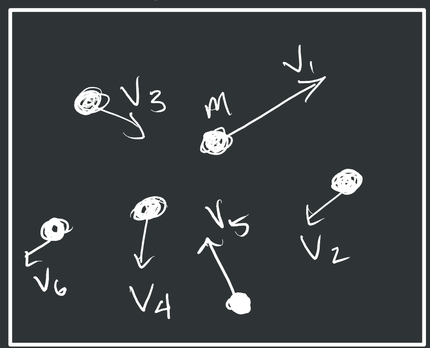
After this video you can

- discuss the scope of thermodynamics
- discuss the physical interpretation of temperature
- distinguish between a microscopic and macroscopic view of matter

thermodynamics → physics of heat
→ energy is stored in matter
→ extract energy from matter

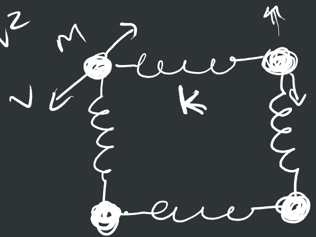
gas

$K = \frac{1}{2} m v^2$



solid

$K = \frac{1}{2} m v^2$



pressure
volume
number

} ideal gas law

want to know the energy stored in matter

internal energy

$K_t = N \cdot \langle K \rangle$

→ per particle

$U_{int} = N \langle U \rangle$

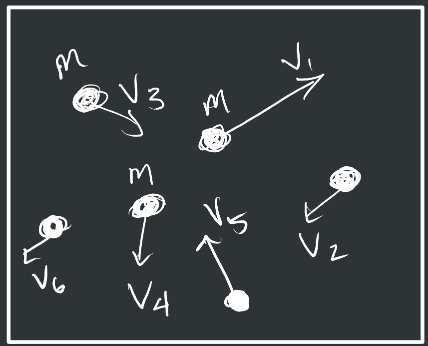
$K_t = U_i$

← int. energy

temperature → proportional to the average energy per particle

After this you can

- discuss the ways of measure the amount of atoms/molecules in a collection
- use molar mass to determine the number of particles or moles of particles in a collection



volume

$$\boxed{\rho = \frac{M}{V}}$$

mass density
(volumetric mass density)

mass

- total mass, M
- mass per particle, m
- $M = m \cdot N$
- units, kg, atomic mass units

number

- $N = \frac{M}{m}$

$\frac{M}{N} = m$

volume

- container
- m^3, liter

$\frac{N}{V}$ = number density

m, mass per particle (atom)

number of protons and neutrons in an atom/molecule is equal to the mass (in grams) of <u>one mole</u> of that substance

$$He \rightarrow 4 \text{ amu}$$

$$\underbrace{4\ \frac{\text{gram}}{\text{mole}}}$$

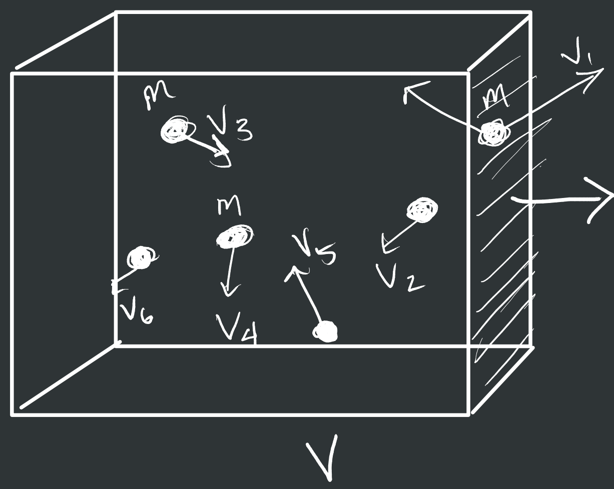
$$\underbrace{1 \text{ mole} = 6.022 \cdot 10^{23} \text{ particles}}_{\text{Avagadro's number} = N_A}$$

$$n_m = \frac{N}{N_A}$$

$$4\ \frac{\text{grams}}{\cancel{\text{mole}}} \cdot \frac{1\ \cancel{\text{mole}}}{6.022 \cdot 10^{23} \text{ particles}} = \underline{\qquad\qquad}\ \frac{\text{grams}}{\text{particle}}$$

After this you can
- discuss pressure as a macroscopic quantity
- discuss the model of a gas known as the idea gas law
- connect the temperature of a gas to the kinetic energy and average velocity

↳ of an ideal gas



$$\frac{\langle F \rangle}{A} = \text{Pressure}$$

$$\left[\frac{\text{Newton}}{m^2}\right] = [\text{Pascal}]$$

$1\ atm = 101.3\ kPa$

$1\ atm = 1.013 \cdot 10^5\ Pa$

gauge pressure vs. absolute pressure

$$P_{abs} = P_{gauge} + P_{atm}$$

Ideal Gas Law - relates pressure, volume, number and temperature

microscopic form $\boxed{P \cdot V = N k_B T}$

↳ Boltzmann's constant

$k_B = 1.38 \cdot 10^{-23}\ J/K$

macroscopic form

$$\boxed{P \cdot V = n_m R \cdot T}$$

$\hookrightarrow$ universal gas constant

$R = 8.31 \ J/K \cdot mol$

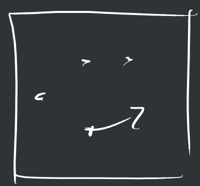
$$n_m \cdot R = N \cdot k_B$$

$\uparrow$ 1 mole

$\uparrow$ $6.022 \cdot 10^{23}$ part. $= N_A$

$$R = N_A \cdot k_B = 6.022 \cdot \cancel{10^{23}} \cdot 1.38 \cdot \cancel{10^{-23}}$$

$$R = 8.31 \ J/K \cdot mol$$



ideal gas

$\langle K \rangle \propto T$

$\hookrightarrow \langle K \rangle = T \times$ some constant

$$\boxed{\langle K \rangle = \frac{3}{2} k_B \cdot T}$$

$$K = \frac{1}{2} m v^2$$

$$\underbrace{\langle K \rangle = \frac{1}{\cancel{2}} m \langle v^2 \rangle = \frac{3}{\cancel{2}} k_B T}$$

$$m \langle v^2 \rangle = 3 k_B T$$

$\downarrow$

$$K_t = N \cdot \langle K \rangle$$

$$\boxed{K_t = \frac{3}{2}\underbrace{N k_B T}_{PV = N k_B T}}$$

$$\boxed{K_t = \frac{3}{2} \cdot P \cdot V}$$

$$\langle v^2 \rangle = \frac{3 k_B T}{m}$$

$$\underbrace{\sqrt{\langle v^2 \rangle}}_{\text{root mean square velocity}} = \sqrt{\frac{3 k_B T}{m}}$$

root mean square velocity

$$\rightarrow \boxed{V_{rms} = \sqrt{\frac{3 k_B T}{m}}}$$