Thermodynamik

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Zusammenfassung

Formelsammlung Thermodynamik

Zustandsgrößen, thermodynamische Kräfte :

$P = -\left(\frac{\partial E}{\partial V}\right)_S = -\left(\frac{\partial F}{\partial V}\right)_T$	Druck
$S = -\left(\frac{\partial F}{\partial T}\right)_V = -\left(\frac{\partial G}{\partial T}\right)_P$	Entropie
$V = \left(\frac{\partial G}{\partial P}\right)_T = \left(\frac{\partial H}{\partial P}\right)_S$	Volumen
$T = \left(\frac{\partial H}{\partial S}\right)_P = \left(\frac{\partial E}{\partial S}\right)_V$	Temperatur

Thermodynamische Potentiale :

$E(S,V)$	$dE = TdS - PdV = \left(\frac{\partial E}{\partial S}\right)_V dS + \left(\frac{\partial E}{\partial V}\right)_S dV$	Innere Energie
$F(T,V) = E - TS$	$dF = -SdT - PdV = \left(\frac{\partial F}{\partial T}\right)_V dT + \left(\frac{\partial F}{\partial V}\right)_T dV$	Freie Energie
$H(S,P) = E + PV$	$dH = TdS + VdP = \left(\frac{\partial H}{\partial S}\right)_P dS + \left(\frac{\partial H}{\partial P}\right)_S dP$	Enthalpie
$G(T,P) = E + PV - TS$	$dG = -SdT + VdP = \left(\frac{\partial G}{\partial T}\right)_P dT + \left(\frac{\partial G}{\partial P}\right)_T dP$	Freie Enthalpie

Gleichgewichtszustände sind durch 2 Zustandsvariable festgelegt :

$$dS = \left(\frac{\partial S}{\partial T}\right)_V dT + \left(\frac{\partial S}{\partial V}\right)_T dV$$

$$dV = \left(\frac{\partial V}{\partial T}\right)_P dT + \left(\frac{\partial V}{\partial P}\right)_T dP$$

Erster Hauptsatz :

$$\begin{aligned} dE &= dQ + dW \\ dQ &= TdS \\ dW &= -PdV \end{aligned}$$

Temperatur :

$$T = \left(\frac{\partial Q}{\partial S}\right)_P$$

Wärmekapazitäten :

$$\begin{aligned} c_V &= \left(\frac{\partial Q}{\partial T}\right)_V = \left(\frac{\partial E}{\partial T}\right)_V = T\left(\frac{\partial S}{\partial T}\right)_V \\ c_P &= \left(\frac{\partial Q}{\partial T}\right)_P = \left(\frac{\partial H}{\partial T}\right)_P = T\left(\frac{\partial S}{\partial T}\right)_P \\ \frac{c_P}{c_V} &= \gamma \qquad \text{Adiabatenindex, } c_P > c_V \\ c_G & \ \ldots \ \text{Randbedingung ist hydrostatisches Gleichgewicht} \end{aligned}$$

Maxwell-Relationen aus $\frac{\partial^2 f}{\partial x \partial y} = \frac{\partial^2 f}{\partial y \partial x}$ mit f Potential:

für $f = E$ $$\left(\frac{\partial T}{\partial V}\right)_S = -\left(\frac{\partial P}{\partial S}\right)_V$$

für $f = F$ $$\left(\frac{\partial S}{\partial V}\right)_T = \left(\frac{\partial P}{\partial T}\right)_V$$

für $f = H$ $$\left(\frac{\partial T}{\partial P}\right)_S = \left(\frac{\partial V}{\partial S}\right)_P$$

für $f = G$ $$-\left(\frac{\partial S}{\partial P}\right)_T = \left(\frac{\partial V}{\partial T}\right)_P$$

sonstiges :

$$E = F + TS = F - T\left(\frac{\partial F}{\partial T}\right)_V = -T^2\frac{\partial}{\partial T}\left(\frac{F}{T}\right)$$

Ideale Gasgleichung :

$$pV = nRT = NkT$$