{P\hat{V}^2}{RT} - \hat{V} - B = 0$$

$$\Rightarrow \frac{10\,\text{atm}}{0.08206\,\frac{\text{L atm}}{\text{mol K}} \times 308.2\,\text{K}} \hat{V}^2 - \hat{V} + 0.1745 = 0$$

$$\Rightarrow 0.395\,\hat{V}^2 - \hat{V} + 0.1745 = 0$$

$$\Rightarrow \hat{V} = \frac{1 \pm \sqrt{1-4(0.305)(0.1745)}}{2\times(0.395)} \frac{\text{L}}{\text{mol}}$$

$$= \frac{1 \pm 0.851}{0.790}$$

$$= 2.345\ \text{L/mol or } 0.188\ \text{L/mol}$$

$$\hat{V}_{ideal} = \frac{RT}{P} = \frac{0.08206 \times 308.2}{10.0}$$

$$= 2.53\ \text{L/mol}$$

$\therefore$ 0.188 L/mol is <u>not acceptable</u>

$$\therefore \hat{V} = 2.343\ \text{L/mol}$$

(b) compressibility factor is given by:

$$z = \frac{P\hat{V}}{RT} = \frac{10.0\,\text{atm}}{0.08206\,\frac{\text{L atm}}{\text{mol K}}} \times \frac{2.343\ \text{L/mol}}{308.2\,\text{K}}$$

$$= 0.926$$

(c) mass flow rate = mol flowrate × molecular wt.

$$= \frac{\dot V}{\hat V} \times \frac{30\,g}{mol} \times \frac{1\,kg}{1000\,g} \qquad \left[\hat V = \frac{\dot V}{\dot n} = V/n \right]$$

$$= \frac{1000\,L}{h} \times \frac{mol}{2.343\,L} \times \frac{30\,g}{mol} \times \frac{1\,kg}{1000\,g}$$

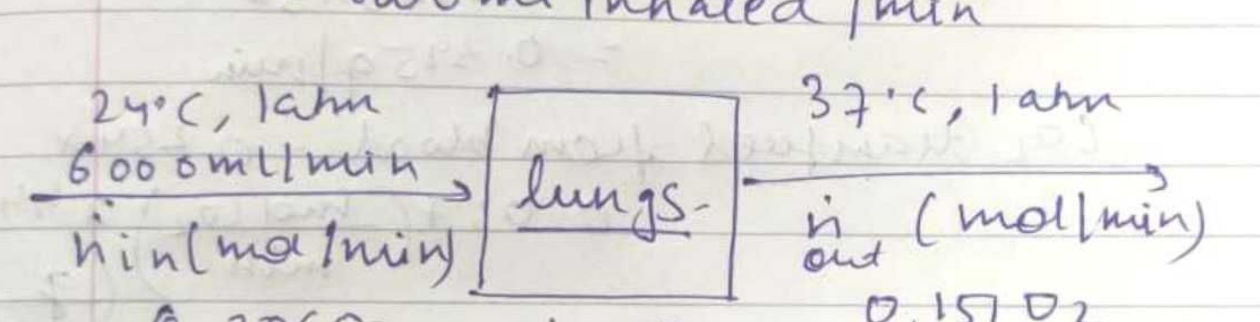
$$= 12.8\,kg/h$$

(mol. wt of C_2H_6 = 30g)

Q4 (a) Basis: 12 breaths/min

(500 ml air inhaled/breath)

= 6000 ml inhaled/min



at STP condns:

$$\dot n_{in} = \frac{6000\,mL}{min} \times \frac{1\,L}{10^3\,mL} \times \frac{273\,K}{297\,K} \times \frac{1\,mol}{22.4\,L}$$

$= 0.246\,mol/min.$

O_2 transferred to blood $= O_2\text{-in} - O_2\text{-out}$

$= [(0.246)(0.206) - (\dot n_{out})(0.151)] \times 32\,g/mol$

Here, $\dot n_{out}$, we can get from N_2 balance:

$(0.774) \times 0.246 = 0.750 \times \dot n_{out}$.

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$\Rightarrow \dot{n}_{out} = \frac{0.774 \times 0.246}{0.750}$

$= 0.254$ mol exhaled / min

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O_2 transferred to blood $= [0.0507 - 0.151 \times 0.254] \times 32$

$= 0.0123 \times 32$

$= 0.395$ g/min

CO_2 transferred from blood $= 0.254 \times 0.037 \left(\frac{mol\, CO_2}{min}\right) \times 44.01 \left(\frac{g}{mol}\right)$

$= 0.414$ g CO_2/min

H_2O transferred from blood $= (H_2O)_{out} - (H_2O)_{in}$

$= [(0.254 \times 0.062) - (0.246 \times 0.020)] \times 18.02$ g/min

$= 0.01083 \times 18.02$

$= 0.195$ g/min

(b) Assume it follows ideal gas eqn, & no pressure change,

$\therefore \frac{PV_{in}}{PV_{out}} = \frac{\dot{n}_{in} RT_{in}}{\dot{n}_{out} RT_{out}}$

[V_{out} = exhaled amount]

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$$\frac{V_{out}}{V_{in}} = \frac{\dot{n}_{out}\, T_{out}}{\dot{n}_{in}\, T_{in}}$$

$$= \frac{0.254 \text{ mol/min}}{0.246 \text{ mol/min}} \times \left(\frac{310\text{K}}{297\text{K}}\right)$$

$$= 1.0325 \times 1.044$$

$$= 1.078 \frac{\text{mL exhaled}}{\text{mL inhaled}}$$

(c) Body loosing weight = loss of CO_2/min + loss of H_2O/min − gain of O_2/min

$$= (0.414 + 0.195 - 0.395) \text{ g/min}$$

$$= 0.215 \text{ g/min.}$$

—x—x—