$A = U - TS$

Helmholtz

$G = H - TS$

Gibb's

At const T

$dA = dU - TdS$

$dG = dH - TdS$

$dA_{T,V} \leq 0$

$dG_{T,P} \leq 0$

$dU = TdS - pdV = dq_{rev} + dw_{rev} = dq_{irr} + dw_{irr}$

$dU \leq TdS$

$$TdS \geq dq \qquad dU = dq + dw$$

$$dU \leq TdS + dw$$

$$dw \geq dU - TdS$$

$$dw \geq dA \equiv dw_{max}$$

$A \equiv$ work function

$$dG = dH - TdS - SdT = dq + dw + pdV + Vdp - TdS - SdT$$

$$dH = d(U + pV) = dU + pdV + Vdp = dq + dw + pdV + Vdp$$

$$dq_{rev} = TdS \qquad dw_{rev} = -pdV + w_{add}$$

$$dG = \cancel{TdS} \cancel{- pdV} + w_{add} \cancel{+ pdV} + Vdp \cancel{- TdS} - SdT$$

At const p & T $\qquad dG = w_{add,max}$

$dS_{U,V}$ / $dS_{H,p} \geq 0$

$dU_{S,V} \leq 0$

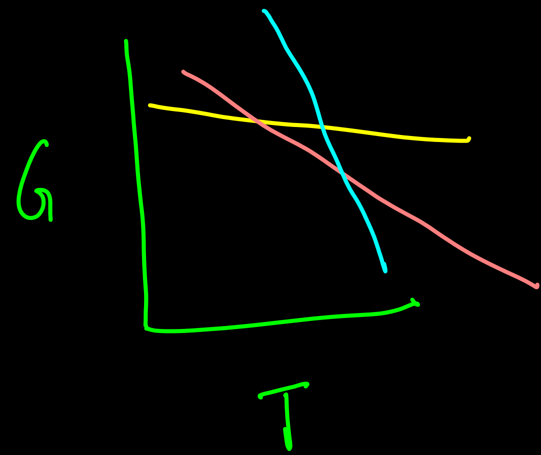
$dH_{S,p} \leq 0$

$dA_{T,V} \leq 0$

$dG_{T,p} \leq 0$

$$\boxed{\begin{aligned} dU &= TdS - pdV \\ dH &= TdS + Vdp \\ dA &= -SdT - pdV \\ dG &= -SdT + Vdp \end{aligned}}$$

Fundamental Equations



$$A = U - TS$$

$$dA = dU - TdS - SdT$$

$$= TdS - pdV - SdT - TdS$$

$$= -SdT - pdV$$

$$dG = dH - TdS - SdT$$

$$\cancel{TdS} + Vdp - \cancel{TdS} - SdT \quad = -SdT + Vdp$$

$$dU = TdS - pdV$$

$$dH = TdS + Vdp$$

$$dA = -SdT - pdV$$

$$dG = -SdT + Vdp$$

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

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

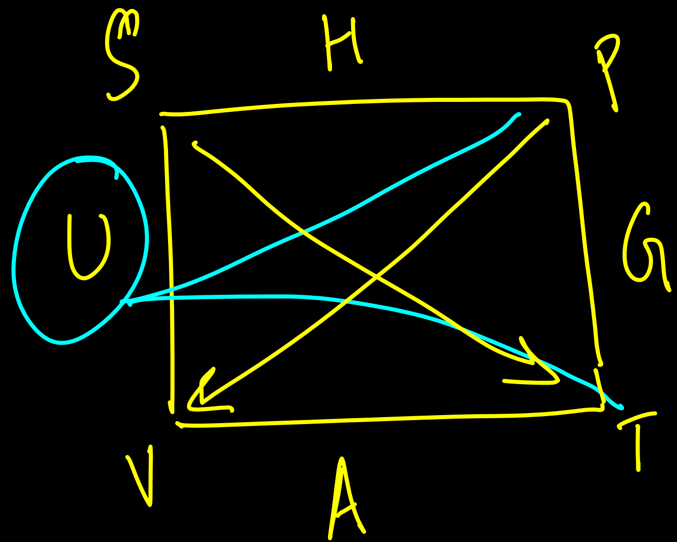
$$\left(\frac{\partial S}{\partial V}\right)_T = \left(\frac{\partial p}{\partial T}\right)_V$$

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

Maxwell Relations

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

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



$$dU = TdS - pdV$$

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

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

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

$$U = H - pV = G - T\left(\frac{\partial G}{\partial T}\right)_p - p\left(\frac{\partial G}{\partial p}\right)_T$$

$$A = U - TS = G - p\left(\frac{\partial G}{\partial p}\right)_T$$

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

$\approx G(T)$ for small pr. changes for l/S

$$\left(\frac{\partial G}{\partial p}\right)_T = V$$

$$G(P_2, T) = G(P_1, T) + \int_{P_1}^{P_2} V\,dp$$

$$G(P_2, T) = G(P_1, T) + RT \ln \frac{P_2}{P_1}$$

$$P_1 = P^{\ominus} = 1\,\text{bar}$$

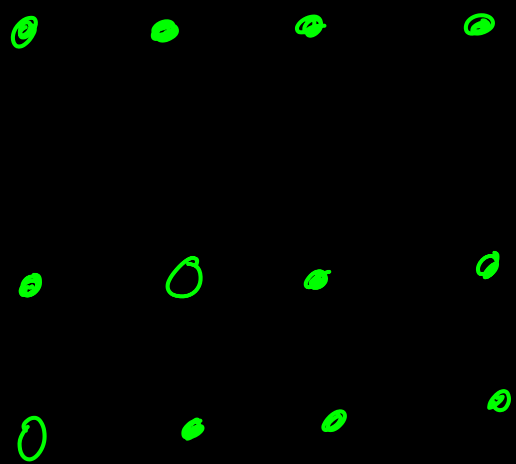
— always in bar

$$G_m(P,T) = G_m^\ominus(T) + RT\ln P$$

$$-S_m(P,T) = -S_m^\ominus(T) + R\ln P$$

Chemical potential

$G_m \equiv \mu$



$k\ln W$

$k\ln 4$