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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$Q = \frac{(q_{elec} q_{trans} q_{vib} q_{rot})^N}{N!}$$

$$q_{elec} \cong g_1 e^{-\beta E_i}$$

$$q_{trans} = \left(\frac{2\pi m k_B T}{h^2}\right)^{3/2} * V = \left(\frac{2\pi m}{\beta h^2}\right)^{3/2} * V$$

$$q_{rot} = \frac{T}{\sigma \Theta_{\mathrm{rot}}}, \quad \Theta_{\mathrm{rot}} = \frac{h^2}{8\pi^2 I k_B} = \frac{hB}{k_B}$$

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

$$w = -\int_{V_1}^{V_2} P_{ext} dV + w'$$

$$w = -nRT ln \frac{V_2}{V_1}$$

$$dU = \delta q + \delta w$$