VIRAL EQN

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

$$= \frac{RT}{V_m}\left[\frac{1}{1 - b/V_m}\right] - \frac{a}{V_m^2}$$

$$= \frac{RT}{V_m} \sum_{m=0}^{\infty} \left(\frac{b}{V_m}\right)^n - \frac{a}{V_m^2}$$

$$= \frac{RT}{V_m}\left[1 + \frac{b^2}{V_m} + O\left(\frac{1}{V_m^2}\right)\right] - \frac{a}{V_m^2}$$

$$= RT\left[\frac{1}{V_m} + \left(b - \frac{a}{RT}\right)\frac{1}{V_m^2} + O\left(\frac{1}{V_m^3}\right]\right.$$

$$B(T) = b - \frac{a}{RT}$$

COMPRESSION FACTOR

$$Z \equiv \frac{pV_m}{RT}$$

$$p = \frac{RT}{V_m - b} - \frac{a}{V_m^2}$$

$$pV_m = \frac{RTV_m}{V_m - b} - \frac{a}{V_m}$$

$$\boxed{Z = \frac{V_m}{V_m - b} - \frac{a}{RTV_m}}$$

Ideal Gas $\quad Z = 1$

NOW WE USE THE REDUCED VARIABLES

$$p = p_c p_r \qquad V_m = V_c V_r$$

$$T = T_c T_r$$

$$Z = \frac{P_c P_r V_c V_r}{R T_c T_r} = \underbrace{\left(\frac{P_c V_c}{R T_c}\right)}_{\frac{3}{8} \text{ FOR Van der Waals}} \frac{P_r V_r}{T_r}$$

$$Z = \frac{3}{8} Z_r \Rightarrow \frac{8}{3} Z = Z_r$$

$$Z = \frac{V_c V_r}{V_c V_r - b} - \frac{a}{R T_c V_c} \frac{1}{T_r V_r}$$

$$b = \frac{V_c}{3}$$

$$a = \frac{9}{8} R T_c V_c$$

$$Z = \frac{3 V_r}{3 V_r - 1} - \frac{9}{8} \frac{1}{T_r V_r}$$

$$\boxed{Z_r = \frac{8 V_r}{3 V_r - 1} - \frac{3}{T_r V_r}}$$

CHEMICAL POTENTIAL IDEAL GAS

$$\mu(T,P) = \mu^{\circ}(T,P^{\circ}) + RT\ln\left(\frac{P}{P^{\circ}}\right)$$

REAL GAS

$$\mu(T,P) \equiv \mu^{\circ}(T,f^{\circ}) + RT\ln\left(\frac{f}{f^{\circ}}\right)$$

$f \equiv$ FUGACITY

FOR ANY GAS

$$dG_m = V_m\, dP$$

$$\Downarrow$$

$$d\mu = V_m\, dP$$

$$d\mu^{Ideal} = V_m^{Ideal}\, dP$$

$$d\mu - d\mu^{Ideal} = (V_m - V_m^{Ideal})\,dP'$$

$$\int_{P_f}^{P} (d\mu - d\mu^{Ideal}) = \int_{P_f}^{P} (V_m - V_m^{Ideal})\,dP'$$

$$\boxed{\begin{aligned} &\mu(T,P) - \mu(T,P_f) - (\mu^{Ideal}(T,P) - \mu^{Ideal}(T,P_f)) \\ &= \int_{P_f}^{P} \left[V_m - \frac{RT}{P'}\right] dP' \end{aligned}}$$

IF $P_f \rightarrow 0 \Rightarrow \mu(T,P_f) \rightarrow \mu^{Ideal}(T,P_f)$

OR $\frac{f}{f^0} \rightarrow \frac{P}{P^0}$

$$f^0 = P^0$$

$$\mu(T,P) - \mu^{\text{Ideal}}(T,P) = \int_0^P \left[V_m - \frac{RT}{P'}\right] dP'$$

SAME REFERENCE CHEMICAL POTENTIAL

$$\ln\left(\frac{f}{p^\circ}\right) - \ln\left(\frac{p}{p^\circ}\right) = \int_0^p \frac{\left[\frac{p' V_m}{RT} - 1\right]}{p'} dp'$$

$$\boxed{f = p\, e^{\int_0^p \frac{Z(p') - 1}{p'} dp'}}$$

$$f = p\,\gamma(p)$$

$$\boxed{\mu(T,P) = \mu^0(T,P^0) + RT \ln(P\gamma(P))}$$

$$\boxed{\gamma(p) = e^{\int_0^p \frac{Z(p')-1}{p'} dp'}}$$

FUGACITY COEFFICIENT

$$\frac{f}{f^0} = \frac{\gamma(p)\, p}{p^0}$$

$$\lim_{p \to 0} \gamma(p) = 1$$

$$\lim_{p \to 0} \frac{f}{f^0} = \frac{p}{p^0}$$

EQUILIBRIUM CONSTANT

$$K_f = K_\gamma K_p$$

$$\ln K_p \quad \frac{P_i}{P^0} \longrightarrow \frac{f_i}{f^0} = \frac{\gamma_i P_i}{P^0} \rightarrow K_f$$