• Lots of definitions today!

$$\beta \equiv \frac{1}{V}\left(\frac{\partial V}{\partial T}\right)_P \qquad \text{coeff of thermal expansion}$$

$$\kappa_T \equiv -\frac{1}{V}\left(\frac{\partial V}{\partial P}\right)_T \qquad \text{coeff of isothermal compressibility}$$

$$\kappa_{adi} \equiv -\frac{1}{V}\left(\frac{\partial V}{\partial P}\right)_{adi} \qquad \text{coeff of adiabatic compressibility}$$

$$C_V \equiv \left(\frac{dQ}{dT}\right)_V \qquad \text{heat capacity at constant volume}$$

$$C_P \equiv \left(\frac{dQ}{dT}\right)_P \qquad \text{heat capacity at constant pressure}$$

$$\gamma \equiv \frac{C_P}{C_V}$$

Note that C_V and C_P are *extensive* (so depend on how much stuff there is, and thus can't be just looked up on the internet), the others are *intensive* (so can be looked up in a table or on the internet). We can form intensive (look-up-able) versions of C_P and C_V by dividing by another extensive quantity, e.g. the *specific heats*: $c_V \equiv C_V/n$ and $c_P \equiv C_P/n$.

Always the case that $\gamma \equiv C_P/C_V > 1$: more heat required, for fixed ΔT, in case of $P = constant$, because some goes into doing a positive amount of work, whereas at constant V no work is done, so all added heat goes toward increasing the internal energy, and thus the temperature.

We'll then derive some formulae, e.g.

$$dP = \frac{\beta}{\kappa_T}dT - \frac{1}{\kappa_T V}dV$$

Integrate it:

$$P_f - P_i \approx \frac{\beta}{\kappa_T}(T_f - T_i) - \frac{1}{\kappa_T V_{av}}(V_f - V_i).$$

(Give an example here.)

Write $U = U(T,V)$. Exact differential means

$$dU = \left(\frac{\partial U}{\partial T}\right)_V dT + \left(\frac{\partial U}{\partial V}\right)_T dV, \quad \text{with} \quad \left(\frac{\partial}{\partial V}\left(\frac{\partial U}{\partial T}\right)_V\right)_T = \left(\frac{\partial}{\partial T}\left(\frac{\partial U}{\partial V}\right)_T\right)_V.$$

We also see that

$$C_V = \left(\frac{\partial U}{\partial T}\right)_V, \qquad C_P = \left(\frac{\partial U}{\partial T}\right)_V + \left[\left(\frac{\partial U}{\partial V}\right)_T + P\right]V\beta.$$

Ideal gas: $U = C_V T$. $\beta = 1/T$, $\kappa_T = 1/P$, $C_P = C_V + nR$. $C_V = nR/(\gamma - 1)$, $C_P = \gamma nR/(\gamma - 1)$. We'll see later: γ depends on the type of molecule: $\gamma = (f+2)/f$; i.e. $\gamma = 5/3$ for monatomic, $7/5$ for diatomic etc. (up to additional quantum corrections).

Ideal gas, and adiabatic: $PdV = -C_V dT$, $VdP = C_P dT$, $C_V VdP = -C_P PdV$. $dP/P = -\gamma dV/V$, so $PV^\gamma = constant$. $\left(\frac{\partial P}{\partial V}\right)_{adi} = -\gamma P/V = \gamma \left(\frac{\partial P}{\partial V}\right)_T > \left(\frac{\partial P}{\partial V}\right)_T$. So adiabatic curve has steeper slope than isothermal curve in P/V diagram. See here $\kappa_T = \gamma \kappa_{adi}$ (and more generally too).