Equipartition: Gives a link between internal energy U of a substance (valid for gases+solids) and its temperature.

$$U = \frac{N_{DOF}}{2} N k T + \text{const}$$

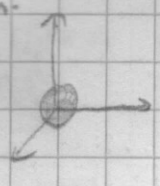
N = # of atoms/molecules, k = Boltzmann const, T = temp (K)

$Nk = nR$ — n = moles, R = ideal gas const

The const N_{DOF} is determined by the degrees of freedom of each particle making up the substance that are "active" at temp T.

$$C_V = \frac{dQ}{dT} = \left(\frac{dU}{dT}\right)_{V,N} = \frac{N_{DOF}}{2} Nk$$

1 atom:



$$U = \frac{3}{2} NkT + \text{const}$$

$$C_V = \left(\frac{dQ}{dT}\right)_V = \left(\frac{dU}{dT}\right)_V = \frac{3}{2} Nk$$

Motion in x, y, z axis. 3 degrees of freedom.

An atom by itself will not rotate. Quantum shows the energy needed is too high.

2 atoms:

O–O   x, y, z   2 rotational

$$U = \frac{3+2}{2} NkT = \frac{5}{2} NkT$$

O~~O   x, y, z   2 rotation   Vibration (mom.+pot)

$$\frac{3+2+2}{2} NkT$$

Heat capacity:

$$C_V = \frac{N_{DOF}}{2} R$$

Simple model for solids

$PV = NkT$ does not apply

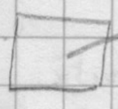
Equipartition does work!

Quick shortcut:

$N_{DOF} = 3 + 2(\text{num springs})$

HW2: Heat capacity + Temp   10/11/23

1)



10^4 molecules

2500 nitrogen } in thermal eq

7500 argon

$m_{N_2} = 28\,\text{g/mol}$

$M_{Ar} = 40\,\text{g/mol}$

$Q = 5 \times 10^{-17}\,\text{J}$

$T = ?$

$dU = dQ - \cancel{pdV}$ $U = Q$

$Q_A = \frac{3}{2}(7500)kT$ $Q_{N_2} = \frac{5}{2}(2500)kT$ $k = 1.38e{-23}$

$5 \times 10^{-17} = 17500\,kT$

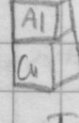
$\boxed{T = 207\ \text{Kelvin}}$

2)

Al – 27 g/mol

Cu – 63.5 g/mol

Are like mass on spring.



Al 200 g $T_{al} = 76.85°C$

Cu 500 g $T_{Cu} = 26.85°C$

$T_F = ?$

$Q = C\Delta T$

$-C_{Al}(T_F - T_i) = C_{Cu}(T_F - T_i)$

$C_{Al}T_F - C_{Al}T_i + C_{Cu}T_F - C_{Cu}T_2$

$T_F(C_{Al} + C_{Cu}) = C_{Al}T_i + C_{Cu}T_2$

$C_{Al} = \frac{6}{2}Nk_B = 3\left(\underbrace{200/27}_{\text{moles}} \cdot \underbrace{6.022 \times 10^{23}}_{\text{avagadro}}\right) \cdot 1.381 \times 10^{-23}$

≈ 184.8

$C_{Cu} \approx 196.96$

$\boxed{T_F \approx 51.1°C}$