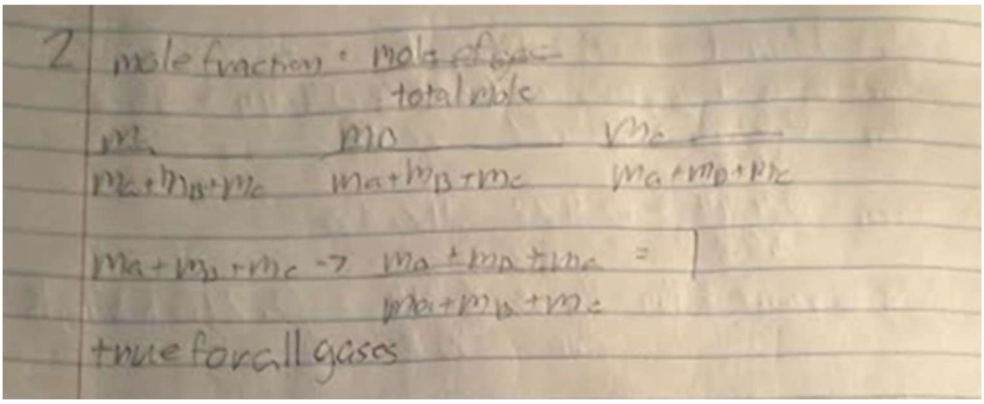
Cameron Sutter and Shawn Newman HW 3.3

13-1) Yes, the mass fraction will be identical because the masses of each gas are identical.

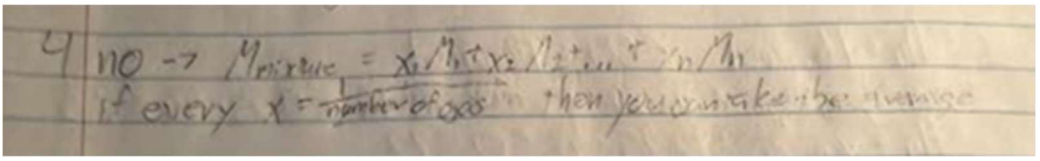
No, the mole fraction will not be identical because the number of moles vary between different gases and depend on their molar mass.



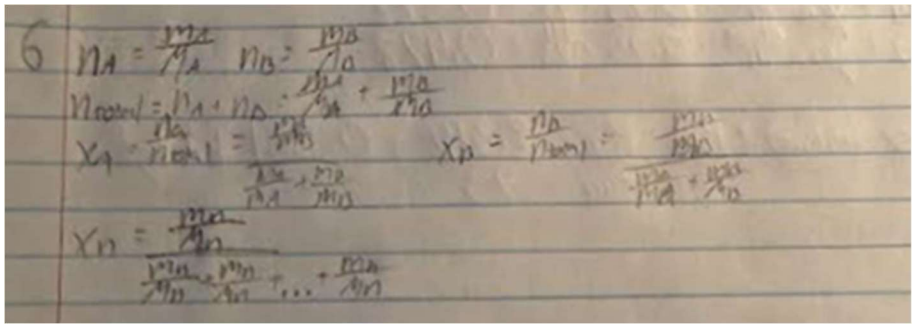

13-3.) $CO_2$: $M = 44.01$ kg/kmol

$N_2O$: $M = 44.01$ kg/kmol

∴ Molar masses (M) are identical, as provided by table A-1. Therefor mole fraction is identical.




13-5.) Apparent molar mass is the average of molar masses in a mixture. It does not represent the mass of each molecule in the mixture since it is an average.


6
$n_A = \frac{m_A}{M_A}$ $n_B = \frac{m_B}{M_B}$
$n_{total} = n_A + n_B = \frac{m_A}{M_A} + \frac{m_B}{M_B}$
$x_A = \frac{n_A}{n_{total}} = \frac{\frac{m_A}{M_A}}{\frac{m_A}{M_A} + \frac{m_B}{M_B}}$
$x_B = \frac{n_B}{n_{total}} = \frac{\frac{m_B}{M_B}}{\frac{m_A}{M_A} + \frac{m_B}{M_B}}$
$x_n = \frac{\frac{m_n}{M_n}}{\frac{m_A}{M_A} + \frac{m_B}{M_B} + \ldots + \frac{m_n}{M_n}}$

13-7.) $y_A = \frac{M_B}{M_A(1/mf_A - 1) + M_B}$ $\quad y_B = 1 - y_A$

Mass fraction: $mf_A = \frac{m_A}{m_A + m_B}$ $\quad mf_B = \frac{m_B}{m_A + m_B}$ $\quad mf_A + mf_B = 1$

Mole fraction: $y_A = \frac{N_A}{N_A + N_B}$ $\quad y_B = \frac{N_B}{N_A + N_B}$ $\quad y_A + y_B = 1$

$m = NM \quad \therefore \quad m_A = N_A M_A \quad m_B = N_B M_B$

Substitute:

$$mf_A = \frac{N_A M_A}{N_A M_A + N_B M_B}$$

$$(N_A M_A + N_B M_B) mf_A = N_A M_A$$

$$N_A M_A = mf_A (N_A M_A + N_B M_B)$$

$$N_A M_A (1 - mf_A) = mf_A N_B M_B$$

$$\frac{N_A}{N_B} = \frac{mf_A M_B}{(1 - mf_A) M_A}$$

Substitute into mole fraction:

$$y_A = \frac{N_A}{N_A + N_B}$$

8 $N_2 = 28$ g/mol $O_2 = 32$ g/mol $H_2O = 18$ g/mol

$M = \sum y_i M_i = 0.78 \cdot 28 + 0.2 \cdot 32 + 0.02 \cdot 18 = 28.6$ kg/kmol

$N_2 = y_{N_2} \frac{M_{N_2}}{M} = 0.78 \cdot \frac{28}{28.6} = 0.76$

$O_2 = y_{O_2} \frac{M_{O_2}}{M} = 0.2 \cdot \frac{32}{28.6} = 0.22$

$H_2O = y_{H_2O} \frac{M_{H_2O}}{M} = 0.02 \cdot \frac{18}{28.6} = 0.013$

13-9.) $N_2$ 60% $CO_2$ 40%

Table A-1: $M_{N_2} = 28.013$ kg/kmol $M_{CO_2} = 44.01$ kg/kmol

$N_{N_2} = 0.60$ $N_{CO_2} = 0.40$

Gravimetric analysis and Molar mass:

~~$M_m = M_{N_2} + M_{CO_2}$~~

~~$= 28.013 + 44.01$~~

~~$M_m = 72.023$ kg/kmol~~

$M_m = M_{N_2} + M_{CO_2}$

$= .6(28.013) + .4(44.01)$

$m_m = 34.4118$

$mf_{N_2} = \frac{.6(28.013)}{34.4118} = .488 = 48.8\%$

$mf_{CO_2} = \frac{.4(44.01)}{34.4118} = .512 = 51.2\%$

Gas Constant: $R_m = \frac{R_u}{M_m} = \frac{8.314}{34.4118} = 0.242$ kJ/kg·K

10 $O_2 = 32$ g/mol $CO_2 = 44$ g/mol

$M_m = y_{O_2} M_{O_2} + y_{CO_2} M_{CO_2} = 0.6 \cdot 32 + 0.4 \cdot 44 = 36.8$

$m_{O_2} = \frac{0.6 \cdot 32}{36.8} = 0.522 = 52.2\%$

$m_{CO_2} = \frac{0.4 \cdot 44}{36.8} = 0.478 = 47.8\%$

gas constant $= R_m = \frac{R_u}{M_m} = \frac{8.314}{36.8} = 0.226$ kJ/kg·K

13-11) 2 kg $O_2$ $M_{O_2} = 31.999$ kg/kmol
5 kg $N_2$ $M_{N_2} = 28.013$ kg/kmol } Table A-1
7 kg $CO_2$ $M_{CO_2} = 44.01$ kg/kmol
$m_m = 2+5+7 = 14$ kg

a) $mf_{O_2} = \frac{m_{O_2}}{m_m} = \frac{2}{14} = 0.143$

$mf_{N_2} = \frac{m_{N_2}}{m_m} = \frac{5}{14} = 0.357$

$mf_{CO_2} = \frac{m_{CO_2}}{m_m} = \frac{7}{14} = 0.5$

b) $O_2 \rightarrow N_{O_2} = \frac{m_{O_2}}{M_{O_2}} = \frac{2}{31.999} = 0.063$

$N_2 \rightarrow N_{N_2} = \frac{m_{N_2}}{M_{N_2}} = \frac{5}{28.013} = 0.238$

$CO_2 \rightarrow N_{CO_2} = \frac{m_{CO_2}}{M_{CO_2}} = \frac{7}{44.01} = 0.159$

$N_m = 0.063 + 0.238 + 0.159 = 0.46$

$y_{O_2} = \frac{N_{O_2}}{N_m} = \frac{0.063}{0.46} = 0.137$

$y_{N_2} = \frac{N_{N_2}}{N_m} = \frac{0.238}{0.46} = 0.517$

$y_{CO_2} = \frac{N_{CO_2}}{N_m} = \frac{0.159}{0.46} = 0.347$

c) $M_m = \frac{m_m}{N_m} = \frac{14}{0.46} = 30.43$ kg/kmol

$R_m = \frac{R_u}{M_m} = \frac{8.314}{30.43} = 0.273$ kJ/kg·K

12 $CH_4 = 16$ g/mol  $CO_2 = 44$ g/mol

$M_m = y_{CH_4} M_{CH_4} + y_{CO_2} + M_{CO_2} = 0.75 \cdot 16 + 0.25 \cdot 44 = 23$

$CH_4 = y_{CH_4} \frac{M_{CH_4}}{M_m} = 0.75 \cdot \frac{16}{23} = 0.522$

$CO_2 = y_{CO_2} \frac{M_{CO_2}}{M_m} = 0.25 \cdot \frac{44}{23} = 0.478$

gas constant $= R_m = \frac{R_u}{M_m} = \frac{8.314}{23} = 0.361$ kJ/kg·K

(3-13.) 6 kmol $H_2$  $H_2 = 2.0$ kg/kmol

2 kmol $N_2$  $N_2 = 28$ kg/kmol

a.) $m_{H_2} = N_{H_2} M_{H_2} = (6)(2) = 12$ kg

$m_{N_2} = N_{N_2} M_{N_2} = (2)(28) = 56$ kg

b.) $m_m = m_{H_2} + m_{N_2} = 12 + 56 = 68$ kg

$N_m = N_{H_2} + N_{N_2} = 6 + 2 = 8$

$M_m = \frac{m_m}{N_m} = \frac{68}{8} = 8.5$ kg/kmol

$R_m = \frac{R_u}{M_m} = \frac{8.314}{8.5} = 0.978$ kJ/kg·K

13-30.) $CO_2$ 20 kPa  Find $y_i$  $R_m$

$O_2$ 30 kPa  $m_{fi}$  $Cv_m$

$N_2$ 50 kPa  $M_m$  $k_m$

a.) $y_i = \frac{P_i}{P_m}$  $P_m = 100$ kPa

$y_{CO_2} = \frac{20}{100} = \boxed{0.2}$  $y_{O_2} = \frac{30}{100} = \boxed{0.3}$  $y_{N_2} = \frac{50}{100} = \boxed{0.50}$

Table A-1: $CO_2 = 44.01$ kg/kmol

$O_2 = 31.999$ kg/kmol

$N_2 = 28.013$ kg/kmol

$m_{CO_2} = y_{CO_2} \times M_{CO_2} = 0.2(44.01) = 8.802$

$m_{O_2} = y_{O_2} \times M_{O_2} = 0.3(31.999) = 9.5997$

$m_{N_2} = y_{N_2} \times M_{N_2} = 0.5(28.013) = 14.0065$

$m_m = 32.4082$ kg/kmol

$mf_{CO_2} = \frac{m_{CO_2}}{m_m} = 0.272$

$mf_{O_2} = \frac{m_{O_2}}{m_m} = 0.296$

$mf_{N_2} = \frac{m_{N_2}}{m_m} = 0.432$

b) $\boxed{M_m = 32.4082 \text{ kg/kmol}}$

$R_m = \frac{R_u}{M_m} = \frac{8.314}{32.4082} = \boxed{0.257 \text{ kJ/kg·k}}$

Used table A-2 for $C_p$, $C_v$ at 300k

$C_{v,m} = \sum mf_i C_{v,i}$

$= (0.272)(0.657) + (0.296)(0.658) + (0.432)(0.743)$

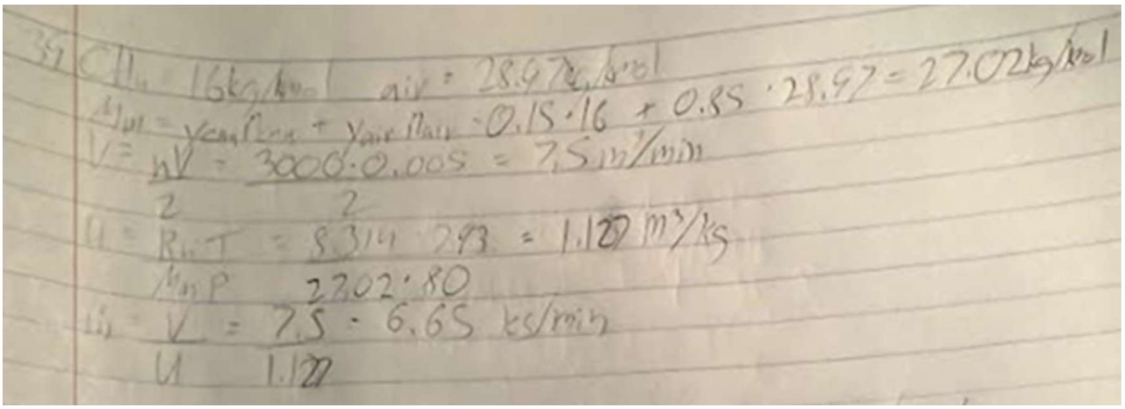
$\boxed{C_{v,m} = 0.6944 \text{ kJ/kg·k}}$

$C_{p,m} = \sum mf_i C_{p,i}$

$= (0.272)(0.846) + (0.296)(0.918) + (0.432)(1.039)$

$= 0.9507$ kJ/kg·k

$k = \frac{C_{p,m}}{C_{v,m}} = \frac{0.9507}{0.6944} = \boxed{1.369}$


$M_{CH_4} = 16\ kg/kmol$ $M_{air} = 28.97\ kg/kmol$
$M_{gas} = y_{CH_4} \cdot M_{CH_4} + y_{air} \cdot M_{air} = 0.15 \cdot 16 + 0.85 \cdot 28.97 = 27.02\ kg/kmol$
$V = \frac{\dot{n}V}{2} = \frac{3000 \cdot 0.005}{2} = 7.5\ m^3/min$
$U = \frac{R_u \cdot T}{M_{gas} \cdot P} = \frac{8.314 \cdot 293}{27.02 \cdot 80} = 1.127\ m^3/kg$
$\dot{m}_g = \frac{V}{U} = \frac{7.5 \cdot 6.65\ kg/min}{1.127}$

13-54.)

| Ne | Ar |
|---|---|
| T=20°C | T=50°C |
| P=100kPa | P=200kPa |

$Q_{out} = 15\ kJ$

$V = 0.9\ m^3$

$M_{Ne} = 20.183\ kg/kmol$

$M_{Ar} = 0.2081\ kg/kmol$

$P_{Ne} V_{Ne} = N_{Ne} R_u T_{Ne}$

$N_{Ne} = \frac{P_{Ne} V_{Ne}}{R_u T_{Ne}} = \frac{(100)(0.45)}{(8.314)(20+273)} = 0.0185\ kmol$

$N_{Ar} = \frac{P_{Ar} V_{Ar}}{R_u T_{Ar}} = \frac{(200)(0.45)}{(8.314)(50+273)} = 0.0335\ kmol$

$N_m = N_{Ar} + N_{Ne} = 0.052\ kmol$

a) $-Q_{out} = \Delta U$ (Used table A-2 for $C_v$) (Assume 300k)

$-15 = (m C_v (T_m - T_1))_{Ne} + (m C_v (T_m - T_2))_{Ar}$

$-15 = (0.373 \cdot 0.6179 (T_m - 20)) + (0.0069 \cdot 0.3122 (T_m - 50))$

$-15 = 0.2305 T_m - 4.6095 + 0.00215 T_m - 0.1077$

$\boxed{T_m = 44.19°C}$

$m_{Ne} = NM = (0.0185)(20.183) = 0.373$

$m_{Ar} = NM = (0.0335)(0.2081) = 0.0069$

b.) $P_m V_m = N_m R_u T_m$

$P_m = \frac{N_m R_u T_m}{V_m} = \frac{(0.052)(8.314)(44.19+273)}{0.9} = \boxed{152.37\ kPa}$

59 $C_1H_4 = 16\ kg/kmol$ $C_3H_8 = 44\ kg/kmol$ $C_4H_{10} = 58\ kg/kmol$

$M_m = y_{CH_4} M_{CH_4} + y_{C_3H_8} M_{C_3H_8} + y_{C_4H_{10}} M_{C_4H_{10}}$

$M_m = 0.6 \cdot 16 + 0.25 \cdot 44 + 0.15 \cdot 58 = 29.3\ g/mol$

$R = \frac{8.315}{29.3} = 0.284\ kJ/kgK$

$W_{in} = RT \ln\left(\frac{P_2}{P_1}\right) = 0.284 \cdot 293 \cdot \ln\left(\frac{1000}{100}\right) = 191.60\ kJ/kg$