3.6 Summary

Type of process	Exchanged Quantity	Governing Variable	Relation
thermal	energy	temperature	$\frac{1}{T} = \left(\frac{\partial S}{\partial U}\right)_{V,N}$
mechanical	volume	pressure	$\frac{P}{T} = \left(\frac{\partial S}{\partial V}\right)_{U,N}$
diffusive	particles	chemical potentia	$\frac{\mu}{T} = -\left(\frac{\partial S}{\partial N}\right)_{U,V}$

Classical thermodynamics $dU = TdS - PdV + \mu dN$

These are statistical relations that hold in the thermodynamic limit.

For large # of particles, fluctuations are minor and classical thermodynamics is deterministic.

In the thermodynamic limit, entropy increases or stays constant.

Two systems in thermal equilibrium must have $\Delta S_a = -\Delta S_b$ for any process that exchanges between a and b.

$$\Rightarrow \left(\frac{\partial S_a}{\partial U_a}\right)_{V_a,N_a} = \left(\frac{\partial S_b}{\partial U_b}\right)_{V_b,N_b} \Rightarrow T_a = T_b$$

$$\left(\frac{\partial S_a}{\partial V_a}\right)_{U_a,N_a} = \left(\frac{\partial S_b}{\partial U_b}\right)_{U_b N_b} \Rightarrow P_a = P_b$$

$$\left(\frac{\partial S_a}{\partial N_a}\right)_{U_a V_a} = \left(\frac{\partial S_b}{\partial N_b}\right)_{U_b V_b} \Rightarrow \mu_a = \mu_b$$