Spontaneous Reaction

$$\Delta S_{\mathrm{TOT}} > 0$$

$$dS > \frac{dq}{T}$$

$$dA_{T,V} < 0 \qquad dG_{T,p} < 0$$

Reversible Reaction

$$\Delta S_{\mathrm{TOT}} = 0$$

$$dS = \frac{dq_{\mathrm{rev}}}{T} \qquad \Delta S = \int_{\mathrm{i}}^{\mathrm{f}} \frac{dq_{\mathrm{rev}}}{T}$$

$$dA_{T,V} = 0 \qquad dG_{T,p} = 0$$

Isothermal Ideal Gas

$$\Delta S = nR \ln\left(\frac{V_{\mathrm{f}}}{V_{\mathrm{i}}}\right)$$

$$\Delta S = nR \ln\left(\frac{P_{\mathrm{i}}}{P_{\mathrm{f}}}\right)$$

Entropy Equations

$$\Delta S_{\mathrm{const}\,V} = C_V \ln\left(\frac{T_{\mathrm{f}}}{T_{\mathrm{i}}}\right)$$

$$\Delta S_{\mathrm{const}\,P} = C_P \ln\left(\frac{T_{\mathrm{f}}}{T_{\mathrm{i}}}\right)$$

System & Surroundings

$$\Delta S_{\mathrm{sur}} = \frac{q_{\mathrm{sur}}}{T_{\mathrm{sur}}} \qquad \Delta S_{\mathrm{sur}} = \frac{-q_{\mathrm{sys}}}{T_{\mathrm{sur}}}$$

If $q_{\mathrm{sur}} = 0$ (adiabatic change) $\quad \Delta S_{\mathrm{sur}} = 0$

$$\Delta_{\mathrm{trs}} S = \frac{\Delta_{\mathrm{trs}} H}{T_{\mathrm{trs}}}$$

Efficiency & Cycles

$$\varepsilon = \frac{|w|}{q_{\mathrm{h}}} = 1 + \frac{q_{\mathrm{c}}}{q_{\mathrm{h}}}$$

$$\varepsilon_{\mathrm{rev}} = 1 - \frac{T_{\mathrm{c}}}{T_{\mathrm{h}}}$$

$$w_{\mathrm{rev}} = -nR(T_{\mathrm{h}}-T_{\mathrm{c}})\ln\left(\frac{V_{\mathrm{f}}}{V_{\mathrm{i}}}\right)$$

Chemical Reactions

$$\Delta_{\mathrm{r}} S^{\mathrm{o}} = \sum_{\mathrm{products}} \nu S_m^{\mathrm{o}} - \sum_{\mathrm{reactants}} \nu S_m^{\mathrm{o}}$$

$$= \sum_{\mathrm{J}} \nu_{\mathrm{J}} S_m^{\mathrm{o}}(\mathrm{J})$$

$$\Delta_{\mathrm{r}} G^{\mathrm{o}} = \sum_{\mathrm{products}} \nu \Delta_{\mathrm{f}} G^{\mathrm{o}} - \sum_{\mathrm{reactants}} \nu \Delta_{\mathrm{f}} G^{\mathrm{o}}$$

$$= \sum_{\mathrm{J}} \nu_{\mathrm{J}} \Delta_{\mathrm{f}} G^{\mathrm{o}}(\mathrm{J})$$

Clausius Inequality

$$dS - \frac{dq}{T} \geq 0$$

General Expressions

$$A = U - TS$$

$$G = H - TS$$

Constant Volume

$$dA = dU - T\,dS$$

Constant Pressure

$$dG = dH - T\,dS$$

Spontaneity

$$dA_{T,V} < 0 \qquad dG_{T,p} < 0$$

Fundamental Equation

$$dU = T\,dS - p\,dV$$

$$dU = \left(\frac{\partial U}{\partial S}\right)_V dS + \left(\frac{\partial U}{\partial V}\right)_S dV$$

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

Maxwell Relations

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

$$\left(\frac{\partial T}{\partial p}\right)_S = \left(\frac{\partial V}{\partial S}\right)_p$$

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

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

Gibbs Energy

$$dG = V\,dp - S\,dT$$

$$\left(\frac{\partial G}{\partial T}\right)_p = -S \qquad \left(\frac{\partial G}{\partial p}\right)_T = V$$

$$\left(\frac{\partial}{\partial T}\left(\frac{G}{T}\right)\right)_p = -\frac{H}{T^2}$$

$$\left(\frac{\partial(G/T)}{\partial(1/T)}\right)_p = H$$

$$G_{\mathrm{m}}(p) = G_{\mathrm{m}}^{\mathrm{o}} + RT \ln\left(\frac{p}{p^{\mathrm{o}}}\right)$$

Chemical Potential

$$\mu = \left(\frac{\partial G}{\partial n}\right)_{T,p}$$

$$\mu = \mu^{\mathrm{o}} + RT \ln\left(\frac{p}{p^{\mathrm{o}}}\right)$$

$$\mu = \mu^{\mathrm{o}} + RT \ln\left(\frac{f}{p^{\mathrm{o}}}\right) \qquad f = \phi p$$

$$\left(\frac{\partial \mu}{\partial T}\right)_p = -S_m \qquad \left(\frac{\partial \mu}{\partial p}\right)_T = V_m$$

Applied & Vapour Pressure

$$p = p^* e^{V_m \Delta P / RT}$$

Clapeyron Equation

$$\frac{dp}{dT} = \frac{\Delta_{\mathrm{trs}} S}{\Delta_{\mathrm{trs}} V}$$

Phase Boundaries

$$\frac{dp}{dT} = \frac{\Delta_{\mathrm{fus}} H}{T\,\Delta_{\mathrm{fus}} V} \qquad \frac{dp}{dT} = \frac{\Delta_{\mathrm{vap}} H}{T\,\Delta_{\mathrm{vap}} V}$$

$$p = p^* e^{-\chi}, \qquad \chi = \frac{\Delta_{\mathrm{vap}} H}{R}\left(\frac{1}{T} - \frac{1}{T^*}\right)$$

$$\frac{dp}{dT} = \frac{\Delta_{\mathrm{vap}} H}{T\,(RT/p)}, \qquad \frac{d \ln p}{dT} = \frac{\Delta_{\mathrm{vap}} H}{RT^2}$$

Surface Tension

$$p = \rho g h \qquad h = \frac{2\gamma}{\rho g r}$$

$$p_{\mathrm{in}} = p_{\mathrm{out}} + \frac{2\gamma}{r} \qquad p = p^* e^{2\gamma V_{\mathrm{m}}/rRT}$$