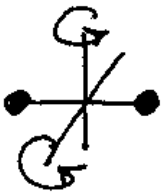
For a monatomic gas, the only energy available to He, Ne, Ar, etc is TRANSLATIONAL KE in three dimensions. Basically each "dimension" contributes $\frac{1}{2} k_B T$ to the internal energy of the gas

$$E_{int} = N\langle KE\rangle = \frac{3}{2} N k_B T = \frac{3}{2} nRT$$

In this case the molar specific heat

$$C_V = \frac{3}{2} R = 12.5 \text{ J/mol K}$$

For a diatomic molecule  the molecule can rotate as well. We call the # of different ways a molecule can store energy the # of DEGREES OF FREEDOM - f



What about vibration? These cannot be excited at room temp. Requires 1000K

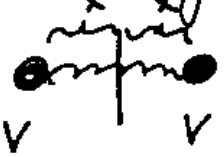
Diatomic molecule 3 TRANSLATIONAL 2 ROTATIONAL

each degree of freedom contributes $\frac{1}{2} kT$ to the internal energy

$$E_{int} = \frac{5}{2} N k_B T = \frac{5}{2} nRT$$

$$C_V = \frac{5}{2} R = 20.8 \text{ J/mol K}$$

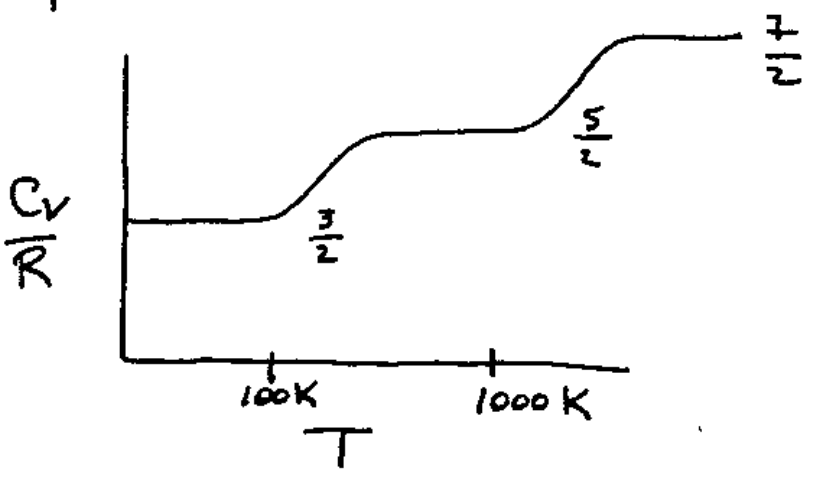
where $\frac{7}{2}R$ ←

What about <u>Vibration</u> - for a diatomic molecule there are two addl degrees of freedom (Corresponding to 

$\frac{1}{2}kx^2$ and $\frac{1}{2}mV^2$) <u>BUT</u> these energies are quantized (so are rotational energies) with typical energies

$$E \sim k \cdot 1000\,K$$

i.e. they cannot be excited at room temperature



In general

$$E_{int} = \frac{f}{2}NkT = \frac{f}{2}nRT$$

$$C_V = \frac{f}{2}R$$

For a solid, an atom can have both K.E. + P.E. in each of 3D, each contributes $\frac{1}{2} k_B T$ to the internal energy of the material

so $E_{int} = \frac{6}{2} N k_B T = 3 N k_B T = 3 n R T$

$$C_V = 3R = 24.9 \text{ J/mol K}$$

In general

$$E_{int} = \frac{f}{2} N k_B T = \frac{f}{2} n R T$$

$$C_V = \frac{f}{2} R$$

Water is unusual for its high specific heat capacity - this is a v. good thing for life on earth - that's why we use hot water bottles + radiators. Maintains heat when hot; takes alot of heat out of engine preventing it from. This is largely because water is a polar molecule e^- bound more tightly to O leaving H as essentially free p^+. Gives a result electrical interactions form a short range ordered molecular structure as a result of PE within this structure, breaking structure apart, etc. Specific heat is v. high