

Thermal equilibrium:

Energy is transferred from a region of high temperature to a region of low temperature

When two objects are in contact with each other and they are the same temperature, there is no net transfer of energy between them

Kelvin (absolute scale)

$$T(K) = \theta(^{\circ}C) + 273$$

$$0^{\circ}C = 273K \quad 10^{\circ}C = 283K$$

The Celsius scale is based on the boiling and freezing point of water which depend on pressure

Solids: particles vibrate in a fixed ordered

If temp $\uparrow$ amplitude of vibrations $\uparrow$

Little spacing between particles



Liquids: particles can flow past each other

vibrate but not in fixed positions

Slightly larger spacing between particles



Gas: particles are far apart.

They don't exert forces on each other except in collision.

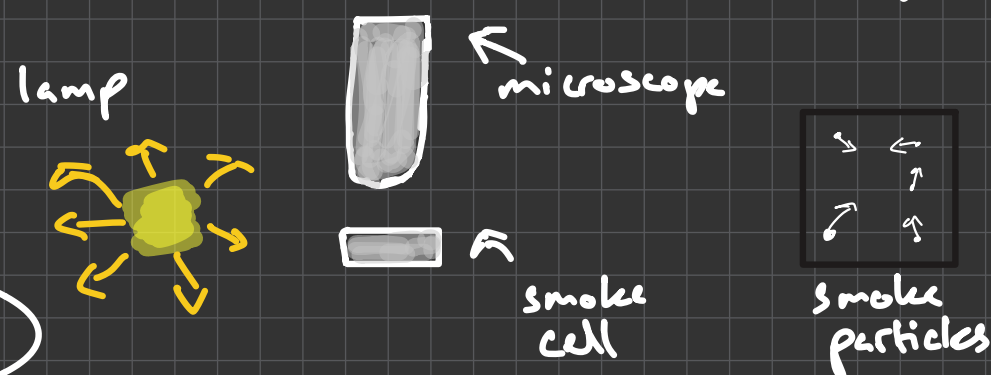
The particles move in random linear motion



Thermal Physics

Brownian motion

Smoke cell experiment / Pollen grains in a liquid



Observations:

The smoke particles are moving in random linear motion

The air particles can not be seen

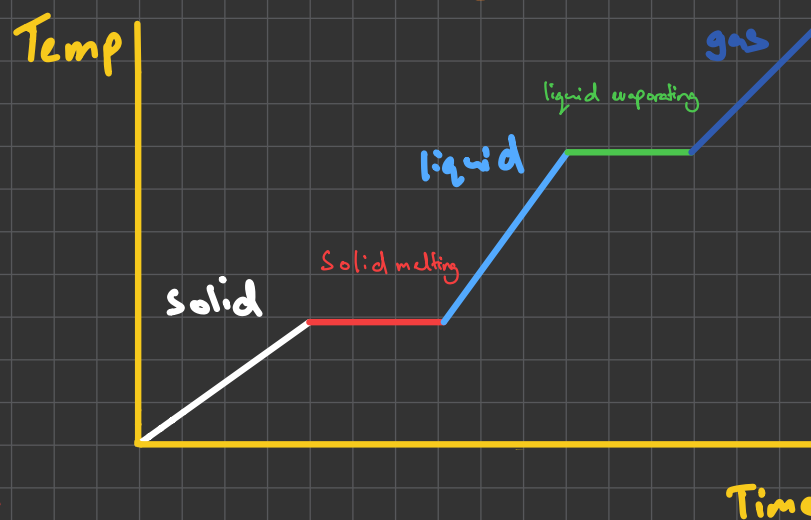
Conclusions:

The smoke particles are colliding with the air particles, which must also be moving with random linear motion.

The air particles must be a lot smaller than the smoke particles

Internal energy is the sum of the randomly distributed kinetic and potential energies of all of the particles of a substance.

$$\text{internal energy} = \sum KE + \sum PE$$



$KE \uparrow$ PE increases by a small amount

KE constant $PE \uparrow$

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Specific heat capacity:

Definition: energy required to raise the temperature of 1kg of a substance by 1K

$$E = mc \Delta \theta \quad c = \frac{E}{m \Delta \theta}$$

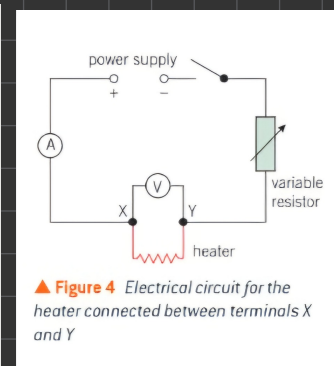
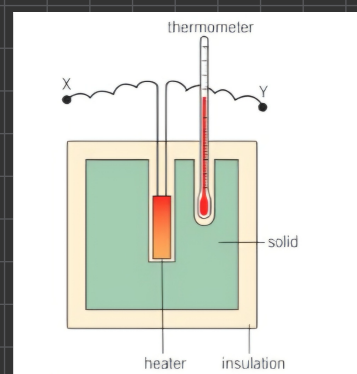


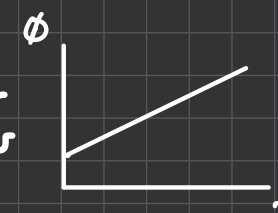
Figure 4 Electrical circuit for the heater connected between terminals X and Y

Measure the mass of the water using a top pan balance
Measure the current with an ammeter and V with voltmeter
Measure the temperature on set intervals with a thermometer
Measure the time interval with a stop clock

To reduce uncertainty stir the liquid regularly as the temperature of the liquid will be uneven

Some of the energy will go into the container and this can be included in calculations

Plot a graph of temp against time



$$E = mc \Delta \theta$$

$$P \times t = mc \Delta \theta$$

$$P = mc \frac{\Delta \theta}{t}$$

$$P = mc \times \text{gradient}$$

$$c = \frac{P}{m \times \text{gradient}}$$

$$c = \frac{VI}{m \times \text{gradient}}$$

Specific Latent Heat

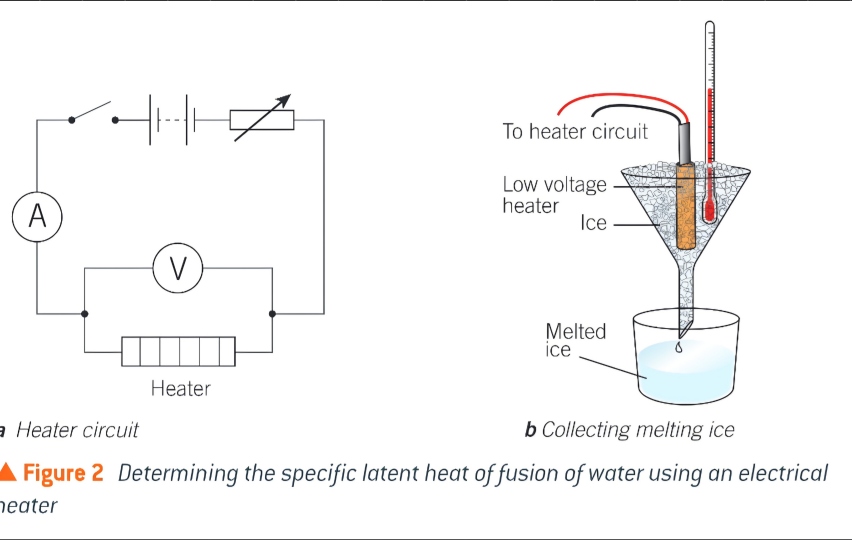
The specific latent heat of a substance is the energy per kg required to change its state without any change in temperature

The specific latent heat of a substance is the energy per kg required to melt a substance at a constant temperature

The specific latent heat of vaporisation is the energy per kg required to vaporise a substance at a constant temperature

$E = mL$ $L = \frac{E}{m}$

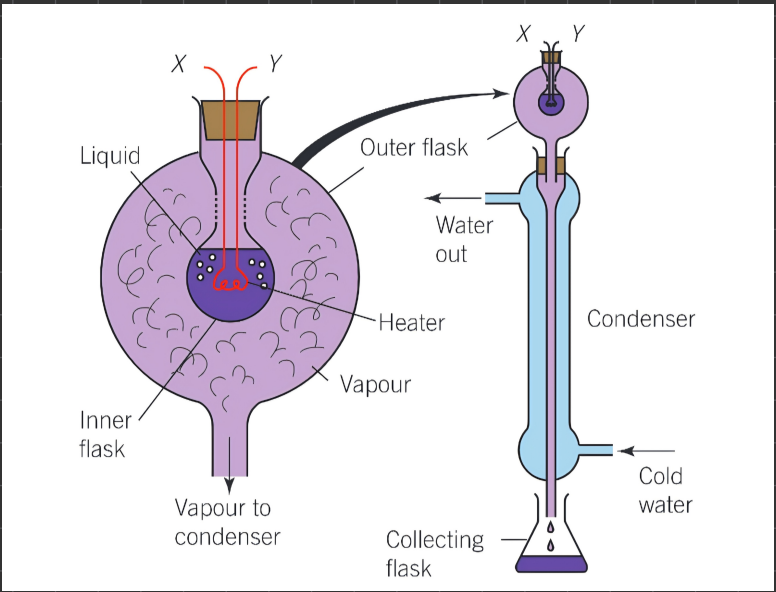
Experiment to determine specific latent heat



Measure current with an ammeter
Measure voltage with a voltmeter
Let the heat melt the ice for a set time, measured with a stopwatch
Measure the mass of the ice that has melted.

Subtract the mass of the ice melted from the control

Use: $E = mL_f$
 $L_f = \frac{E}{m} = \frac{VI}{m}$



Mole: the amount of substance which contains the same number of particles as there atoms in 12g of Carbon 12

$N_A = 6.02 \times 10^{23}$ particles

number of moles = $\frac{\text{mass}}{\text{molar mass}}$

number of particles = NO of moles $\times N_A$

Ideal gasses

Assumptions of the model of the kinetic theory of gasses:

1. Large number of particles in a random rapid motion
2. Individual particles occupy negligible volume compared to the volume of the gas
3. All collisions are perfectly elastic and the time spent in collision is negligible compared to the time spent between collisions
4. Negligible forces between particles except during collision

1. Take a condenser to collect and measure the mass of a liquid that has changed phase.
2. Measure the current with an ammeter and voltage with a voltmeter
3. Turn on the supply and heat the material for a time measured with a timer until all the liquid has boiled
4. The thermometer should be regularly checked to ensure that the temperature of the material remains at its boiling point
5. Use $L = \frac{E}{M}$ to determine the specific latent heat of vaporisation of the material where $E = VIt$
 $L_v = \frac{VIt}{m}$

The ideal gas law equation

In an ideal gas, the forces between particles are assumed to be zero except during collision

The potential energy of the gas is assumed to be zero

$PV = nRT$
 pressure (P), Volume (V), number of moles (n), gas law constant (R = 8.31), temp in kelvin (T)

$PV = NkT$
 number of particles (N), Boltzmann's constant (k = 1.38×10^{-23}), Temp in Kelvin (T)

$nR = Nk$

$k = \frac{nR}{N}$ $N = n \times N_A$ $k = \frac{nR}{n \times N_A} = \frac{R}{N_A}$

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

Boyle's Law

$T = \text{constant}$ for a fixed amount of gas

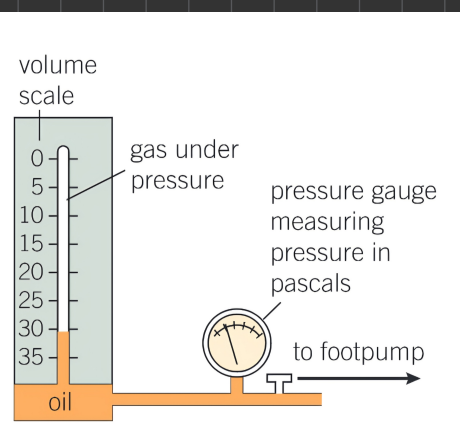
$$pV = nRT$$

$$pV = \text{constant}$$

$$p = \frac{\text{constant}}{V}$$

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

Boyle's Law Experiment



Take a sealed tube of pressured gas with a volume scale

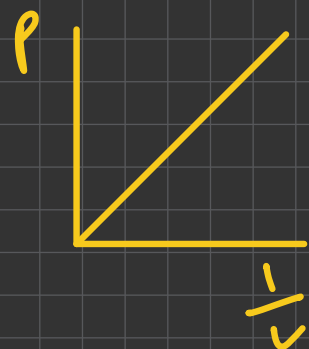
Vary the pressure of the gas and record the volume of the gas

Plot a graph of p against $1/V$

If the graph is a straight line through the origin this shows that our relationship is correct

Measurements:

- volume with the scale
- pressure with the pressure gauge/sensor
- vary the pressure slowly so that temp remains constant



$$pV = \text{constant}$$

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

$$p = \frac{k}{V}$$

$$p = \left(\frac{k}{V} \right) \times \left(\frac{1}{V} \right) + 0$$

gradient = nRT

Pressure - Temperature law

$$V = \text{constant} \quad n = \text{constant}$$

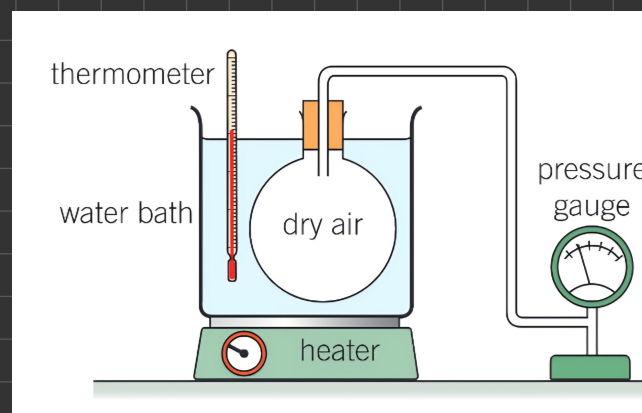
$$pV = nRT$$

$$p = \frac{nR}{V} T \quad \frac{nR}{V} \text{ is a constant}$$

$$p = \text{constant} \times T$$

$$p \propto T$$

Pressure - Temperature Law Experiment



Submerge a round bottom flask of fixed volume in a water bath

Place the water bath on a heater or use a bunsen burner to heat the water

Vary the temperature and measure the pressure

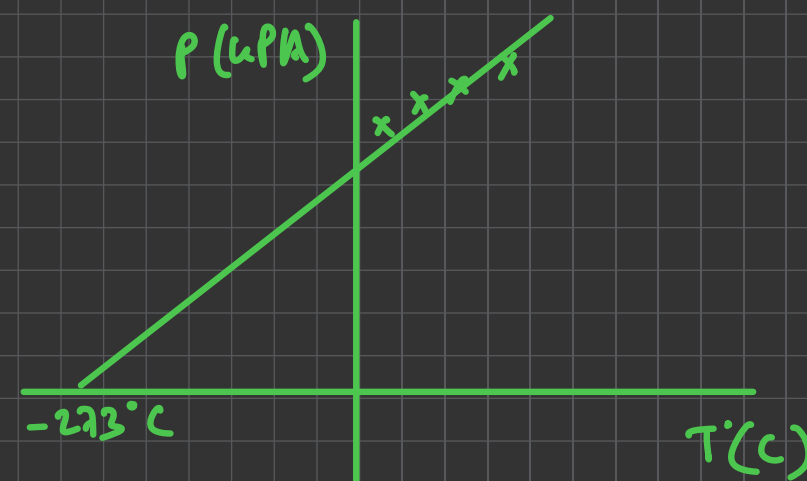
Measurements:

- pressure with a pressure gauge
- temperature with a thermometer

Plot a graph of p against T

Draw a line of best fit and extrapolate to find absolute zero

At zero pressure you will find absolute zero



$$F = pA \quad p = h\rho g$$

$$F = h\rho gA$$

$$F = pVg$$

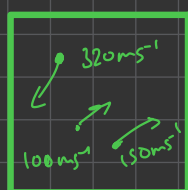
Pressure in terms of the kinetic model

$$1) \Delta p = mv - m(-v) = -2mv$$

$$2) F = \frac{\Delta p}{\Delta t} = \frac{-2mv}{\Delta t}$$

$$3) P = \frac{\text{sum of all forces}}{\text{Area}} = \frac{\sum F}{A}$$

Root mean squared speed



$$\frac{320^2 + 150^2 + 100^2}{3}$$

$$= 4.4967 \times 10^4 \text{ m}^2 \text{ s}^{-2}$$

$$\sqrt{4.4967 \times 10^4} = 210 \text{ ms}^{-1}$$

$$pV = \frac{1}{3} Nm \bar{c}^2$$

$$p = \frac{1}{3} p \times \bar{c}^2$$

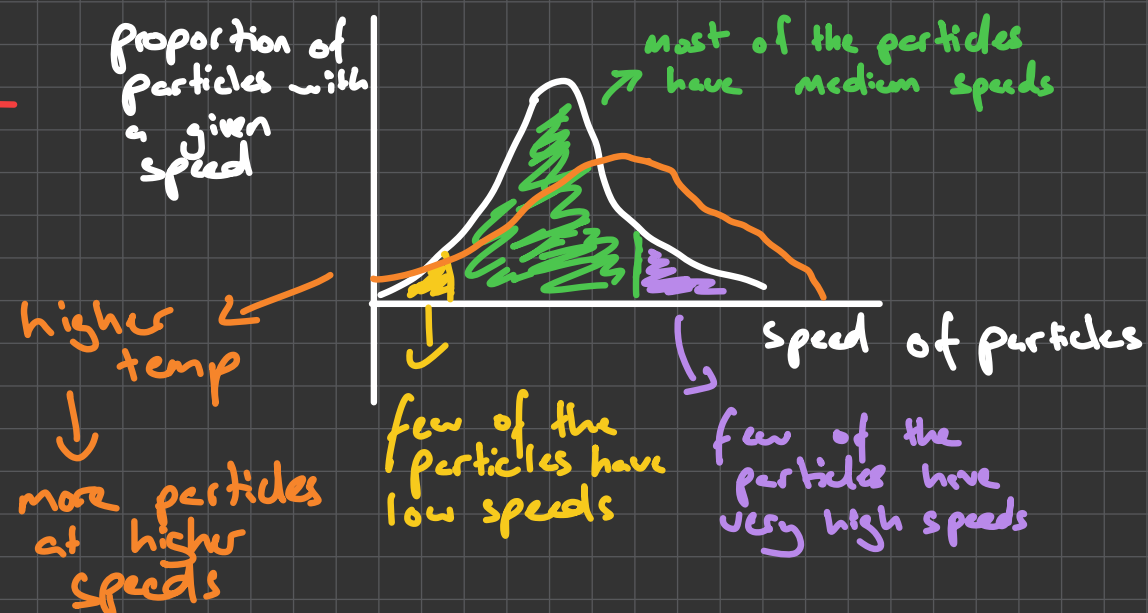
$$p = \frac{m}{V} \quad p = \frac{Nm}{V}$$

$$V = \frac{Nm}{p}$$

$$p \times \frac{Nm}{p} = \frac{1}{3} Nm \bar{c}^2$$

$$p = \frac{1}{3} p \times \bar{c}^2$$

Maxwell Boltzmann Distribution



$$\frac{1}{2} m \bar{c}^2 = \frac{3}{2} kT$$

mass of a particle of a gas

Squared mean speed

temperature in k

Boltzmann's constant 1.38×10^{-23}

$$pV = \frac{1}{3} Nm \bar{c}^2$$

$$pV = NkT$$

$$\frac{1}{3} Nm \bar{c}^2 = NkT$$

$$\frac{1}{3} m \bar{c}^2 = kT$$

$$\frac{2}{3} \times \frac{1}{2} m \bar{c}^2 = kT$$

$$\frac{1}{2} m \bar{c}^2 = \frac{3}{2} kT$$