Module 5

Properties of Gas Mixtures

Non Reacting Gas Mixtures

Two ways to describe the composition of a mixture:

- *Gravimetric analysis*
- *Molar analysis*

mixture condition	component	mass	mole number
p_{mix}	1	m_1	N_1
	2	m_2	N_2
V_{mix}	3	m_3	N_3
	⋮	⋮	⋮
T_{mix}	i	m_i	N_i

$$m_{mix} = \sum m_i$$

$$N_{mix} = \sum N_i$$

A homogeneous mixture of i number of compoments

$$m_{mix} = \sum_{i=1}^{k} m_i$$

- *Mass of a mixture is equal to the sum of the masses of its components.*

$$N_{mix} = \sum_{i=1}^{k} N_i$$

- *Total number of moles of a mixture is equal to the sum of the number of moles of its components*

Mass fraction (x)

- *Mass fraction of a component in a mixture is ratio of the mass of the component to the mass of the mixture.*

$$x_i = \frac{m_i}{m_{mix}}$$

$$\textbf{Also,} \qquad \sum_{i=1}^{k} x_i = 1$$

Mole fraction (y)

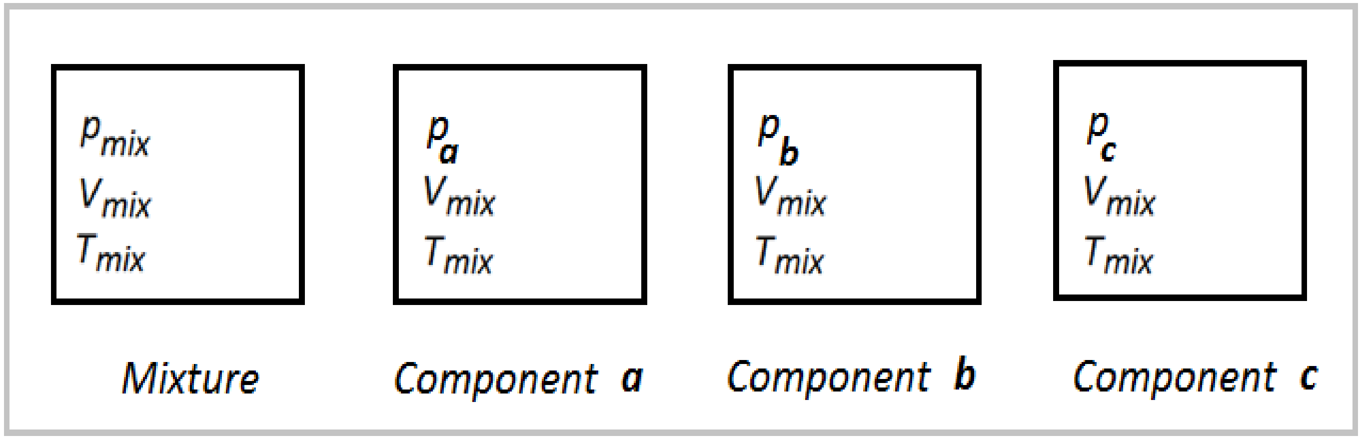
- *Mole fraction of a component in a mixture is ratio of the mole number of the component to the mole number of the mixture.*

$$y_i = \frac{N_i}{N_{mix}}$$

$$\textbf{Also,} \qquad \sum_{i=1}^{k} y_i = 1$$

Partial pressure (p)

- *Partial pressure of any component in a mixture of gases is the pressure exerted by the component if it alone occupies the entire volume of the mixture at the mixture temperature.*



Dalton's law of additive pressures

- *The pressure of a gas mixture of ideal gases is equal to the sum of the pressures each gas would exert if it existed alone at the mixture temperature and mixture volume.*

$$p_{mix} = \sum_{i=1}^{k} p_i \Big]_{T_{mix}, V_{mix},}$$

I.e. Total pressure is the sum of the partial pressures.

Amagat's law of additive volumes

- *The volume of a gas mixture of ideal gases is equal to the sum of the volumes each gas would occupy if it existed alone at the mixture pressure and mixture temperature.*

$$V_{mix} = \sum_{i=1}^{k} V_i \Big]_{p_{mix},T_{mix},}$$

Pressure fraction $\left(P_f\right)$ *and Volume fraction* $\left(V_f\right)$

- *Pressure fraction of a component in a mixture is ratio of the partial pressure of the component to the mixture pressure.*

$$i.e. \quad P_{fi} = \frac{P_i}{P_{mix}}\bigg]_{T_{mix},V_{mix},}$$

- *Volume fraction of a component in a mixture is ratio of the volume of the component to the mixture volume.*

$$i.e. \quad V_{fi} = \frac{V_i}{V_{mix}}\bigg]_{p_{mix},T_{mix},}$$

Ideal gas law

To the component (a)

- $Dalton's model \Rightarrow \quad p_a V_{mix} = m_a R_a T_{mix}$ ①
  $\Rightarrow \quad p_a \, V_{mix} = N_a \bar{R} T_{mix}$

- $Amagat's model \Rightarrow p_{mix} V_a = m_a R_a T_{mix}$ ②
  $\Rightarrow p_{mix} \, V_a = N_a \bar{R} T_{mix}$

To the mixture

- $p_{mix} V_{mix} = m_{mix} R_{mix} T_{mix}$ ③
- $p_{mix} V_{mix} = N_{mix} \bar{R} T_{mix}$

- (1) / (3)
- ⇨ $$\frac{p_a V_{mix}}{p_{mix} V_{mix}} = \frac{N_a \bar{R} T_{mix}}{N_{mix} \bar{R} T_{mix}}$$
- $$\frac{p_a}{p_{mix}} = \frac{N_a}{N_{mix}}$$
- *Generalizing,* $\frac{p_i}{p_{mix}} = \frac{N_i}{N_{mix}}$ $\boxed{i.e.\ P_{fi} = y_i}$
- *Similarly,* $\frac{V_i}{V_{mix}} = \frac{N_i}{N_{mix}}$ $\boxed{i.e.\ V_{fi} = y_i}$

$$\boxed{P_{fi} = V_{fi} = y_i}$$

Gibbs- Dalton law:

- *The Internal energy, Enthalpy and entropy of mixture of gases are respectively equal to the sum of the individual Internal energies, Enthalpies and Entropies, if each component occupied the volume of the mixture at the temperature of the mixture*

Molecular weight of the mixture (M_{mix})

- $m_{mix} = m_a + m_b + m_c$
- $N_{mix}M_{mix} = N_aM_a + N_bM_b + N_cM_c$
- $\therefore M_{mix} = \left(\frac{N_a}{N_{mix}}\right)M_a + \left(\frac{N_b}{N_{mix}}\right)M_b + \left(\frac{N_c}{N_{mix}}\right)M_c$

By defenition, $y_i = \frac{N_i}{N_{mix}}$

$$M_{mix} = (y_a)M_a + (y_b)M_b + (y_c)M_c$$

$$Hence, \quad M_{mix} = \sum y_i M_i$$

The molecular weight of the mixture equals the sum of the products of the mole fraction and the molecular weight of each component.

- $p_a V_{mix} = m_a R_a T_{mix}$
- $p_b V_{mix} = m_b R_b T_{mix}$
- $p_c V_{mix} = m_c R_c T_{mix}$

$$[p_a + p_b + p_c]V_{mix} = [m_a R_a + m_b R_b + m_c R_c]T_{mix}$$

- $i.e., \; p_{mix} V_{mix} = [m_a R_a + m_b R_b + m_c R_c]T_{mix}$
- $But, \; p_{mix} V_{mix} = m_{mix} R_{mix} T_{mix}$

- $R_{mix} = \left[\frac{(m_a R_a + m_b R_b + m_c R_c)}{m_{mix}}\right]$
- $\frac{\bar{R}}{M_{mix}} = x_a \frac{\bar{R}}{M_a} + x_b \frac{\bar{R}}{M_b} + x_c \frac{\bar{R}}{M_c}$
- $M_{mix} = \frac{1}{\left[\frac{x_a}{M_a} + \frac{x_b}{M_b} + \frac{x_c}{M_c}\right]}$

$$\boxed{M_{mix} = \frac{1}{\sum\left(\frac{x_i}{M_i}\right)}}$$

Gas constant of the mixture (R_{mix})

- $p_{mix} = \quad p_a + p_b + p_c$
- $p_{mix} = \frac{m_a R_a T_{mix}}{V_{mix}} + \frac{m_b R_b T_{mix}}{V_{mix}} + \frac{m_c R_c T_{mix}}{V_{mix}}$
- $p_{mix} = \frac{m_{mix} R_{mix} T_{mix}}{V_{mix}}$
- $R_{mix} = \frac{m_a}{m_{mix}} R_a + \frac{m_b}{m_{mix}} R_b + \frac{m_c}{m_{mix}} R_c$
- $R_{mix} = x_a R_a + x_b R_b + x_c R_c$

$$\boxed{R_{mix} = \sum x_i R_i}$$