Picture taken from Wikipedia

Thermodynamic potentials

Maxwell relations

Internal energy U

$$dU = TdS - pdV$$

$$U = U(S,V)$$

$$\mathrm{d}U = \left(\frac{\partial U}{\partial S}\right)_V \mathrm{d}S + \left(\frac{\partial U}{\partial V}\right)_S \mathrm{d}V$$

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

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

recommend to have on the cheat sheet

Enthalpy *H*

$$H \equiv U + pV$$
$$\mathrm{d}H = \mathrm{d}U + p\mathrm{d}V + V\mathrm{d}p = T\mathrm{d}S + V\mathrm{d}p$$
$$\mathrm{d}U = T\mathrm{d}S - p\mathrm{d}V$$

$$H = H(S, p)$$
$$\mathrm{d}H = \left(\frac{\partial H}{\partial S}\right)_p \mathrm{d}S + \left(\frac{\partial H}{\partial p}\right)_S \mathrm{d}p$$

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

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

Helmholtz Free Energy *F*

$$F \equiv U - TS$$

$$\mathrm{d}F = \mathrm{d}U - T\mathrm{d}S - S\mathrm{d}T = -S\mathrm{d}T - p\mathrm{d}V$$

$$\mathrm{d}U = T\mathrm{d}S - p\mathrm{d}V$$

$$F = F(T, V)$$

$$\mathrm{d}F = \left(\frac{\partial F}{\partial T}\right)_V \mathrm{d}T + \left(\frac{\partial F}{\partial V}\right)_T \mathrm{d}V$$

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

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

Gibbs Free Energy *G*

$$\mathrm{G} \equiv \mathrm{H} - \mathrm{TS} = U + pV - TS$$

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

$$\mathrm{d}U = T\mathrm{d}S - p\mathrm{d}V$$

$$\mathrm{d}G = -S\mathrm{d}T + V\mathrm{d}p$$

$$G = G(T, p)$$

$$\mathrm{d}G = \left(\frac{\partial G}{\partial T}\right)_p \mathrm{d}T + \left(\frac{\partial G}{\partial p}\right)_T \mathrm{d}p$$

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

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

Summary

$$\mathrm{d}U = T\mathrm{d}S - p\mathrm{d}V$$

$$\mathrm{d}H = T\mathrm{d}S + V\mathrm{d}p$$

$$\mathrm{d}F = -S\mathrm{d}T - p\mathrm{d}V$$

$$\mathrm{d}G = -S\mathrm{d}T + V\mathrm{d}p$$

Summary 2

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

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

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

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