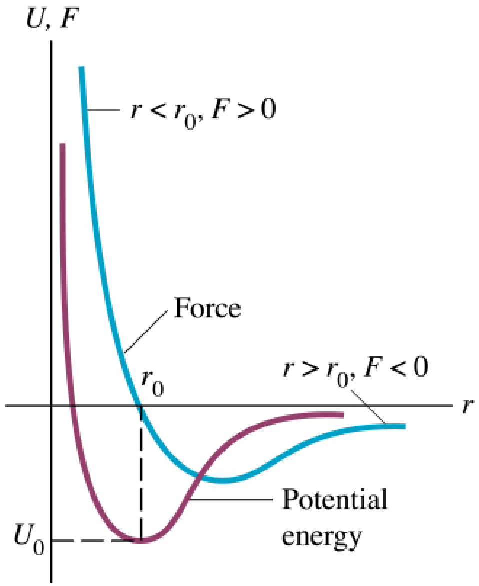
18-2. Molecular Properties of Matter

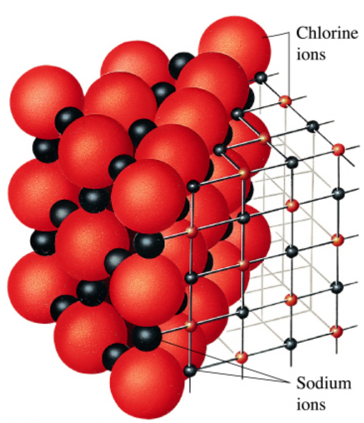


$F(r) = -dU/dr$

$r > r_o$, $F < 0$, U increases w/ increasing r

$r < r_o$, $F > 0$, U increases w/ decreasing r

At r_o, $F = 0$, U at minumum



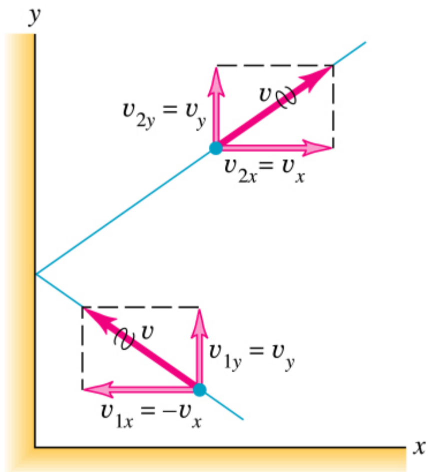
Temperature rises:

Solid ⟶ liquid ⟶ gas

Intermolecular distance ↗

Molecular kinetic energy ↗

18-3. Kinetic-Molecular Model of an Ideal Gas



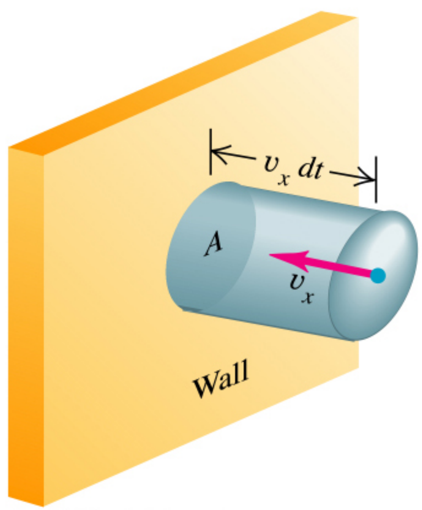
Average translational kinetic energy for N molecules

$$K_{tr} = \frac{1}{2} m (v^2)_{av} \times N$$

$$p = \frac{F}{A} = \frac{Nm(v^2)_{av}}{3V}$$

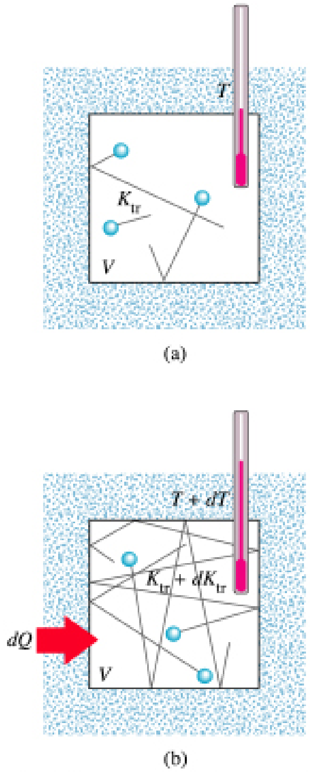
$$pV = \frac{2}{3} N [\frac{1}{2} m (v^2)_{av}] = \frac{2}{3} K_{tr}$$

$$K_{tr} = \frac{3}{2} nRT$$



$$\frac{1}{2} m (v^2)_{av} = \frac{3}{2} kT$$ —Average translational kinetic energy of a gas molecule

18-4. Heat Capacity



Consider a gas at constant volume

Define molar heat capacity at const. Volume: C_V

Adding heat dQ into the system:

$$dQ = nC_V dT$$

$$dK_{tr} = \frac{3}{2} nRdT$$

Thus

$$nC_V dT = \frac{3}{2} nRdT$$

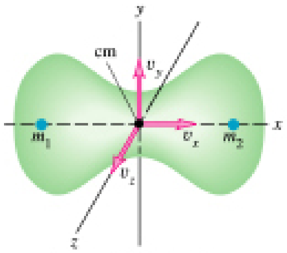
$$\boxed{C_V = \frac{3}{2} R}$$

Ideal gas of point particles

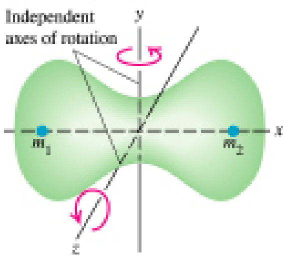
$$= 12.47 \text{ J/mol} \cdot \text{K}$$

Applies to monatomic gases, way off for diatomic & polyatomic gases

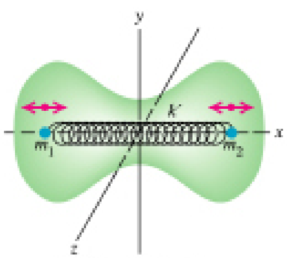
Equipartition of Energy



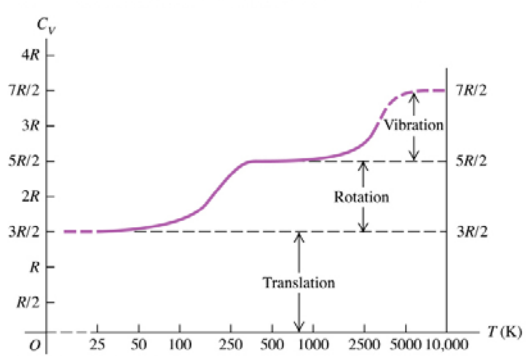
(a) Translational motion



(b) Rotational motion



(c) Vibrational motion



Equipartition of Energy:

Each velocity component (linear or angular) is associated with a kinetic energy per molecule of $kT/2$.

Degrees of freedom:

# of velocity components needed to describe the motion of a molecule completely.

Monatomic gas (He, Ar, etc):

3 degrees of freedom

av. kinetic energy/molecule 3 ($kT/2$)

C_V=3R/2 =12.47 J/mol K

Diatomic molecules

3 translational + 2 rotational degrees of freedom = 5

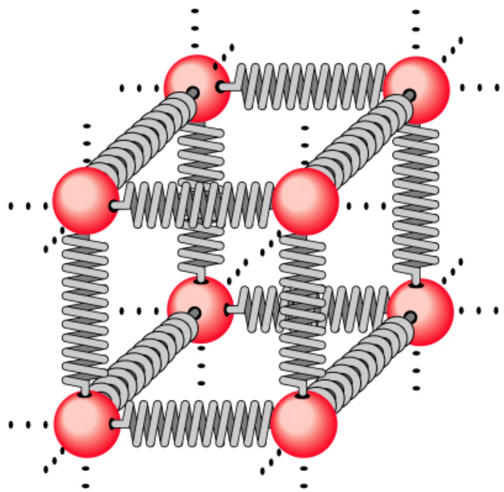
av. kinetic energy/molecule 5 ($kT/2$)

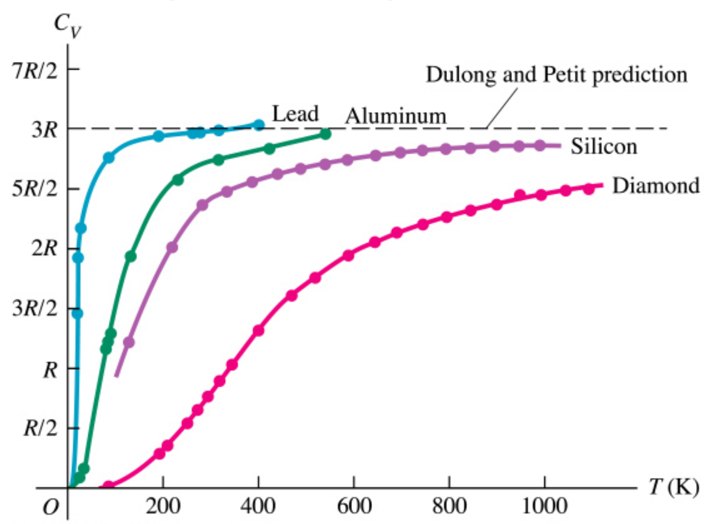
C_V=5R/2 = 20.79 J/mol K

Vibrational motion:

Also contribute, at higher energy (temperature)

Heat Capacity of Solids





Monatomic Solid:

Crystal with N identical atoms

Each atom has $3kT$ energy
kinetic + potential

$E_{total}=3NkT=3nRT$

Rule of Dulong & Petit

$C_V=3R$ – *ideal monatomic solid*
$= 24.9$ J/mol K

18-6. Phases of Matter