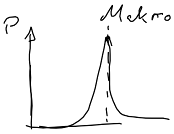
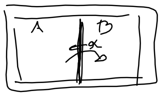
Likevekt mellom to systemer

	tot		A		B
	N	=	N_A	+	N_B
	V	=	V_A	+	V_B
	U	=	U_A	+	U_B
	Ω_{tot}	=	Ω_A	$\times$	Ω_B

tilstandsvariable
Makroskopiske



Isolert



Likevekt når Ω_{tot} er maksimal

$\alpha = \begin{cases} N \\ U \\ V \end{cases}$ mens de andre er konstant

$$\frac{\partial \Omega_{tot}}{\partial \alpha_A} = 0$$

$$\frac{\partial(\Omega_A \cdot \Omega_B)}{\partial \alpha_A} = \Omega_A \frac{\partial \Omega_B}{\partial \alpha_A} + \Omega_B \frac{\partial \Omega_A}{\partial \alpha_A} = 0$$

$$= -\Omega_A \frac{\partial \Omega_B}{\partial \alpha_B} + \Omega_B \frac{\partial \Omega_A}{\partial \alpha_A} = 0$$

$\alpha_{tot} = \alpha_A + \alpha_B$
$\alpha_A = \alpha_{tot} - \alpha_B$
$d\alpha_A = -d\alpha_B$

$$\frac{1}{\Omega_B}\frac{\partial \Omega_B}{\partial \alpha_B} = \frac{1}{\Omega_A}\frac{\partial \Omega_A}{\partial \alpha_A}$$

$$k\frac{\partial \ln \Omega_B}{\partial \alpha_B} = k\frac{\partial \ln \Omega_A}{\partial \alpha_A}$$

Entropi til et isolert system med N, V, U konstant er

$$S = k \ln \Omega(N, V, U)$$

Likevektskriterie $\quad \frac{\partial S_A}{\partial \alpha_A} = \frac{\partial S_B}{\partial \alpha_B}$ når de andre α (N, V, U) er konstant

Termisk likevekt $\quad \alpha = U \quad \alpha_A = U_A$

$$\left(\frac{\partial S_A}{\partial U_A}\right)_{N,V} = \left(\frac{\partial S_B}{\partial U_B}\right)_{N,V} \Rightarrow \left(\frac{\partial U_B}{\partial S_B}\right)_{N,V} = \left(\frac{\partial U_A}{\partial S_A}\right)_{N,V}$$

Temperatur: "energi per tilstand" (Einsteinkrystallen) $\quad T_A = T_B$

Definisjon av temperatur $\quad \frac{1}{T} \equiv \left(\frac{\partial S}{\partial U}\right)_{N,V} \qquad T = \left(\frac{\partial U}{\partial S}\right)_{N,V}$

Likevektskriteriet: $\quad T_A = T_B$

Mekanisk likevekt $\quad \alpha_A = V_A \qquad p_A = p_B \qquad T\left(\frac{\partial S_A}{\partial V_A}\right)_{U_A,N_A} = \left(\frac{\partial S_B}{\partial V_B}\right)_{U_B,N_B} T$

Dim. analyse $\quad [p] = \left[\frac{F}{A}\right] = \left[\frac{U}{A \cdot L}\right] = \left[\frac{U}{V}\right] = \left[\frac{kT}{V}\right] = \left[\frac{ST}{V}\right]$

$[S] = \left[\frac{U}{T}\right] \quad [kT] = [U]$

Trykk $\quad p \equiv T\left(\frac{\partial S}{\partial V}\right)_{U,N}$

Kjemisk likevekt $\quad \alpha_A = N_A \quad -T\left(\frac{\partial S_A}{\partial N_A}\right)_{U_A,V_A} = -\left(\frac{\partial S_B}{\partial N_B}\right)_{U_B,V_B} T$

kjemisk potensial $\quad \mu_A = \mu_B$

$[\mu] = [U] = [kT]$

Def. Kjemisk potensial $\quad \mu \equiv -T\left(\frac{\partial S}{\partial N}\right)_{U,V}$

Termodynamikkens 2. lov:
For et isolert system vil entropien øke til det er likevekt
$$\Delta S \geq 0$$

Egenskap $\quad S_{tot} = k\ln\Omega_{tot} = k\ln\Omega_A + k\ln\Omega_B = S_A + S_B$

Materialegenskap

Varmekapasitet $\quad \boxed{C_V} \equiv \left(\frac{\partial U}{\partial T}\right)_{N,V} \qquad \left(C_P \equiv \left(\frac{\partial U}{\partial T}\right)_{N,P}\right)$

Å måle entropi

N & V konst $\quad T = \frac{dU}{dS} \Rightarrow dS = \frac{dU}{T} \qquad dU = C_V dT$

Varm opp $W=0 \quad dU = Q \qquad dS = \frac{Q}{T}$

$$C_V = \frac{dU}{dT} \Rightarrow dS = \frac{C_V dT}{T}$$

$$\Delta S = S(T_2) - S(T_1) = \int_{T_1}^{T_2} \frac{C_V}{T} dT$$

Måle C_V => beregne ΔS

$T_1 = 0$ Absolut S: $S(T) - S(T=0) = \int_0^{T_2} \frac{C_V}{T} dT \qquad C_V \to 0$ når $T \to 0$

Termodynamikkens 3. lov:
$S \to$ konstant når $T \to 0$

$T=0$ mikrotilstander grunntilstand $\quad \Omega = \cancel{1}$? liten

Den termodynamiske identitet

Hva er endringen i S når N, V, U varierer?

$$dS = \underbrace{\left(\frac{\partial S}{\partial U}\right)_{N,V}}_{1} dU + \underbrace{\left(\frac{\partial S}{\partial V}\right)_{U,N}}_{2} dV + \underbrace{\left(\frac{\partial S}{\partial N}\right)_{V,U}}_{3} dN$$

$$= \frac{1}{T} dU + \frac{P}{T} dV - \frac{\mu}{T} dN$$

$$\boxed{dU = TdS - PdV + \mu dN}$$

$$\left(\frac{\partial S}{\partial U}\right)_{N,V} = \frac{1}{T}$$

$$T\left(\frac{\partial S}{\partial V}\right)_{N,U} = P$$

$$-T\left(\frac{\partial S}{\partial N}\right)_{V,U} = \mu$$

Av TI følger
× definisjon T, P, μ
× Termodyn. 1. lov.

$$dU = \underbrace{dQ}_{TdS} + \underbrace{dW}_{-PdV} + \mu dN$$

× Adiabatisk $dU = -PdV$

Adiabatisk: Ingen varme eller partikler utveksles $\quad dQ = 0$, $dN = 0$