Summary Sheet

Criteria for spontaneity/equilibrium ($TdS \geq đq$)

Constants		Criterion
None	$dS_{\text{univ}} \geq 0$	(isolated system: $dS \geq 0$)
U, V		$dS \geq 0$
S, V		$dU \leq 0$
S, P		$dH \leq 0$
T, V		$dA \leq 0$
T, P		$dG \leq 0$

Fundamental Equations (reversible processes, only expansion work)

$$dU = TdS - PdV + \sum_i \mu_i dn_i$$

$$dH = TdS + VdP + \sum_i \mu_i dn_i \qquad \text{H = U + PV}$$

$$dA = -SdT - PdV + \sum_i \mu_i dn_i \qquad \text{A = U – TS}$$

$$dG = -SdT + VdP + \sum_i \mu_i dn_i \qquad \text{G = U – TS + PV (= H – TS)}$$

Maxwell Relations (closed systems, single component)

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

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

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

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