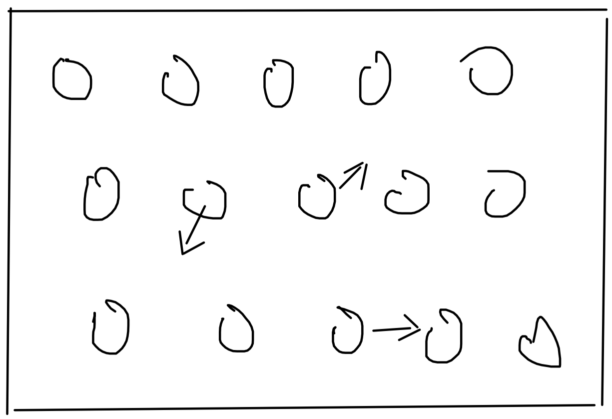
show an understanding that internal energy is determined by the state of the system and that it can be expressed as the sum of a random distribution of kinetic and potential energies associated with the molecules of a system

Internal Energy

Dr K M Hock

What is heat?



Molecules move

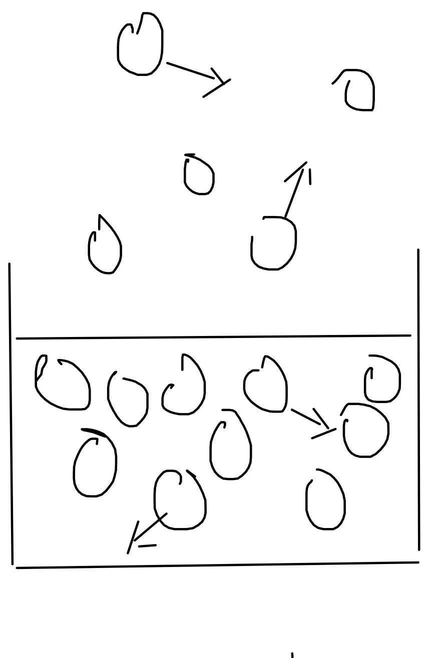
↓

Kinetic energy

Molecules attract

↓

Potential energy



Heat

↓

KE ↑ PE ↑

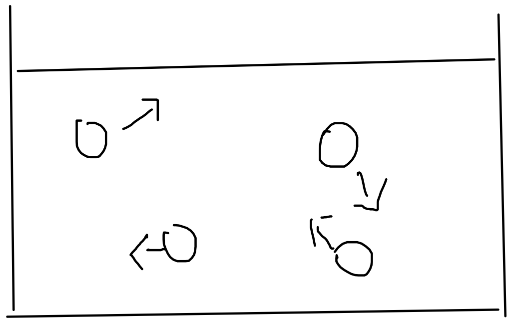
Internal energy, $U = PE + KE$ of molecules relate a rise in temperature of a body to an increase in its internal energy

Temperature

Dr K M Hock

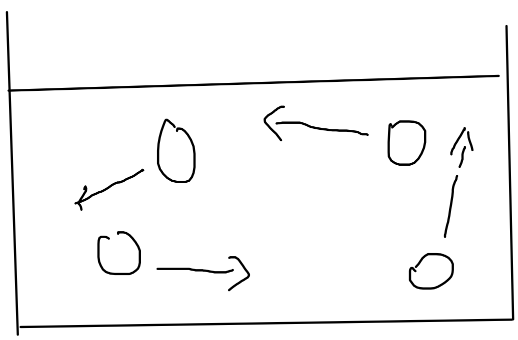
Internal Energy

25°C



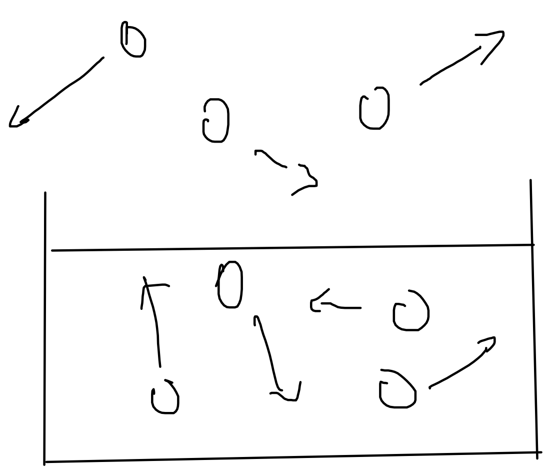
KE , PE

60°C



KE↑ , PE

100°C

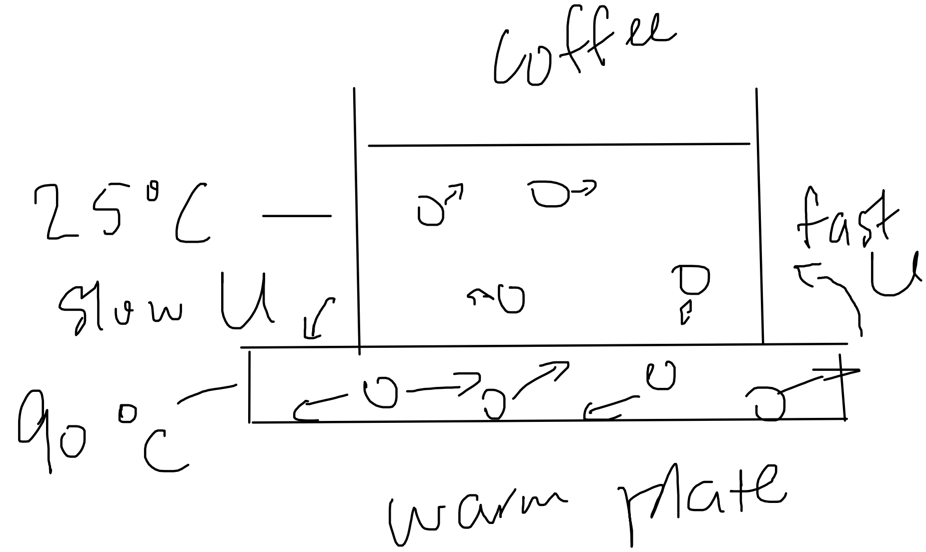


KE↑ PE↑

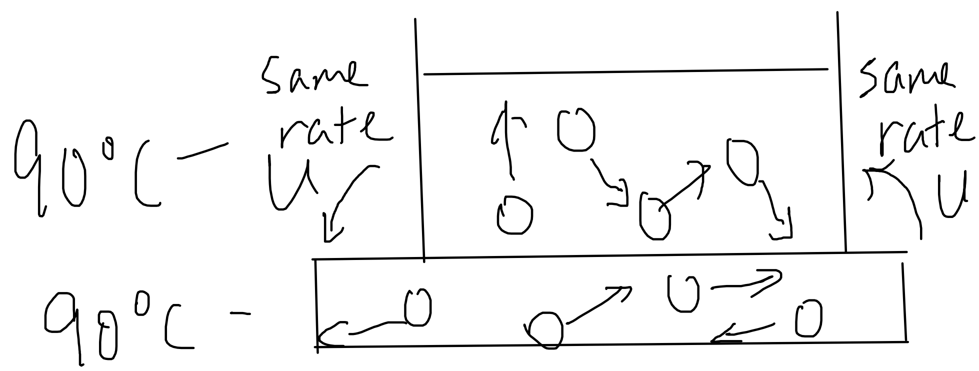
show an understanding that regions of equal temperature are in thermal equilibrium

Thermal Equilibrium

Dr K M Hock



Heat transfer



0 Net Transfer

Thermal equilibrium

↕

Equal temperature

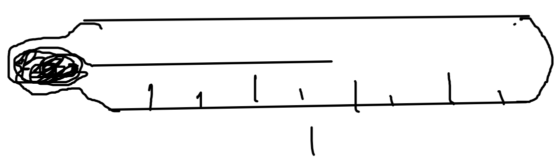
(bodies in contact)

show an understanding that there is an absolute scale of temperature which does not depend on the property of any particular substance, i.e. the thermodynamic scale

Temperature Scale

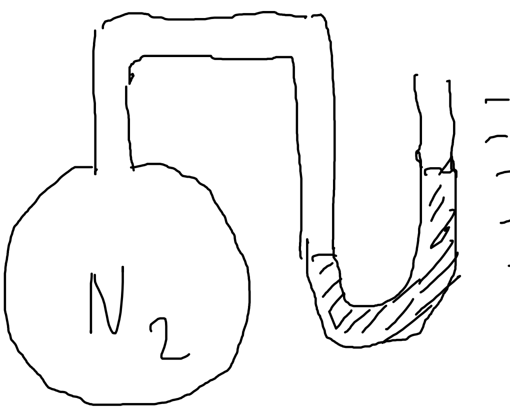
Dr K M Hock

Thermometers make use of materials.



- Mercury

15°C – Can be a bit different if alcohol used.



– 298 K

– Can also be a bit different if different gas used.

But if pressure very low → ideal gas, does not depend on actual gas (material) used:

Absolute scale: $T(K) = \theta(°C) + 273.15$

apply the concept that, on the thermodynamic (Kelvin) scale, absolute zero is the temperature at which all substances have a minimum internal energy

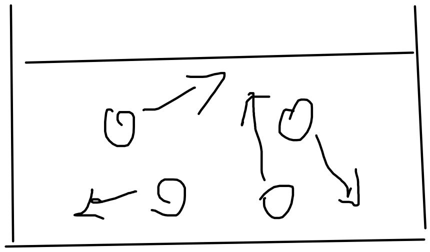
Thermodynamic Scale

Dr K M Hock

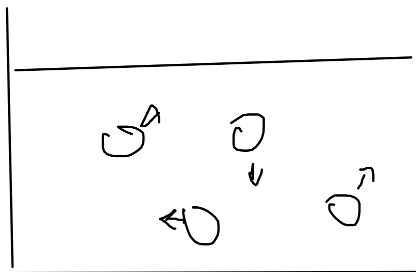
Internal energy

KE PE

K	°C
298.15	25

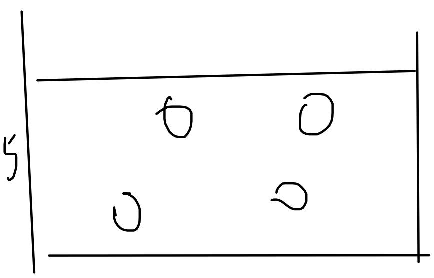


K	°C
273.15	0



KE ↓ PE ↓

K	°C
0	−273.15



KE ~0 PE ~0

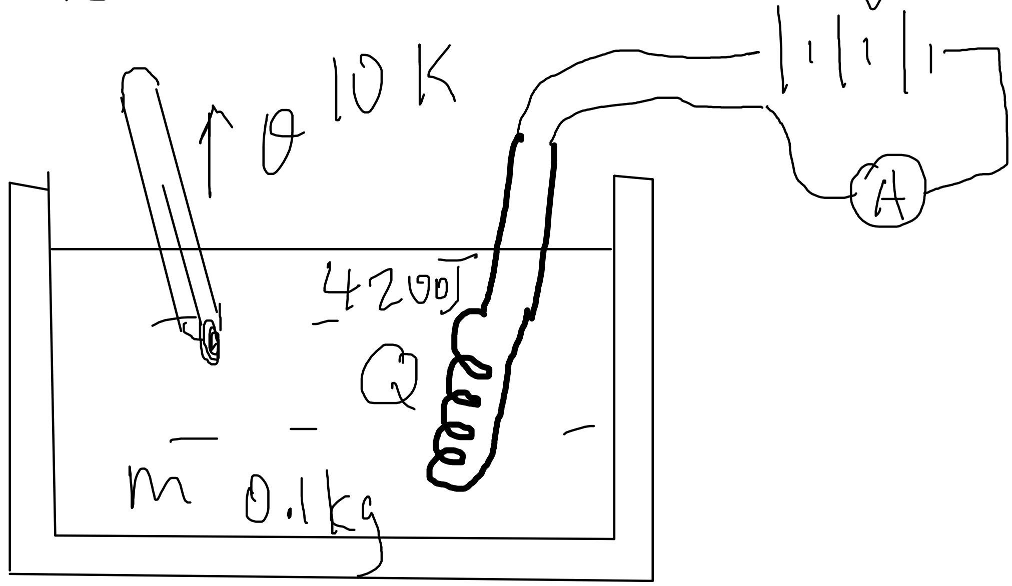
Absolute zero

define and use the concept of specific heat capacity, and identify the main principles of its determination by electrical methods

Specific Heat Capacity

Dr K M Hock

Q = heat



e.g. How much heat is needed to warm 1kg of the liquid by 1K?

$$\text{Answer} = \frac{\text{heat} \sim 4200\,\text{J}}{\text{mass} \times \text{temperature change}}$$

mass: 0.1kg, temperature change: 10 K

$$\boxed{c = \frac{Q}{m\theta}}$$

Q — VIt if electrical

specific heat capacity

specific → per unit mass

define and use the concept of specific latent heat, and identify the main principles of its determination by electrical methods

Specific Latent Heat

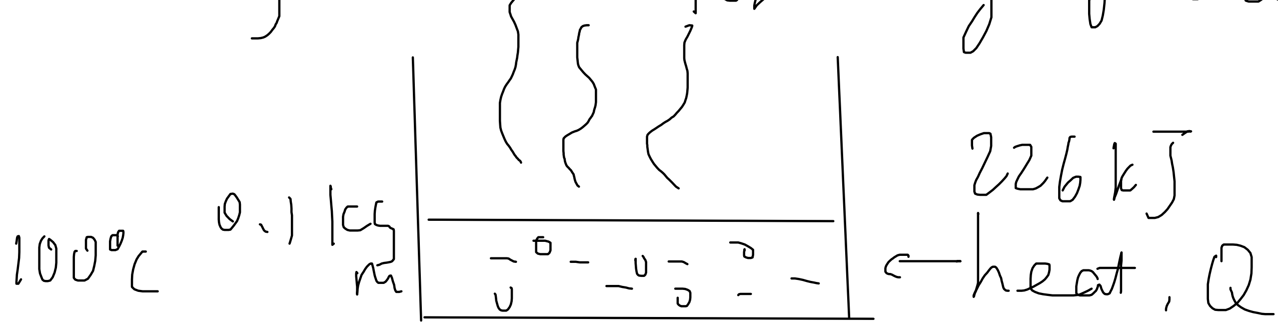
Dr K M Hock

Melting - heat for 1kg of ice?

specific latent heat of fusion = $\frac{\text{heat}}{\text{mass}}$ (heat ~ 33.4 kJ, mass ~ 0.1kg)

$$l_f = \frac{Q}{m}$$

Boiling - heat for 1kg of water?



Specific latent heat of vaporisation = $\frac{\text{heat}}{\text{mass}}$ (heat ~ 226 kJ, mass ~ 0.1kg)

Specific → per unit mass

$$l_v = \frac{Q}{m}$$

Q → VIt if electrical

explain using a simple kinetic model for matter why (i) melting and boiling take place without a change in temperat
(ii) the specific latent heat of vaporisation is higher than specific latent heat of fusion for the same substance (iii) cooling effect accompanies evaporation

Simple Kinetic Model

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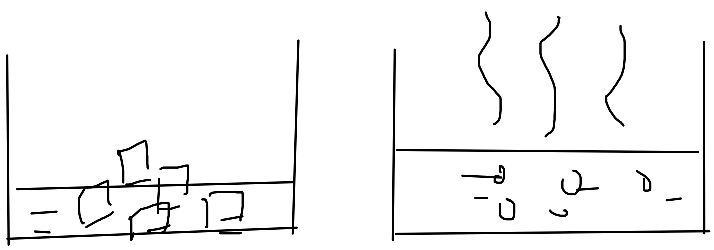
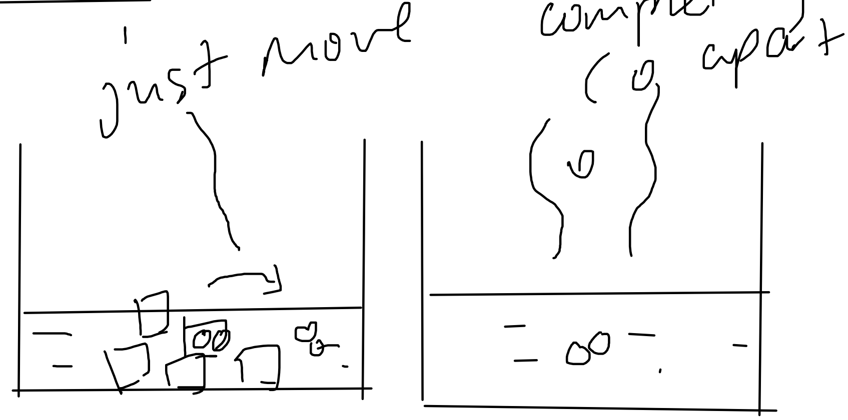
Temperature fixed



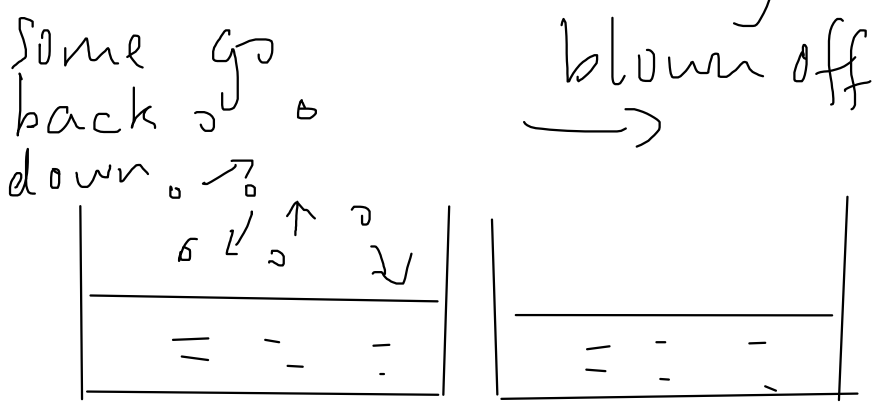
heat
↓
Overcome attraction
↓
KE ~ same

Specific Latent Heat

Much more heat to boil than to melt



Evaporation Cooling



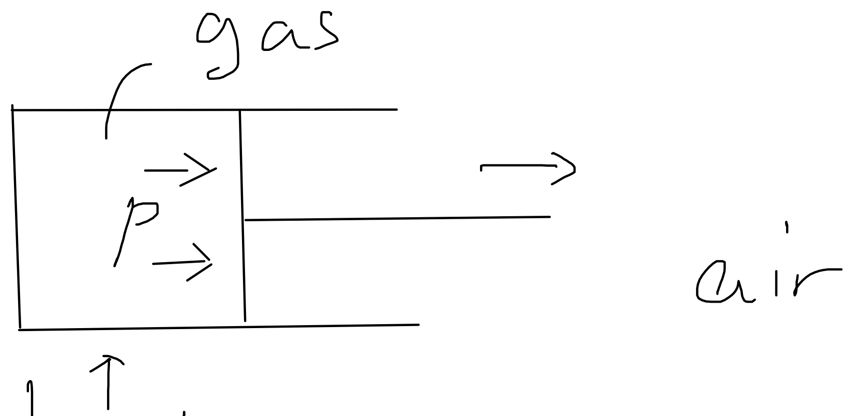
– KE

KE cannot go back in

recall and use the first law of thermodynamics expressed in terms of the change in internal energy, the heating of the system and the work done on the system

1st Law of Thermodynamics

Dr K M Hock

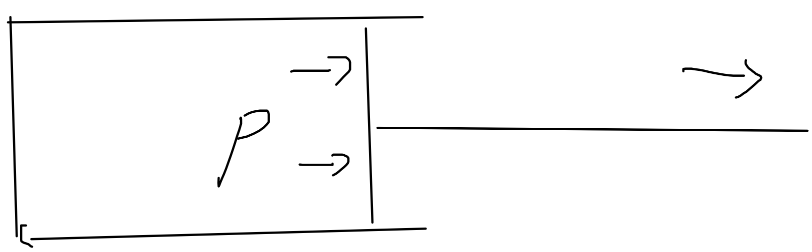


Q heat

Internal energy, U

W, work done by gas when it expands

} Q, U, W.



Conservation of energy

$$Q = \Delta U + W$$

ΔU: increase in U

recall and use the ideal gas equation pV = nRT, where n is the amount of gas in moles

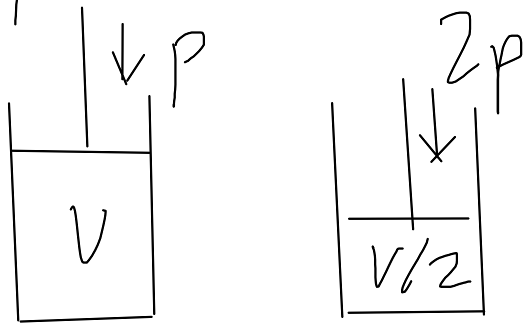
Ideal Gas Law

Dr K M Hock

Boyle's law

T fixed

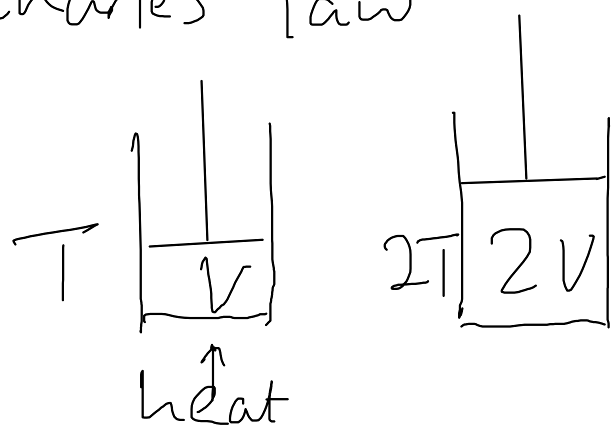
$V \propto \frac{1}{p}$



Charle's law

p fixed

$V \propto T$



Ideal Gas law

Combine

$V \propto \frac{T}{p}$

$$pV = nRT$$

n: no. of moles

R: 8.31 J/K/mol

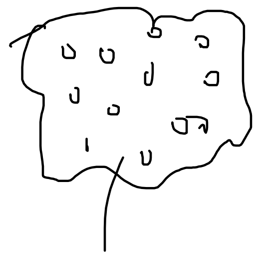
show an understanding of the significance of the Avogadro constant as the number of atoms in 0.012 kg of carbon-12

Avogadro Constant

Dr K M Hock

$$N_A = 6.022 \times 10^{23}$$

Carbon-12



— 0.012 g

no. of atoms $= 6.022 \times 10^{23}$

Way to count atoms.

6.022×10^{23} particles = 1 mole

e.g. 1 pair of shoes = 2 shoes

1 dozen eggs = 12 eggs

1 mole of carbon atoms = 6.022×10^{23} atoms

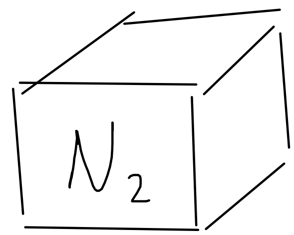
1 mole of O_2 gas = 6.022×10^{23} molecules

use molar quantities where one mole of any substance is the amount containing a number of particles equal to the Avogadro constant

Mole Concept

Dr K M Hock

e.g.



$p = 10^5$ Pa

$V = 10^{-3}$ m^3

$T = 300$ K

Find the no. of moles of N_2, and no. of molecules.

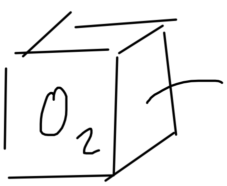
$pV = nRT \rightarrow n = \frac{pV}{RT}$

$n = \frac{10^5 \times 10^{-3}}{8.31 \times 300} = 0.04011$ mol

No. of molecules $= n \times N_A$

$= 0.04011 \times 6.022 \times 10^{23} = 2.415 \times 10^{22}$

e.g.



$p = 10^5$ Pa, $T = 298$ K, $n = 1$ mol. Find V.

$V = \frac{nRT}{p} = \frac{1 \times 8.31 \times 298}{10^5} = 0.024$ m^3

recall and apply the relationship that the mean kinetic energy of a molecule of an ideal gas is proportional to the thermodynamic temperature to new situations or to solve related problems.

KE and Temperature

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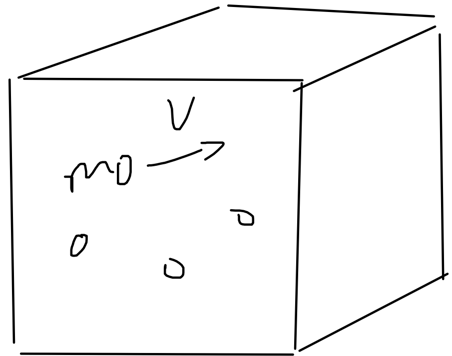
Ideal gas



$\frac{1}{2}mv^2 \propto T$

(no PE ∵ no attraction)

e.g. if $T \times 2$, then $KE \times 2$.

Total KE of molecules (1 mole)

$$U = \frac{3}{2}RT$$

R: 8.31 J/K/mol