

Chapter 12 SUMMARY

- A mixture of two or more gases of fixed chemical composition is called a *nonreacting gas mixture*. The composition of a gas mixture is described by specifying either the *mole fraction* or the *mass fraction* of each component, defined as

$$mf_i = \frac{m_i}{m_m} \quad \text{and} \quad y_i = \frac{N_i}{N_m}$$

where

$$m_m = \sum_{i=1}^k m_i \quad \text{and} \quad N_m = \sum_{i=1}^k N_i$$

- The *apparent* (or average) *molar mass* and *gas constant* of a mixture are expressed as

$$M_m = \frac{m_m}{N_m} = \sum_{i=1}^k y_i M_i \quad (\text{kg/kmol})$$

and

$$R_m = \frac{R_u}{M_m} \quad [\text{kJ}/(\text{kg} \cdot \text{K})]$$

- *Dalton's law of additive pressures* states that the pressure of a gas mixture is equal to the sum of the pressures each gas would exert if it existed alone at the mixture temperature and volume.
- *Amagat's law of additive volumes* states that the volume of a gas mixture is equal to the sum of the volumes each gas would occupy if it existed alone at the mixture temperature and pressure.
- Dalton's and Amagat's laws hold exactly for ideal-gas mixtures, but only approximately for real-gas mixtures. They can be expressed as

Dalton's law:
$$P_m = \sum_{i=1}^k P_i(T_m, V_m)$$

Amagat's law:
$$V_m = \sum_{i=1}^k V_i(T_m, V_m)$$

- Here P_i is called the component pressure and V_i is called the component volume. Also, the ratio P_i/P_m is called the *pressure fraction* and the ratio V_i/V_m is called the *volume fraction* of component i . For ideal gases, P_i and V_i can be related to y_i by

$$\frac{P_i}{P_m} = \frac{V_i}{V_m} = \frac{N_i}{N_m} = y_i$$

- The quantity $y_i P_m$ is called the *partial pressure* and the quantity $y_i V_m$ is called the *partial volume*.
- The P - v - T behavior of real-gas mixtures can be predicted by using generalized compressibility charts. The compressibility factor of the mixture can be expressed in terms of the compressibility factors of the individual gases as

$$Z_m = \sum_{i=1}^k y_i Z_i$$

where Z is determined either at T_m and V_m (Dalton's law) or at T_m and P_m (Amagat's law) for each individual gas.

- The P - v - T behavior of a gas mixture can also be predicted approximately by *Kay's rule*, which involves treating a gas mixture as a pure substance with pseudocritical properties determined from

$$P'_{cr,m} = \sum_{i=1}^k y_i P_{cr,i} \quad \text{and} \quad T'_{cr,m} = \sum_{i=1}^k y_i T_{cr,i}$$

- The *extensive properties* of a gas mixture, in general, can be determined by summing the contributions of each component of the mixture. The evaluation of *intensive properties* of a gas mixture, however, involves averaging in terms of mass or mole fractions:

$$U_m = \sum_{i=1}^k U_i = \sum_{i=1}^k m_i u_i = \sum_{i=1}^k N_i \bar{u}_i \quad (\text{kJ})$$

$$H_m = \sum_{i=1}^k H_i = \sum_{i=1}^k m_i h_i = \sum_{i=1}^k N_i \bar{h}_i \quad (\text{kJ})$$

$$S_m = \sum_{i=1}^k S_i = \sum_{i=1}^k m_i s_i = \sum_{i=1}^k N_i \bar{s}_i \quad (\text{kJ} / \text{K})$$

and

$$u_m = \sum_{i=1}^k mf_i u_i \quad \text{and} \quad \bar{u}_m = \sum_{i=1}^k y_i \bar{u}_i \quad (\text{kJ / kg or kJ / kmol})$$

$$h_m = \sum_{i=1}^k mf_i h_i \quad \text{and} \quad \bar{h}_m = \sum_{i=1}^k y_i \bar{h}_i \quad (\text{kJ / kg or kJ / kmol})$$

$$s_m = \sum_{i=1}^k mf_i s_i \quad \text{and} \quad \bar{s}_m = \sum_{i=1}^k y_i \bar{s}_i \quad [\text{kJ / (kg} \cdot \text{K) or kJ / (kmol} \cdot \text{K)}]$$

$$C_{v,m} = \sum_{i=1}^k mf_i C_{v,i} \quad \text{and} \quad \bar{C}_{v,m} = \sum_{i=1}^k y_i C_{v,i}$$

$$C_{p,m} = \sum_{i=1}^k mf_i C_{p,i} \quad \text{and} \quad \bar{C}_{p,m} = \sum_{i=1}^k y_i C_{p,i}$$

- These relations are applicable to both ideal-and real-gas mixtures. The properties or property changes of individual components can be determined by using ideal-gas or real-gas relations developed in earlier chapters.