2.6 SPEZIFISCHE WÄRME(Kapazität)

Erfahrung: $\Delta Q \sim \Delta T$; $\Delta T \sim \frac{1}{m} \sim \frac{1}{n}$ m: Masse, n = Stoffmenge

Def.: spezifische Wärme: $\frac{dQ}{dT} = c \cdot m = C \cdot n$ $[c] = \frac{J}{kg \cdot K}$

$C = c \cdot M_{mol}$ $[C] = \frac{J}{mol \cdot K}$

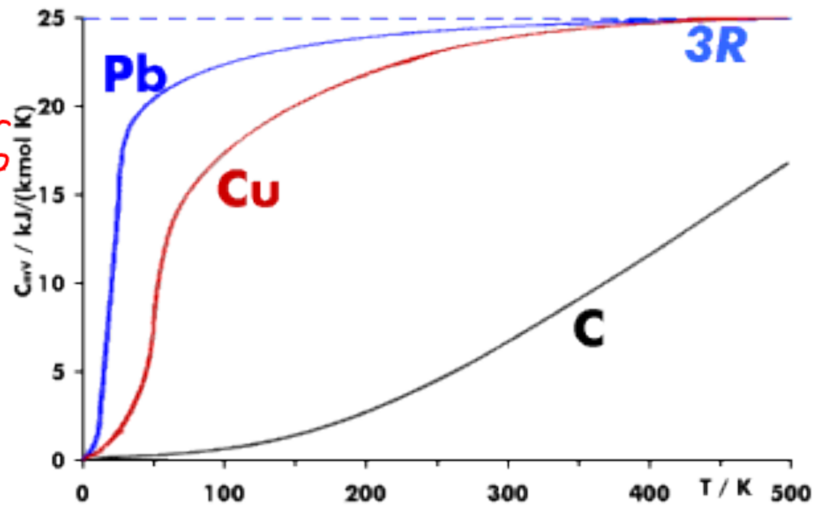
Für FK: $dW \overset{!}{=} 0 \Rightarrow dU = dQ$

$C = \frac{1}{n}\frac{dQ}{dT} = \frac{1}{n}\frac{dU}{dT}$ $U = \frac{1}{2} \cdot f \cdot n \cdot R \cdot T$

einatomige Umstelle f=6

$C = \frac{1}{2} f \cdot R = 3 \cdot R = \frac{24,9\ J}{mol \cdot K}$

$\boxed{\text{Dulong-Petit}}$



für $T > T_{Debye}$ (Debye-Temperatur)

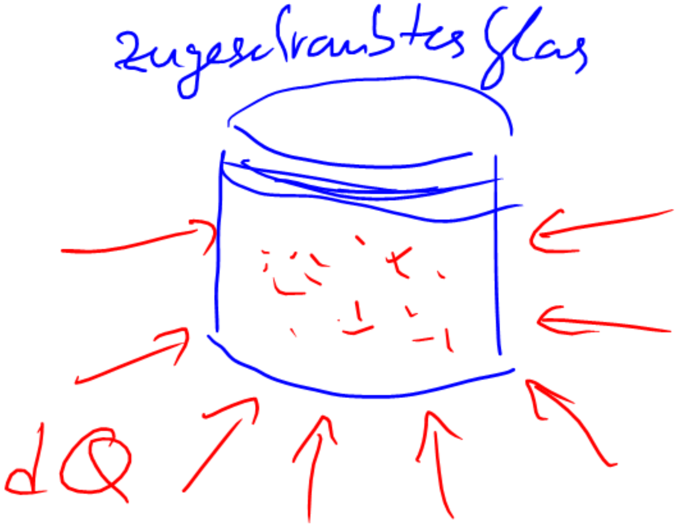
Bild: physik.uni-wuerzburg.de

2.6 SPEZIFISCHE WÄRME(Kapazität) für Gase

Unterscheidung: $p = \text{const} \Leftrightarrow V = \text{const}$

c_p, C_p $\qquad$ c_v, C_v

1) $V = \text{const} \Rightarrow \Delta V = 0$, $\Delta n = 0$ $\qquad$ $\Delta p \neq 0 \quad \Delta T \neq 0 \quad V \Delta p = n R \Delta T$



$$dV = 0 \Rightarrow dW = 0 = -p\,dV$$

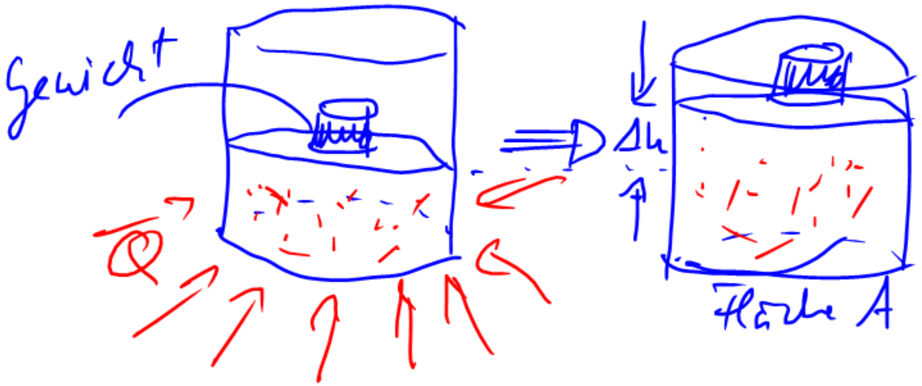
1. Hauptsatz: $dU = dQ + \cancel{dW}$

$$C_V = \frac{1}{n}\frac{dQ}{dT} = \frac{1}{n}\frac{dU}{dT} \qquad U = \frac{1}{2} f \cdot n \cdot R \cdot T$$

$$C_v = \frac{1}{2} \cdot f \cdot R \Rightarrow U = n \cdot C_v \cdot T$$
$$= m \cdot c_v \cdot T$$

2.6 SPEZIFISCHE WÄRME(Kapazität) für Gase

2) $p = \text{const}$



Erfahrung: $\Delta h \Rightarrow \Delta V = A \cdot \Delta h \neq 0$

$\Rightarrow dW = -p\,dV \neq 0$

1. Hauptsatz: $dQ = dU - dW$

zugeführte Wärme geht nicht nur in innere Energie!

• ideale Gas: $d(p \cdot V) = d(nRT)$

$$-\frac{1}{n}\frac{dU}{dT} = \frac{1}{n}\frac{d(pV)}{dT} = \frac{1}{n}\frac{d(nRT)}{dT} = R$$

(• $dW = -p\,dV$)

• $p = \frac{nRT}{V} \Rightarrow T/V = \text{const}!$

$$\frac{V_2}{V_1} = \frac{T_2}{T_1}$$

$$C_p = \frac{1}{n}\frac{dQ}{dT} = \frac{1}{n}\frac{dU}{dT} - \frac{1}{n}\frac{dW}{dT}$$

$$= C_V + R$$

$$= \frac{1}{2} f \cdot R + R$$

$$= \left(\frac{f}{2} + 1\right) R$$

2.6 ISENTROPEN- / ADIABATENKOEFFIZIENT κ

$$\kappa = c_p / c_v = \frac{c_v + R}{c_v} = 1 + \frac{R}{c_v} = 1 + 2/f$$

$$\kappa = 1 + \frac{2}{f} = \begin{cases} 1{,}66 & f = 3 \\ 1{,}4 & f = 5 \\ 1{,}33 & f = 6 \end{cases}$$

2.6 ~~ISOTHERME~~ ZUSTANDSÄNDERUNGEN

$p \cdot V = N k_B \cdot T \qquad dU = dQ + dW$

1) $V = const$, $\Delta V = 0 \Rightarrow dW = 0$ isochore ZÄ.

$p \cdot V = nRT \Rightarrow p/T = const$, $\frac{p_2}{p_1} = \frac{T_2}{T_1}$

2) $p = const$, $\Delta p = 0$ isobare ZÄ.

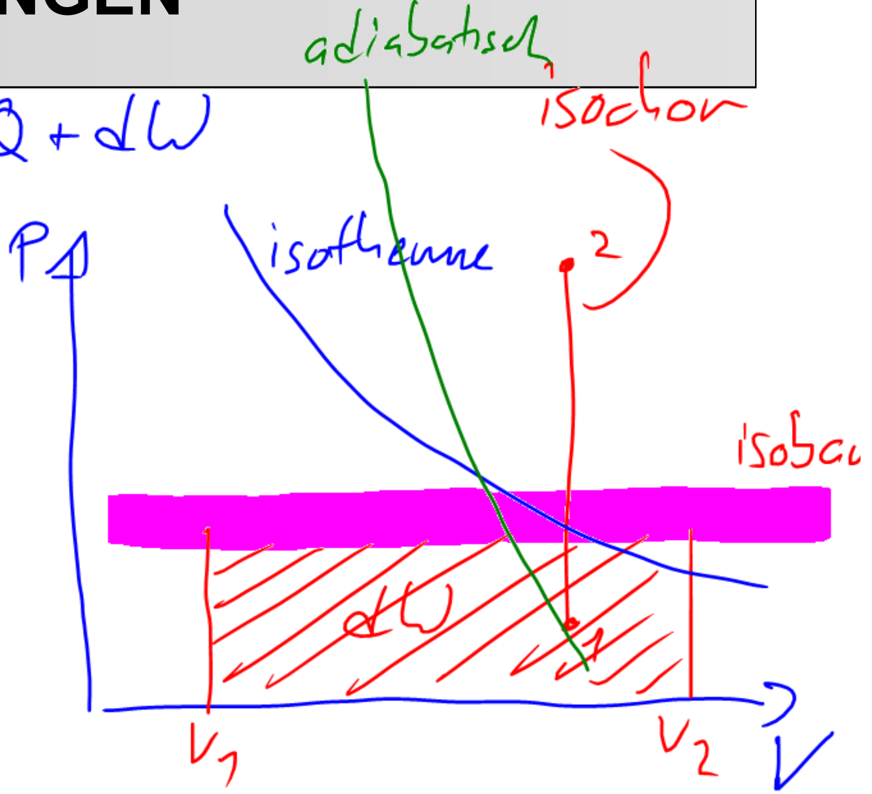
$\frac{V_2}{V_1} = \frac{T_2}{T_1} \qquad dW = -p\,dV$

3) $T = const$; isotherme ZÄ, $dU = 0$

Hyperbeln

4) $dQ = 0 \Rightarrow$ System thermisch isoliert

"adiabatische ZÄ"

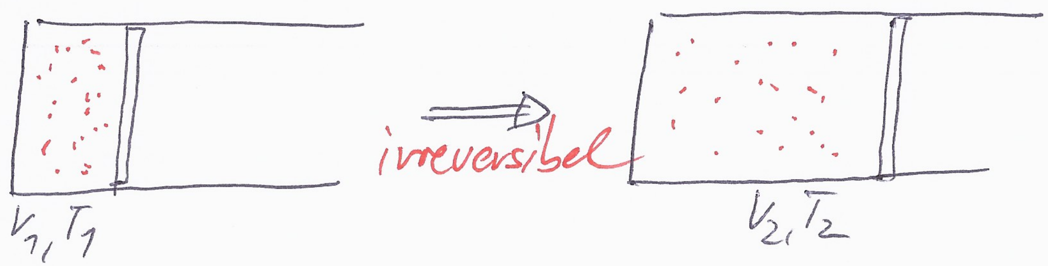


2.6 ISOTHERME ZUSTANDSÄNDERUNGEN

Unterscheide Prozesse ohne und mit Verrichtung von Arbeit:

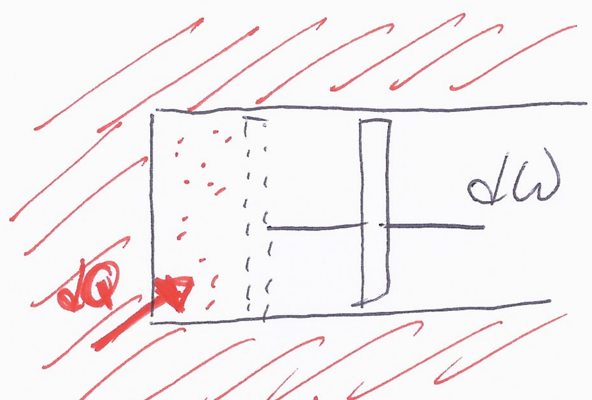
a.) Versuch von Gay-Lussac: isotherme Entspannung

$dW=0,\ dQ=0 \Rightarrow dU=0,\ T=\text{const}$



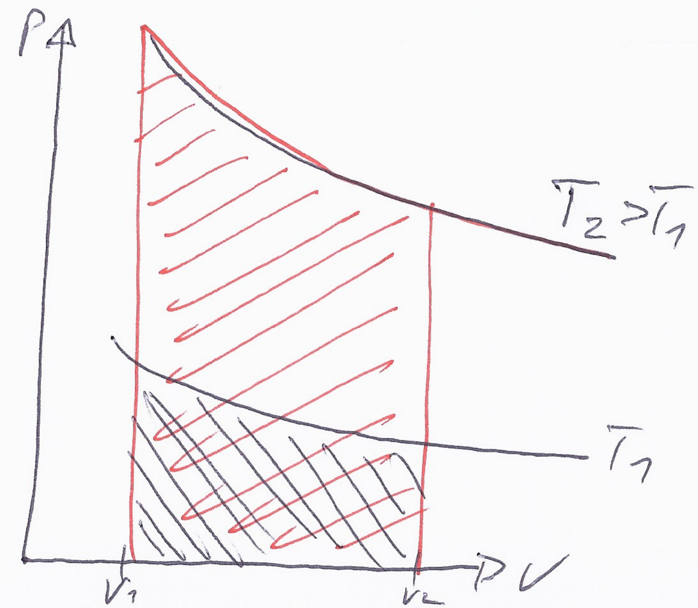
$T_2 = T_1$

b.) $dU=0 \Rightarrow dQ = -dW$



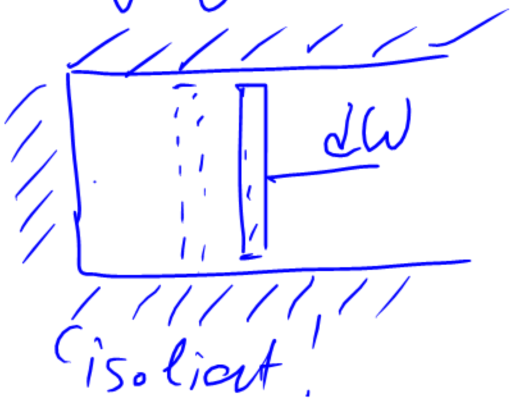
$Q_{1\to2} = -W_{1\to2} = \int_{V_1}^{V_2} p\,dV = \int_{V_1}^{V_2} \frac{nRT}{V}\,dV$

$|W_{1\to2}| = nRT \ln \frac{V_2}{V_1}$



2.6 ADIABATISCHE ZUSTANDSÄNDERUNGEN

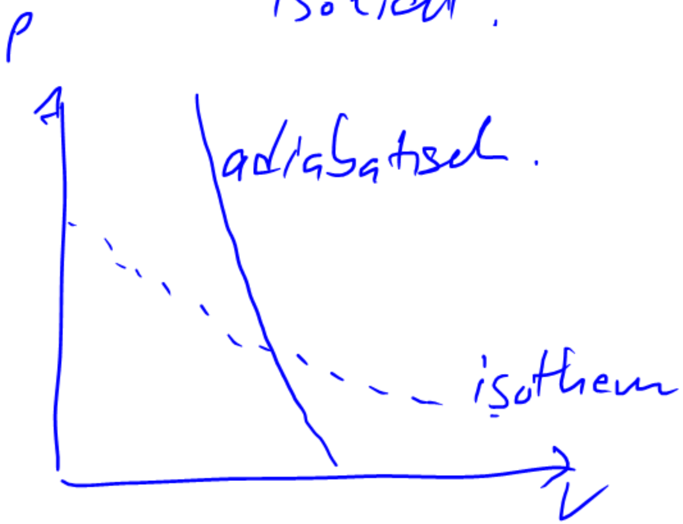
Bedingung: $dQ = 0 \Rightarrow$ wärmeisolierte Systeme



$$0 = dQ = dU - dW = dU + p\,dV$$

$$= n \cdot C_V \cdot dT + \frac{nRT}{V}\,dV \qquad \Big| \cdot \frac{1}{n \cdot C_V \cdot T}$$

$$= \frac{dT}{T} + \frac{R}{C_V}\frac{dV}{V} = \frac{dT}{T} + (\varkappa - 1)\frac{dV}{V}$$



$$0 = \int_{T_1}^{T_2} \frac{dT}{T} + (\varkappa - 1)\int_{V_1}^{V_2} \frac{dV}{V} = \ln\frac{T_2}{T_1} + (\varkappa - 1)\ln\frac{V_2}{V_1}$$

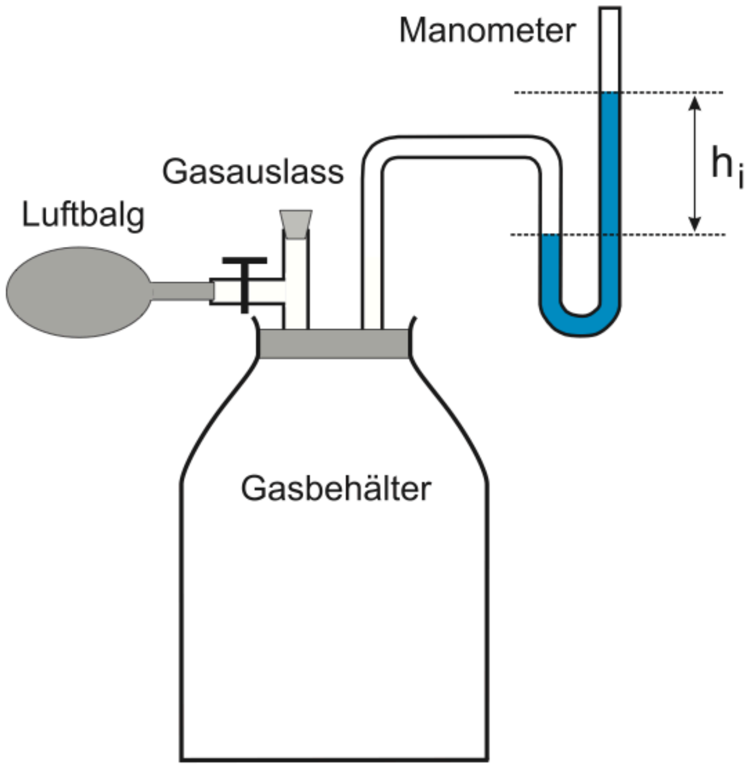
$$\ln\frac{T_2}{T_1} = (\varkappa - 1)\ln\frac{V_1}{V_2} = \ln\left(\frac{V_1}{V_2}\right)^{\varkappa - 1}$$

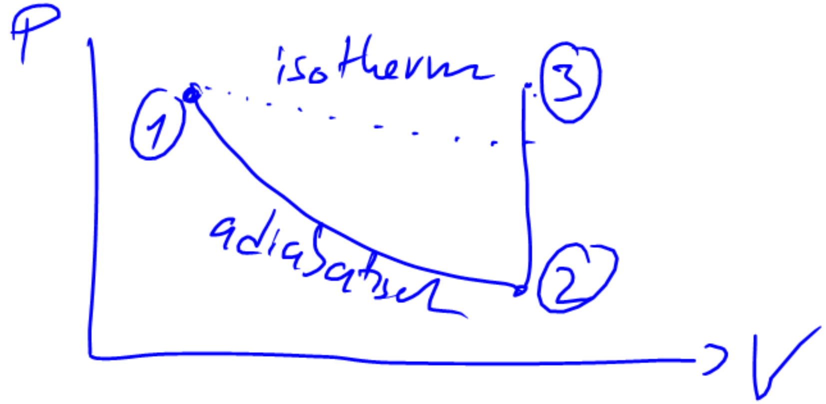
$$\Rightarrow T_2 \cdot V_2^{\varkappa - 1} = T_1 V_1^{\varkappa - 1} \Rightarrow \boxed{T V^{\varkappa - 1} = \text{const} \; ; \; p V^{\varkappa} = \text{const}}$$

Poisson-Gleichungen

2.6 BESTIMMUNG VON κ: CLEMENT-DESORMES

① -> ② Stopfen weg, Abkühlung





② -> ③ Angleichung an Zimmer-T
isochor

③ -> ① isotherm

$$\kappa = \frac{h_1}{h_1 - h_3}$$

Bild: Uni Heidelberg