Specific heat and its features in ideal & real gases

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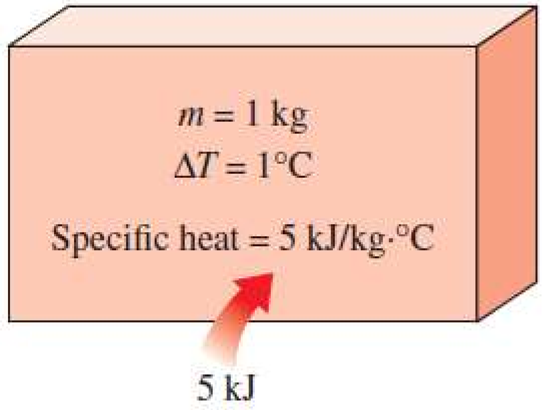
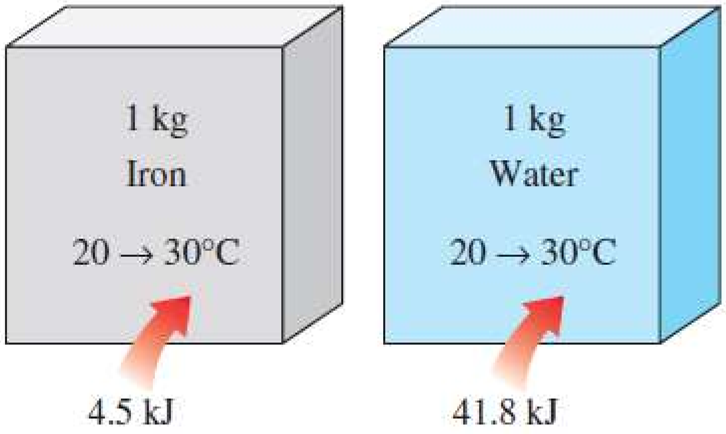
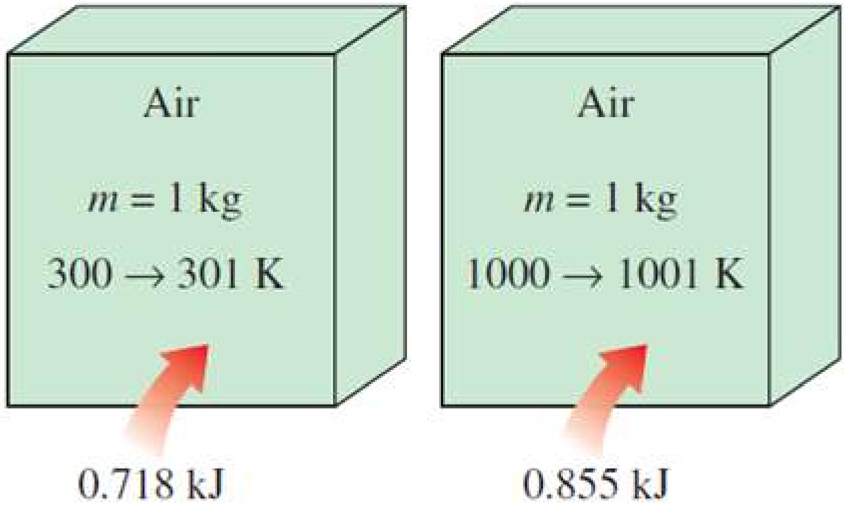
Cyclic processes, Enthalpy & Boundary work for P=0

- Work is a path fxn → Net work from cyclic processes!
- Energy for processes at constant P: $H=U+PV$; $Q - W_{other} = \Delta H$
- Process at $P=0$

Specific heat is a material property

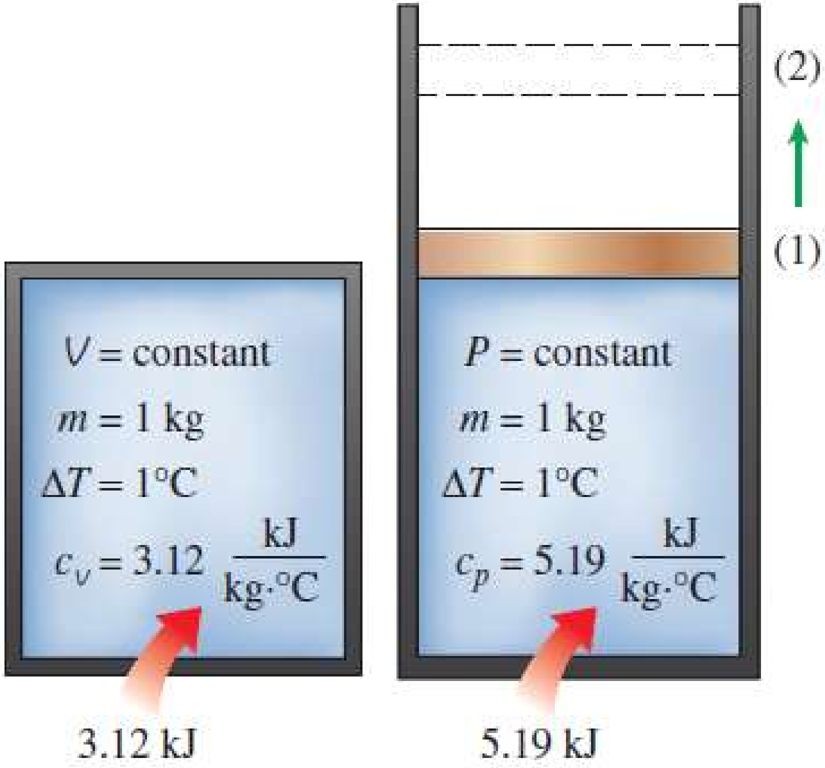






Figs: Cengel & Boles: TD

Specific heat at constant volume and pressure



$$c_v = \left(\frac{\partial u}{\partial T}\right)_v$$

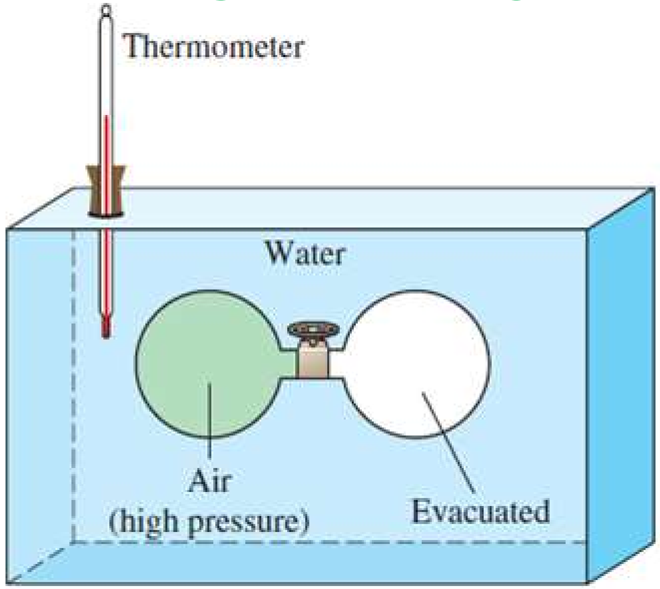
= the change in internal energy with temperature at constant volume

$$c_p = \left(\frac{\partial h}{\partial T}\right)_p$$

= the change in enthalpy with temperature at constant pressure

Figs: Cengel & Boles: TD

Joule's experiment & Specific heat of ideal gas



- No boundary work, P & V varying; Q=0
- T remains constants & hence, U(T)
- Ideal gas: H=U(T)+PV=U(T)+RT=H(T)
- Of course U is U(T)-Degrees of freedom of ideal gas!

$$\Delta u = u_2 - u_1 = \int_1^2 c_v(T)\, dT \qquad \Delta h = h_2 - h_1 = \int_1^2 c_p(T)\, dT$$

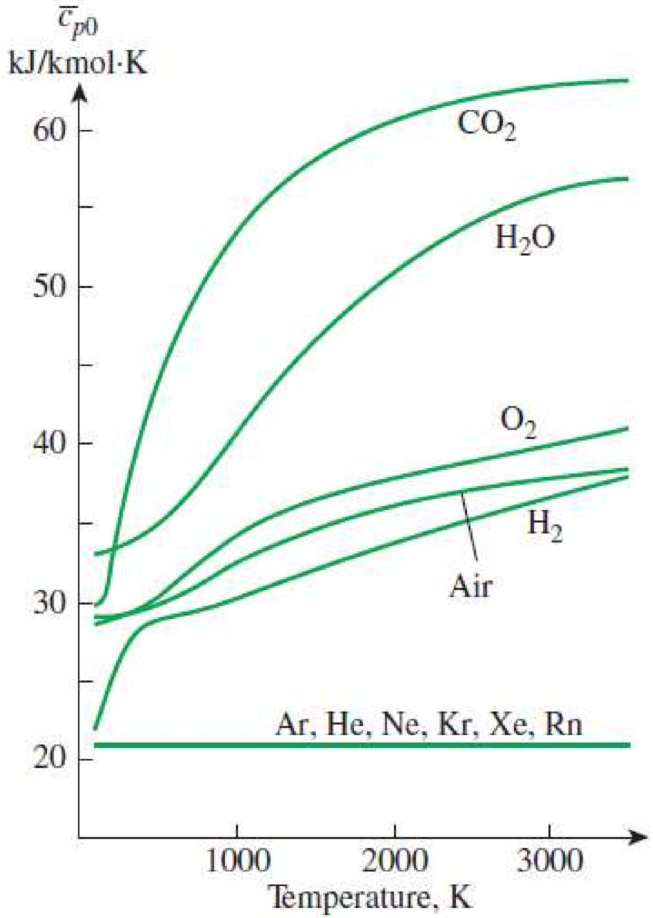
Figs: Cengel & Boles: TD

Specific heat of real gases

- Statistical thermodynamics provides rationale for variation

- Data from charts & tables are used for getting U & H

- Choose an arbitrary reference state and integrate from the reference state



Air

T, K	u, kJ/kg	h, kJ/kg
0	0	0
.	.	.
.	.	.
300	214.07	300.19
310	221.25	310.24
.	.	.

Figs: Cengel & Boles: TD

Three approaches to ΔU & ΔH

$$\Delta u = u_2 - u_1 \text{ (table)}$$

$$\Delta u = \int_1^2 c_v(T)\, dT$$

$$\Delta u \cong c_{v,\text{avg}} \Delta T$$

Figs: Cengel & Boles: TD

Specific heat relationships of ideal gases

$$h = u + RT,$$

$$dh = du + R\,dT$$

$dh = c_p dT$ and $du = c_v dT$

The relationship between c_p, c_v and R

$$c_p = c_v + R \qquad (\mathrm{kJ/kg \cdot K})$$

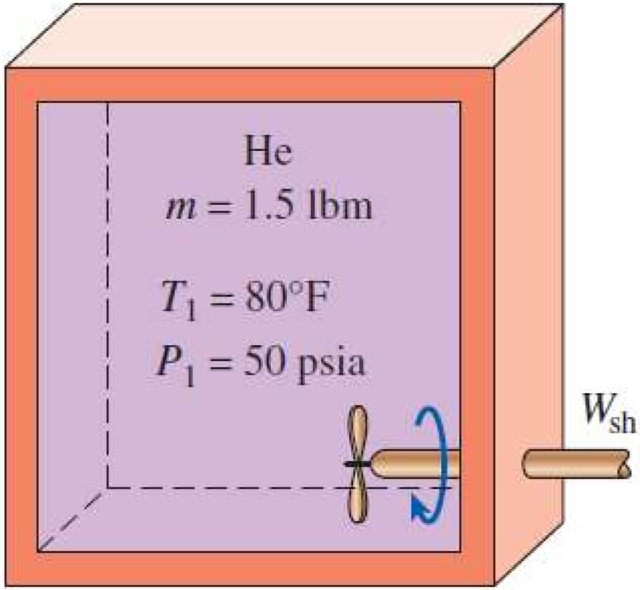
On a molar basis

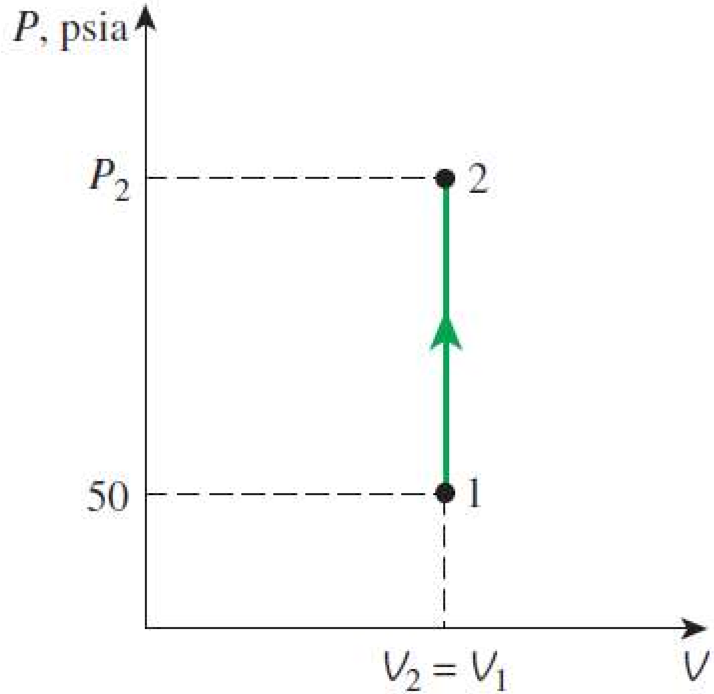
$$\bar{c}_p = \bar{c}_v + R_u \qquad (\mathrm{kJ/kmol \cdot K})$$

$$k = \frac{c_p}{c_v}$$ Specific heat ratio

Figs: Cengel & Boles: TD

Stirring & increase in T & P





$$\underbrace{E_{\text{in}} - E_{\text{out}}}_{\substack{\text{Net energy transfer} \\ \text{by heat, work, and mass}}} = \underbrace{\Delta E_{\text{system}}}_{\substack{\text{Change in internal, kinetic,} \\ \text{potential, etc., energies}}}$$

$$W_{\text{sh,in}} = \Delta U = m(u_2 - u_1) = mc_{\text{v,avg}}(T_2 - T_1)$$

Figs: Cengel & Boles: TD