Chapter - IV

4.1. *What is equation of state of a gas.*

$P\bar{v} = \bar{R}T$

where $\bar{v}$ = molar volume

$\bar{R}$ = universal gas constant

= 8.3143 KJ/kg mol K

4.2 *What is equation of state? Write the same for an ideal gas.*

The equation which relates the properties P, v, T is known as an Equation of state.

(ie) $f(P, v, T) = 0$

The simplest form of equation of state for the ideal gas is given below.

Equation of state: $P\bar{v} = \bar{R}T$

where $\bar{R}$ = universal gas constant in kJ/kgmole.K

$\bar{v}$ = molar volume in m^3/kg mol

Also: $Pv = RT$

where R = Characteristic gas constant in kJ/kgk

v = Specific volume in m^3/kg

The above equation - Equation of state is also called as characteristic gas equation.

4.3. *Have you ever encountered any ideal gas? If so, where,*

Ideal gas do not have intermolecular attractive forces. These ideal gases obey the equation of state at all ranges of pressure and temperature.

Practically, no ideal gas exists in nature. However, hydrogen, oxygen, nitrogen and air behave as an ideal gas under normal condition.

4.4 *Write the Maxwell's equations and also give the basic relations from which these are derived.*

The Maxwell's equations are

(i) $\left(\frac{\partial T}{\partial v}\right)_S = -\left(\frac{\partial P}{\partial S}\right)_v$

(ii) $\left(\frac{\partial T}{\partial P}\right)_S = \left(\frac{\partial v}{\partial S}\right)_P$

(iii) $\left(\frac{\partial P}{\partial T}\right)_v = \left(\frac{\partial S}{\partial v}\right)_T$

(iv) $\left(\frac{\partial v}{\partial T}\right)_P = -\left(\frac{\partial S}{\partial P}\right)_T$

The basic relations from which Maxwell's equations are derived are

(i) $du = Tds - Pdv$

(ii) $dh = Tds + vdp$

(iii) $a = u - Ts$

(iv) $g = h - Ts$

4.5. *What is characteristic gas constant?*

$$R = \frac{\overline{R}}{\mu}$$

Example: $R_{O2} = \frac{\overline{R}}{\mu_{O2}} = \frac{8.3143}{32} = 0.262$ KJ/kg K

4.6 *Explain the following term: (a) Mole fraction, (b)Mass fraction.*

Mole Fraction (Y)

This is the ratio of the mole number of a component N_i to the mole number of the mixture N_m

$$Y_i = \frac{N_i}{N_m}$$

Mass Fraction (m_f)

It is the ratio of the mass of a component m_i to the mass of mixture M_m

$$m_{f_i} = \frac{m_i}{M_m}$$

4.7 *What is coefficient of expansion?*

It is denoted by "β". It is defined as the change in volume with change in temperature per unit volume keeping the pressure constant.

Mathematically

$$\beta = \frac{1}{v}\left(\frac{\partial v}{\partial T}\right)_p$$

4.8 *What is the significance of compressibility factor?*

The ideal gas equation is very simple and thus very convenient to use. But gases deviate from ideal gas behaviour significantly at states near the saturation region and the critical point. This deviation from ideal gas behaviour at a given temperature and pressure can accurately be accounted for by the introduction of a correction factor called the compressibility factor z defined as

$$z = \frac{Pv}{RT}$$

(or)

$$Pv = zRT$$

It can also be expressed as

$$z = \frac{V_{actual}}{V_{ideal}}$$

where $V_{ideal} = \frac{RT}{P}$ obviously, $z = 1$ for ideal gasses. For real gases z can be greater than or less than unity. The farther away z is from unity, the more the gas deviates from ideal gas behaviour.

4.9. *Helmholtz function is expressed as* ________

Ans: $(u - Ts)$

4.10 *Gibbs function is expressed as* ________

Ans: $(U + PV + Ts)$

4.11. *Availability function is expressed as* ________

Ans: $(\phi = U + P \cdot V - TS)$

4.12. *Tds equation taking temperature (T) and Volume (v) as independent variables is* ________

Ans: $\left(m\, C_v\, dT + T\frac{\beta}{K}\, dv\right)$

4.13 *Write the Berthelot equation for real gas.*

$$P = \frac{RT}{v - b} - \frac{a}{Tv^2}$$

4.14. Write Dieterici equation for real gas.

$$P = \frac{RT}{v - b} \cdot e^{(-a/RTv)}$$

4.15. Write Redlich-Kwong equation.

$$P = \frac{RT}{v - b} - \frac{a}{T^{1/2}\, v\,(v + b)}$$

4.16 Write the Van der Walls equation for real gas.

$$\left(P + \frac{a}{v^2}\right)(v - b) = RT$$

4.17. The specific heat at constant pressure is given by ______

Ans: $\left(C_p = T\left(\frac{\partial s}{\partial T}\right)_p\right)$

4.18. Specific heat relation is ______.

Ans: $C_p - C_v = R$