Spontaneity – Formula Sheet:

2nd Law of Thermodynamics:

$$\Delta S_{universe} = \Delta S_{system} + \Delta S_{Surroundings}$$

Entropy Change:

$$\Delta \boldsymbol{S^o}_{rxn} = \sum n\, S^o{}_f(products) - \sum n\, S^o{}_f(reactants)$$

Entropy:

$$\Delta S_{Surr} = -\frac{\Delta H}{T}$$

$$S_{gas} > S_{liquid} > S_{solid} \qquad T \uparrow S \uparrow \;\; \Delta S = +$$

Enthalpy Change:

$$\Delta \boldsymbol{H^o}_{rxn} = \sum n\, H^o{}_f(products) - \sum n\, H^o{}_f(reactants)$$

Gibbs Free Energy Change:

$$\Delta G = \Delta H - T\Delta S$$

Standard Free Energy Change:

$$\Delta \boldsymbol{G^o}_{rxn} = \sum n\, G^o{}_f(products) - \sum n\, G^o{}_f(reactants)$$

The Reaction Quotient:

$$\Delta G = \Delta G° + RT \ln Q$$

$$Q = e^{\frac{\Delta G - \Delta G°}{RT}}$$

$$\boldsymbol{j}A + \boldsymbol{k}B \rightleftarrows \boldsymbol{l}C + \boldsymbol{m}D$$

$$Q = \frac{[C]^{\boldsymbol{l}}[D]^{\boldsymbol{m}}}{[A]^{\boldsymbol{j}}[B]^{\boldsymbol{k}}}$$

The Equilibrium Constant:

$$\Delta G° = -RT \ln K$$

$$K = e^{-\frac{\Delta G°}{RT}}$$

$$\boldsymbol{j}A + \boldsymbol{k}B \rightleftarrows \boldsymbol{l}C + \boldsymbol{m}D$$

$$K_C = \frac{[C]^{\boldsymbol{l}}[D]^{\boldsymbol{m}}}{[A]^{\boldsymbol{j}}[B]^{\boldsymbol{k}}}$$

ln (K) vs (1/T) linear Plot:

$$\ln\left(\frac{K_2}{K_1}\right) = -\frac{\Delta H}{R}\left[\frac{1}{T_2} - \frac{1}{T_1}\right]$$

$$R = 8.3145\ J/mol \cdot K$$

Slope:

$$m = -\frac{\Delta H}{R} = \frac{\Delta \ln(K)}{\Delta(1/T)}$$

ln (K) vs (1/T) linear Plot:

$$\ln(K) = -\frac{\Delta H}{R}\left(\frac{1}{T}\right) + \frac{\Delta S}{R}$$

$$y = mx + B$$

Y-Intercept:

$$B = \frac{\Delta S}{R}$$

Spontaneity:

1. $\Delta G° < 0,\ Spontaneous$
2. $\Delta G° = 0,\ Equilibrium$
3. $\Delta G° > 0,\ Nonspontaneous$

The Equilibrium Constant:

1. $\Delta G° < 0,\ K > 1$
2. $\Delta G° = 0,\ K = 1$
3. $\Delta G° > 0,\ K < 1$

Spontaneity Table:

ΔH	ΔS	T	ΔG	$Spontaneity$:
+	+	$High$	−	$Spontaneous$
		Low	+	$Nonspontaneous$
−	−	$High$	+	$Nonspontaneous$
		Low	−	$Spontaneous$
−	+	$High$	−	$Spontaneous$
		Low	−	$Spontaneous$
+	−	$High$	+	$Nonspontaneous$
		Low	+	$Nonspontaneous$

Gibbs Free Energy Change:

$$\Delta G = \Delta H - T\Delta S$$

Note:

$$\Delta S \rightarrow J/mol \cdot K \qquad \Delta H \rightarrow kJ/mol$$

Convert $\Delta S\ from\ J\ to\ kJ\ to\ match\ with\ \Delta G\ \&\ \Delta H.$

Boiling Point Temperature:

$$A_{(l)} \leftrightarrow A_{(g)}$$

$$T_B = \frac{\Delta H_{Vap}}{\Delta S} \qquad \Delta G = 0$$