$\Delta E = E_2 - E_1 = h\nu$ $\hbar = \frac{h}{2\pi}$ $\nu = \frac{c}{\lambda} = c\tilde{\nu}$

$\tilde{\nu} = \frac{1}{\lambda}$ $E_v = \left(v + \frac{1}{2}\right) h\nu_0 = \left(v + \frac{1}{2}\right) hc\tilde{\nu}_0$ $\tilde{\nu}_0 = \frac{1}{2\pi c}\sqrt{\frac{k}{\mu}}$

$\mu = \frac{m_1 m_2}{m_1 + m_2}$ $E_J = hB[J(J+1)] = hc\tilde{B}[J(J+1)]$ $\tilde{B} = \frac{h}{8\pi^2 cI}$

$I = \mu r^2$ $\tilde{B}_v = \tilde{B}_e - \tilde{\alpha}_e\left(v + \frac{1}{2}\right)$ $F(J) = \tilde{B}_v[J(J+1)] - \tilde{D}J^2(J+1)^2$

$\tilde{\nu} = G(v) - G(0) = v\tilde{\nu}_e - \tilde{x}_e\tilde{\nu}_e v(v+1)$ $G(v) = \left(v + \frac{1}{2}\right)\tilde{\nu}_e - (v + \frac{1}{2})^2\tilde{x}_e\tilde{\nu}_e$

$\tilde{D}_0 = \tilde{D}_e - \frac{\tilde{\nu}_e}{2} + \frac{\tilde{\nu}_e\tilde{x}_e}{4}$

$\hat{H}\psi = E\psi$ $P_{12} \propto |<\mu_{12}>|^2\delta(E_2 - E_1 - h\nu)$

$<\mu_{12}> = \int_\tau \psi_2^* \hat{H}_1 \psi_1 d\tau$ $\hat{H}_{NZ} = \frac{-g_N\beta_N B_0(1-\sigma)}{\hbar}\hat{I}_z$

$\hat{I}_x\alpha = \frac{\hbar}{2}\beta$ $\hat{I}_y\alpha = \frac{i\hbar}{2}\beta$ $\hat{I}_z\alpha = \frac{\hbar}{2}\alpha$

$\hat{I}_x\beta = \frac{\hbar}{2}\alpha$ $\hat{I}_y\beta = \frac{-i\hbar}{2}\alpha$ $\hat{I}_z\beta = \frac{-\hbar}{2}\beta$

$\Delta E = h\nu = g_N\beta_N B_0(1-\sigma)$ $\hat{H}_1 = \frac{-g_N\beta_N B_1}{\hbar}\hat{I}_x$ $\delta_1 - \delta_2 = \frac{\nu_1 - \nu_2}{\nu_{spec}} * 10^6 ppm$

$PV = nRT$ $\bar{V} = \frac{V}{n}$ $P\bar{V} = RT$

$Z = \frac{P\bar{V}}{RT}$ $P = \rho g h$ $P_A = X_A P_T$

$X_A = \frac{n_A}{n_{total}}$ $\sum_{i=1}^{\#comp} X_i = 1$ $\rho = \frac{PM}{RT}$

$P = \frac{RT}{(\bar{V}-b)} - \frac{a}{\bar{V}^2}$ $\left(\frac{\partial P}{\partial \bar{V}}\right)_{T=T_c} = 0$ $\left(\frac{\partial^2 P}{\partial \bar{V}^2}\right)_{T=T_c} = 0$

$Z = 1 + B_{2P} * P + B_{3P} * P^2 + \cdots$ $Z = 1 + B_{2V} * \frac{1}{\bar{V}} + B_{3V} * \frac{1}{\bar{V}^2} + \cdots$

$B_{2V} = \lim_{\frac{1}{\bar{V}}\to 0}\left(\frac{\partial Z}{\partial\left(\frac{1}{\bar{V}}\right)}\right)_T$ $P_j(N,V,T) = \frac{e^{-\beta E_j(N,V)}}{Q(N,V,T)}$ $Q(N,V,T) = \sum_{j=1}^{n} e^{-\beta E_j(N,V)}$

$\beta = \frac{1}{k_B T}$ $<E> = U = -\left(\frac{\partial lnQ}{\partial\beta}\right)_{N,V} = k_B T^2\left(\frac{\partial lnQ}{\partial T}\right)_{N,V}$

$C_V = \left(\frac{\partial <E>}{\partial T}\right)_{N,V} = \left(\frac{\partial U}{\partial T}\right)_{N,V}$ $<P> = k_B T\left(\frac{\partial lnQ}{\partial V}\right)_{N,T}$ $R = k_B N_A$

$Q = q^N$ $Q = \frac{q^N}{N!}$ $q = \sum_{i=E\ levels} g_i e^{-\beta E_i}$

$Q = \frac{(q_{elec} q_{trans} q_{vib} q_{rot})^N}{N!}$ $q_{elec} \cong g_1 e^{-\beta E_i}$

$q_{trans} = \left(\frac{2\pi m k_B T}{h^2}\right)^{3/2} * V = \left(\frac{2\pi m}{\beta h^2}\right)^{3/2} * V$ $q_{rot} = \frac{T}{\sigma \Theta_{\mathrm{rot}}}, \quad \Theta_{\mathrm{rot}} = \frac{h^2}{8\pi^2 I k_B} = \frac{hB}{k_B}$

$q_{vib} = \frac{e^{-\Theta_{\mathrm{vib}}/2\mathrm{T}}}{1 - e^{-\Theta_{\mathrm{vib}}/\mathrm{T}}}, \quad \Theta_{\mathrm{vib}} = \frac{h v_0}{k_B}$

$w = -\int_{V_1}^{V_2} P_{ext} dV + w'$ $w = -nRT ln \frac{V_2}{V_1}$ $dU = \delta q + \delta w$

$H = U + PV$ $dU = TdS - pdV$

$A = U - TS$ $dH = TdS + VdP$

$G = H - TS$ $dA = -SdT - pdV$

$dS = \frac{\delta q_{rev}}{T}$ $dG = -SdT + VdP$

$\left(\frac{\partial P}{\partial S}\right)_V = -\left(\frac{\partial T}{\partial V}\right)_S$ $\left(\frac{\partial V}{\partial S}\right)_P = \left(\frac{\partial T}{\partial P}\right)_S$ $\left(\frac{\partial S}{\partial V}\right)_T = \left(\frac{\partial P}{\partial T}\right)_V$

$\left(\frac{\partial S}{\partial P}\right)_T = -\left(\frac{\partial V}{\partial T}\right)_P$ $\Delta Y = \int_{T_1 V_1}^{T_2 V_2} \left(\frac{\partial Y}{\partial T}\right)_V dT + \left(\frac{\partial Y}{\partial V}\right)_T dV$

$\Delta Y = \int_{T_1 P_1}^{T_2 P_2} \left(\frac{\partial Y}{\partial T}\right)_P dT + \left(\frac{\partial Y}{\partial P}\right)_T dP$ $C_V = \left(\frac{\partial U}{\partial T}\right)_V$ $C_P = \left(\frac{\partial H}{\partial T}\right)_P$

$\frac{C_V}{T} = \left(\frac{\partial S}{\partial T}\right)_V$ $\frac{C_P}{T} = \left(\frac{\partial S}{\partial T}\right)_P$ $V = V_0 e^{\alpha T - \kappa P}$

$\alpha = \frac{1}{V}\left(\frac{\partial V}{\partial T}\right)_P$ $\kappa = -\frac{1}{V}\left(\frac{\partial V}{\partial P}\right)_T$ $\left(\frac{\partial z}{\partial x}\right)_y = -\left(\frac{\partial z}{\partial y}\right)_x \left(\frac{\partial y}{\partial x}\right)_z$

$\left(\frac{\partial z}{\partial x}\right)_y = \frac{1}{\left(\frac{\partial x}{\partial z}\right)_y}$ $1 = -\left(\frac{\partial z}{\partial y}\right)_x \left(\frac{\partial y}{\partial x}\right)_z \left(\frac{\partial x}{\partial z}\right)_y$ $\left(\frac{\partial f}{\partial x}\right)_y = \left(\frac{\partial f}{\partial z}\right)_y \left(\frac{\partial z}{\partial x}\right)_y$

$T_f = T_i + \mu_{JT}(P_f - P_i)$ $\mu_{JT} = \frac{T\left(\frac{\partial V}{\partial T}\right)_P - V}{C_p}$ $Max\ eff = \frac{-w}{q} = 1 - \frac{T_C}{T_H}$

$C.O.P = \frac{q_c}{w} = \frac{T_C}{T_H - T_C}$ $C_p - C_V = T\left(\frac{\partial P}{\partial T}\right)_V \left(\frac{\partial V}{\partial T}\right)_P$

$\Delta_{\mathrm{r}} \bar{H}_T^0 = \sum_{prod} v_p \Delta_{\mathrm{f}} \bar{\mathrm{H}}_{\mathrm{T}}^0(\mathrm{prod}) - \sum_{reac} v_r \Delta_{\mathrm{f}} \bar{\mathrm{H}}_{\mathrm{T}}^0(\mathrm{reac})$

$\Delta_{\mathrm{r}} \bar{S}_T^0 = \sum_{prod} v_p \bar{\mathrm{S}}_{\mathrm{T}}^0(\mathrm{prod}) - \sum_{reac} v_r \bar{\mathrm{S}}_{\mathrm{T}}^0(\mathrm{reac})$

$\Delta_{\mathrm{r}} \bar{G}_T^0 = \Delta_{\mathrm{r}} \bar{H}_T^0 - T\Delta_{\mathrm{r}} \bar{S}_T^0$ $\Delta_{\mathrm{r}} \bar{G}_{298}^0 = \sum_{prod} v_p \Delta_{\mathrm{f}} \bar{\mathrm{G}}_{298}^0(\mathrm{prod}) - \sum_{reac} v_r \Delta_{\mathrm{f}} \bar{\mathrm{G}}_{298}^0(\mathrm{reac})$

$\Delta_{\mathrm{r}} \bar{H}_T^0 = \Delta_{\mathrm{r}} \bar{H}_{298}^0 + \int_{298}^{T} \Delta_{\mathrm{r}} \bar{C}_p^0 dT$ $\Delta_{\mathrm{r}} \bar{C}_p^0 = \sum_{prod} v_p \bar{\mathrm{C}}_{\mathrm{p}}^0(\mathrm{prod}) - \sum_{reac} v_r \bar{\mathrm{C}}_{\mathrm{p}}^0(\mathrm{reac})$

$$\Delta_r\bar{S}_T^0 = \Delta_r\bar{S}_{298}^0 + \int_{298}^{T}\frac{\Delta_r\bar{C}_P^0}{T}dT$$

$$\mu_i = \left(\frac{\partial G}{\partial n_i}\right)_{T,P,n_j}$$

$$\frac{dP}{dT} = \frac{\Delta_{trans}\bar{S}}{\Delta_{trans}\bar{V}} = \frac{\Delta_{trans}\bar{H}}{T\Delta_{trans}\bar{V}}$$

$$ln\left(\frac{P_2}{P_1}\right) = \frac{\Delta_{vap}\bar{H}}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

$$ln\left(\frac{P_2}{P_1}\right) = \frac{\Delta_{sub}\bar{H}}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

$$P_2 - P_1 = \frac{\Delta_{fus}\bar{H}}{\Delta_{fus}\bar{V}}ln\left(\frac{T_2}{T_1}\right)$$

$$J = \sum_{i=components} n_i\bar{J}_i$$

$$\bar{J}_i = \left(\frac{\partial J}{\partial n_i}\right)_{T,P,n_j}$$

$$0 = \sum_{i=comp} n_i d\,\bar{J}_i$$

$$\mu_i = \mu_T^*(i) + RTln\,a_i$$

$$a_i = \frac{P_i}{1\,bar} = \frac{P_i}{P_i^*} = \gamma_i X_i = \gamma_{i,m}m = \gamma_{i,c}[c]$$

$$P = X_A P_A^* + X_B P_B^*$$

$$Y_i = \frac{P_i}{P}$$

$$P_i = k_{H,i}X_i$$

$$dG = -SdT + VdP + \sum_{i=comp}\mu_i dn_i$$

$$n_i = n_i^o \pm \xi$$

$$\left(\frac{dG}{d\xi}\right)_{T,P} = \Delta_r\bar{G}_T^o + RT\ln Q$$

$$Q = \frac{a_C^{\nu_C}a_D^{\nu_D}}{a_A^{\nu_A}a_B^{\nu_B}}$$

$$\Delta_r\bar{G}_T^o = -RT\ln K$$

$$\ln\left(\frac{K_2}{K_1}\right) = \frac{\Delta_r\bar{H}_T^o}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

$$\left(\frac{dG}{d\xi}\right)_{T,P} = RT\ln\frac{Q}{K}$$

$$m = \frac{X_2 * 1000\,g/kg}{M_1}$$

$$\mu_i = \mu_T^*(i) + \int_{P^*}^{P}\bar{V}_i dP$$

$$a_i = \frac{\gamma_i P_i}{P_i^*}$$

$$K = K_\gamma K_P$$