$\boxed{ü}$ Totales Differential:

$$dU = M(x,y)\,dx + N(x,y)\,dy$$

aus ~~...~~-Satz v. Schwarz:

$$\left(\frac{\partial M}{\partial y}\right)_x \overset{!}{=} \left(\frac{\partial N}{\partial x}\right)_y$$

Ausdehnung $\alpha_p = \frac{1}{V}\left(\frac{\partial V}{\partial T}\right)_p$

Wärmekap. $C_V = T\left(\frac{\partial S}{\partial T}\right)_V$

isoth. Kompr. $\kappa_T = -\frac{1}{V}\left(\frac{\partial V}{\partial p}\right)_T$

Clapeyron: $\frac{dp}{dT} = \frac{L}{T(V_g - V_f)}$

$\frac{W}{Q} = \eta = \frac{dT}{T}$

$$\frac{\partial \mu}{\partial p} = \frac{V}{N} \qquad \frac{\partial \mu}{\partial T} = -\frac{S}{N}$$

$$\mu = \frac{\partial F}{\partial N}$$

Shannon-Entropie: N_g von N Plätzen:

$$S = k\ln\binom{N}{N_g} = k\{\ln N! - \ln N_g! - \ln(N-N_g)!\}$$

$$\Rightarrow \frac{S}{k} \cong N\ln N - N_g\ln N_g - (N-N_g)\ln(N-N_g)$$

$$= N\ln\frac{N}{N-N_g} + N_g\ln\frac{N-N_g}{N_g} + \underbrace{\left\{N_g\ln\frac{N}{N-N_g} - N_g\ln\frac{N}{N-N_g}\right\}}_{=0}$$

$$= (N-N_g)\ln\frac{N}{N-N_g} + N_g\ln\frac{N}{N_g}$$

$$\Rightarrow S = -Nk\{(1-c)\ln(1-c) + c\ln c\}$$

Zustandsintegral f. ideales Gas

$$Z(N,V,T) = \frac{1}{h^{3N}N!}\int dx^{3N}\,dp^{3N}\,e^{-\frac{H}{kT}}$$

$$M = -\left(\frac{\partial F}{\partial H}\right)_T \qquad G = F - \frac{\partial F}{\partial V}V$$

Gibbs-Zustandssumme:

$$Z(N,T,p) = \int_0^\infty dV\, Z(T,V,N)\,e^{-\frac{pV}{kT}} \text{ bei } V\equiv 0 \;\Big\}\; G(T,p,N) = -kT\ln Z(T,p,N)$$

$$\overline{(A-\bar{A})^2} = \left(\overline{A^2} - \bar{A}^2\right)$$

$$\chi = \frac{\partial M}{\partial H} = -\frac{\partial^2 F}{\partial H^2}$$

PK van der Waals

$$\left(p + \frac{a}{V^2}\right)(V-b) = RT$$

$C_p = m\cdot c_p$ ... mit $dQ = C_p\,dT \Rightarrow Q = C_p\,\Delta T$; dann $dS = \frac{dQ}{T}$

$\boxed{1} \approx \boxed{2}$ $\quad S = S_1(U_1) + S_2(U_2)$

$\qquad\qquad U = U_1 + U_2 = \text{const}$

$\cancel{W = \oint S\,dT = \Delta S\,\Delta T}$ $\quad \cancel{\Rightarrow \frac{W}{Q} = \frac{S_2 - S_1}{S_1}}$

$\cancel{Q = \int S\,dT = S_1\,\Delta T}$

VL

S U V

⊕ H F ⊖

p G T

Variable: Nachbarn
Ableitung: Diagonal rüber / +/− nach Seite

Maxwell: Satz v. Schwarz; 1. Ableitung einsetzen

Legendre: $U(S,V) \to F(T,V)$

$F(T,V) = U(S,V) \underset{\text{Def!!}}{-} S\underbrace{\left(\frac{\partial U}{\partial S}\right)_V}_{\text{einsetzen}}$

$= U - TS$

$dF = \underbrace{dU}_{\text{einsetzen}} - TdS - SdT = TdS - pdV - TdS - SdT$

$= -pdV - SdT$

Hauptsätze: (1) Wärme ist Form von Energie
$dU = \delta Q + \delta W = dQ - pdV$

(2) Entropie $dS = \frac{1}{T}(dU - pdV)$: Es gibt keine periodische Maschine, die nur mech. Arbeit erzeugt und Wärmespeicher abkühlt

(0): ∃ absolute Temperatur; warm zu kalt

(3) $T=0$ unerreichbar; $T \to 0 \Rightarrow S \to 0$; z.B. aus $S = k \ln W$

Wärmeleitung: $\Delta T = \frac{1}{D}\frac{\partial}{\partial t} T$ $\left\{ \begin{array}{l} \text{aus } \vec{j} = -k\vec{\nabla}T \text{ und } -\frac{\partial u}{\partial t} = \vec{\nabla}\vec{j} \\ \text{mit } \frac{\partial u}{\partial t} = \frac{\partial u}{\partial T}\frac{\partial T}{\partial t} \; ; \; \frac{\partial u}{\partial T} = c \end{array} \right.$

Spezif. Wärme: $C_V = \left(\frac{\partial U}{\partial T}\right)_V$
$V \neq$ const: $\frac{\partial Q}{\partial T} =: C_p$ und id. Gasgleichung
$C_p = C_V + R$

Adiabate: $\delta Q = 0$: $pV^{\kappa} = \text{const}$
$\kappa = \frac{C_p}{C_V} > 1$

Carnot: $\eta := \frac{W}{Q_1}$
$W = \oint p\,dV$

$dS = \frac{dU}{T} + \frac{p}{T}dV$

$dU = TdS - pdV$

Nernst: $S = \int_0^T \frac{C_p}{T}dT$

$\mu(pT) = \frac{G(pT)}{N}$; $\mu = \left(\frac{\partial F}{\partial N}\right)_{T,V}$; $N = -\left(\frac{\partial \Omega}{\partial \mu}\right)$

id. Gas: $\mu(pT) = kT \ln p + \chi(T)$

Gibbs: Phasenregel (r Phasen, n Stoffe, f Freiheitsgr.)
$r + f = 2 + n$

Mischungsentropie: $Q = \int_{V_1}^{V_2} p\,dV = NkT \log 2 \to dS = \frac{dQ}{T}$

Shannon-Information:
$J = -\sum_n p_n \log p_n = \log N$ für $p_n = \frac{1}{N}$ $\Big\}$ $J_{ges} = J_1 + J_2$

Shannon und Boltzmann:
$\bar{E} = \sum_n E_n p_n$ | $p_n = \frac{1}{Z} e^{-\frac{E_n}{kT}}$ | $Z = \sum_n e^{-\frac{E_n}{kT}}$ || $S = -\frac{\partial F}{\partial T}$, $F = -kT \ln Z$

Maxwellverteilung; id. Gas: $Z = \frac{1}{N!}\prod_{i=1}^{N}\left(\frac{V}{h^3}\int_{-\infty}^{\infty} e^{-\frac{p_i^2}{2mkT}} d^3p_i\right)$

$= \frac{V^N}{N!}\left(\frac{2\pi mkT}{h^2}\right)^{3N/2} \approx \left(\frac{Ve}{\lambda_T^3 N}\right)^N$ mit $\lambda_T = \frac{h}{\sqrt{2\pi mkT}}$