Mass and mole fraction of gas mixture

If we want to deal with the problems of gas mixture, two laws should always be taken into consideration. One is the conservation of mass. And the other is the conservation of moles for a nonreacting mixture.

Assuming that a gas mixture consists of l components, according to the conservation of mass, we have:

\[ m_M = \sum_{i=1}^{l} m_i \]

according to the conservation of moles for a nonreacting mixture, we have:

\[ n_M = \sum_{i=1}^{l} n_i \]

(this equation is only available for a nonreacting mixture!)

The subscript "i" denotes the components; the subscript "M" denotes the mixture. The number of components is "l".

For example, we have two containers. One is filled with H\(_2\) of \(m_{H_2}=15\text{kg}\). The other is filled with He of \(m_{He}=30\text{kg}\). If we mix both gases in a third container, then the mass of gas mixture in this third container is \(m_M=m_{H_2}+m_{He} (= 45\text{kg} \text{ in this case})\).

Similarly, we have 1mol H\(_2\) and 2 mol He. Then the number of moles is the sum of the number of moles of its components. In this case we obtain a gas mixture of \(n_M=3\) mol.

In addition, we have mass fraction \(\xi\) and mole fraction \(\gamma\):

\[ \xi_i = \frac{m_i}{m_M} \]
\[ \gamma_i = \frac{n_i}{n_M} \]

And it is obvious that the sum of mass fraction and of mole fraction equals to unity:

\[ \Sigma \xi_i = 1 \]
\[ \Sigma \gamma_i = 1 \]

Since we now obtain these both fractions, we can calculate the following two useful values:

1) Average molar mass:

\[ M_M = \frac{m_M}{n_M} = \frac{\sum (n_i \cdot M_i)}{n_M} = \sum \left( \frac{n_i}{n_M} \cdot M_i \right) = \sum \gamma_i \cdot M_i \]

or:
\[ M_M = \frac{m_M}{n_M} = \frac{m_M}{\sum \left( \frac{m_i}{M_i} \right)} = \frac{1}{\sum \left( \frac{m_i}{m_M} \right) \cdot \frac{1}{M_i} \cdot \xi_i \cdot \frac{1}{M_i}} \]

2) Average gas constant of the mixture:

\[ R_M = \frac{R_u}{M_M} \]

where \( R_u \) is universal gas constant = 8,314 J/(mol·K)