ME 322 Worksheet **Winter 2007**

Gas Mixtures

Air is composed of the following mix of gases

Constituent	volume fraction	y_i	mf_i
Nitrogen	0.7808		
Oxygen	0.20946		
Argon	0.00934		
Carbon dioxide	0.000350		
Neon	1.818×10^{-5}		
Helium	5.24×10^{-6}		
Methane	1.70×10^{-6}		
Krypton	1.14×10^{-6}		
Hydrogen	5.5×10^{-7}		

1. What are the mole fractions of the constituents?
   (Fill in column 3 in the preceding table.)
2. What are the mass fractions of the constituents?
   (Fill in column 4 in the preceding table.)
3. Compute the average molar mass and the gas constant for air.

Solution

1. For an ideal gas, the mole fraction is equal to the volume fraction (and the partial pressure)

$$\frac{V_i}{V_m} = \frac{N_i \mathcal{R}_u T_m / p_m}{N_m \mathcal{R}_u T_m / p_m} = \frac{N_i}{N_m} \equiv y_i$$

$$\frac{p_i}{p_m} = \frac{N_i \mathcal{R}_u T_m / V_m}{N_m \mathcal{R}_u T_m / V_m} = \frac{N_i}{N_m} \equiv y_i$$

Therefore, the y_i column in the table is the same as the volume fraction column.

2. If the number of moles of constituent i is known, then the mass of constituent i is

$$m_i = N_i \mathcal{M}_i = y_i N_m \mathcal{M}_i$$

where $\mathcal{M}_i$ is the molar mass of constituent i. Then the mass fraction of constituent i is

$$\mathrm{mf}_i = \frac{m_i}{m_m} = \frac{y_i N_m \mathcal{M}_i}{\sum y_i N_m \mathcal{M}_i} = \frac{y_i \mathcal{M}_i}{\sum y_i \mathcal{M}_i} = \frac{y_i \mathcal{M}_i}{\mathcal{M}_m}$$

where $\mathcal{M}_m = \sum y_i \mathcal{M}_i$ is the molar mass of the mixture.

To calculate the numerical values, the molar mass of each constituent must be known. The table on the following page shows the values of molar mass and mass fraction, mf_i, of each constituent.

3. The molar mass of the mixture is a byproduct of computing mf_i in the preceding step.

$$\mathcal{M}_m = \sum y_i \mathcal{M}_i = 28.965 \text{ kg/kmol}$$

The gas constant of the mixture is

$$R_m = \frac{\mathcal{R}_u}{\mathcal{M}_m} = \frac{8314 \, \frac{\text{J}}{\text{kmol}\cdot\text{K}}}{28.965 \, \frac{\text{kg}}{\text{kmol}}} = 287.034 \frac{\text{J}}{\text{kg} \cdot \text{K}}.$$

The values of $\mathcal{M}_m$ and $\mathcal{R}_m$ do not agree with the published values of $\mathcal{M}_{\text{air}}$ and $\mathcal{R}_{\text{air}}$ because …

Constituent	Volume fraction and y_i	$\mathcal{M}_i$	mf_i
Nitrogen	0.7808	28.013	0.75517043
Oxygen	0.20946	31.999	0.23139864
Argon	0.00934	39.948	0.01288146
Carbon dioxide	0.000350	44.01	0.00053179
Neon	1.818×10^{-5}	20.183	0.00001267
Helium	5.24×10^{-6}	4.003	0.00000072
Methane	1.70×10^{-6}	16.043	0.00000094
Krypton	1.14×10^{-6}	83.80	0.00000330
Hydrogen	5.5×10^{-7}	2.016	0.00000004