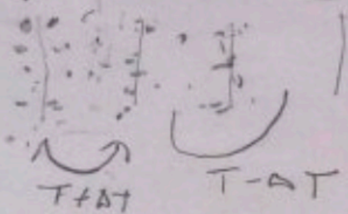
$$C_V = C_P + T\frac{\left(\frac{\partial V}{\partial T}\right)_P^2}{\left(\frac{\partial V}{\partial P}\right)_T}$$

$$C_V - C_P = T\frac{\left(\frac{\partial V}{\partial T}\right)_P^2}{\left(\frac{\partial V}{\partial P}\right)_T}$$

thermal expansion

2 Parameters compressibility

$\left(\frac{\partial V}{\partial P}\right)_S$ sound is adiabatic



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

$$= \frac{\left(\frac{\partial S}{\partial T}\right)_V\left(\frac{\partial V}{\partial P}\right)_T}{\left(\frac{\partial S}{\partial T}\right)_P} = \frac{C_V}{C_P}\left(\frac{\partial V}{\partial P}\right)_T$$

Extensive quantities E, S, F

scale with # particles N

"specific" variables

say energy per particle

$\frac{E}{N} = e$ $\quad E(S,V)$

$E = N e\left(\underbrace{\frac{S}{N}}_{= s}, \underbrace{\frac{V}{N}}_{= v}\right)$

$E = N e(s,v)$

continue this way

$W = N w(s,P)$

$F = N f(T,v)$

$\Phi = N \phi(T,P)$ μ chemical pot.

Variable # particles

$dE = TdS - PdV + \mu dN$

μ: chemical pot.

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

generalized 1^{st} & 2^{nd} law