Thermodynamics Equation Sheet

All symbols have the same meaning as given in class materials.

First Law (general)

$$\Delta U = Q + W - \Delta\left(\frac{1}{2}mv^2\right) - \Delta(mgz)$$

Gibbs phase rule

$$F = 2 - \pi + N$$

Thermal expansion coefficient

$$\alpha = \frac{1}{V}\left(\frac{\partial V}{\partial T}\right)_{P,m}$$

Isothermal compressibility

$$\beta = -\frac{1}{V}\left(\frac{\partial V}{\partial P}\right)_{T,m}$$

Heat capacities

$$C_V = \left(\frac{\partial U}{\partial T}\right)_V = T\left(\frac{\partial S}{\partial T}\right)_V$$

$$C_P = \left(\frac{\partial H}{\partial T}\right)_P = T\left(\frac{\partial S}{\partial T}\right)_P$$

$$C_P - C_V = T\left(\frac{\partial V}{\partial T}\right)_P\left(\frac{\partial P}{\partial T}\right)_V$$

Van der Waals equation of state

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

Virial equation of state

$$Z = 1 + \frac{B}{v} + \frac{C}{v^2} + \frac{D}{v^3} + \ldots$$

Thermodynamic potentials

$$H = U + PV$$
$$A = U - TS$$
$$G = H - TS$$

Fundamental thermodynamic relations

$$\mathrm{d}U = T\mathrm{d}S - P\mathrm{d}V$$
$$\mathrm{d}H = T\mathrm{d}S + V\mathrm{d}P$$
$$\mathrm{d}A = -S\mathrm{d}T - P\mathrm{d}V$$
$$\mathrm{d}G = -S\mathrm{d}T + V\mathrm{d}P$$

Maxwell equations

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

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

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

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

Internal energy and enthalpy

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

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

$$\left(\frac{\partial H}{\partial V}\right)_T = T\left(\frac{\partial P}{\partial T}\right)_V + V\left(\frac{\partial P}{\partial V}\right)_T$$

$$\left(\frac{\partial H}{\partial P}\right)_T = -T\left(\frac{\partial V}{\partial T}\right)_P + V$$

Carnot relationship

$$\left|\frac{Q_1}{Q_2}\right| = \frac{T_1}{T_2}$$

Entropy

$$\Delta S = \int_1^2 \frac{\mathrm{d}Q_{\mathrm{rev}}}{T}$$

$$\mathrm{d}S = \frac{C_P}{T}\mathrm{d}T - \left(\frac{\partial V}{\partial T}\right)_P \mathrm{d}P$$

$$\Delta S_{\mathrm{IG}} = C_P \ln\frac{T_2}{T_1} - nR\ln\frac{P_2}{P_1}$$

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Joule-Thomson coefficient

$$\left(\frac{\partial T}{\partial P}\right)_H = \frac{V}{C_P}\left(\alpha \mathrm{T} - 1\right)$$

Phase equilibrium

$$\frac{\mathrm{d}P^{sat}}{\mathrm{d}T_b} = \frac{\Delta h}{T_b \Delta v}$$

$$\frac{\mathrm{d}P^{sat}}{\mathrm{d}T_b} = \frac{\Delta h P^{sat}}{R T_b^{\ 2}}$$

$$\ln P^{sat} = A - \frac{B}{T_b + C}$$

Multi-component systems (*m* or *M* stand for any extensive property)

$$\mathrm{d}U = T\mathrm{d}S - P\mathrm{d}V + \sum_{i=1} \mu_i \, \mathrm{d}n_i$$

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

$$m = \sum_i x_i \overline{m}_i$$

$$\Delta M_{\mathrm{Mix}} = \sum_i n_i \overline{m}_i - \sum_i n_i m_i^0$$

$$\sum_i x_i \mathrm{d}\overline{m}_i = 0$$

Ideal mixture

$$\mu_i = \mu_i^0 + RT \ln x_i$$

$$U = \sum_i n_i u_i^0$$

$$H = \sum_i n_i h_i^0$$

$$V = \sum_i n_i v_i^0$$

$$S = \sum_i n_i s_i^0 - nR \sum_i x_i \ln x_i$$

$$G = \sum_i n_i \mu_i^0 + nRT \sum_i x_i \ln x_i$$

$$P y_i = P_i^{\mathrm{sat}} x_i$$

Relative volatility

$$\alpha_{ij} = \frac{P_i^{\mathrm{sat}}}{P_j^{\mathrm{sat}}}$$