CAIE Physics A-level

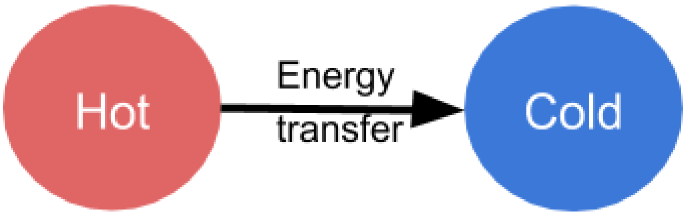
Topic 14: Temperature

Notes

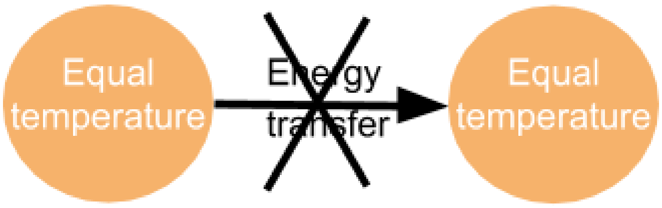
14 - Temperature (A-level only)

14.1 - Thermal Equilibrium

Thermal energy is always transferred from an area of higher temperature to that of a lower temperature, as shown in the diagram below.



Energy will be transferred between objects in thermal contact of different temperatures until they reach the **same** temperature. This is known as **thermal equilibrium**.



It is important to note that if object A is in thermal equilibrium with object B, and B is in thermal equilibrium with object C, then object A and C must also be in thermal equilibrium. This is known as the **zeroth law of thermodynamics**.

14.2 - Temperature Scales

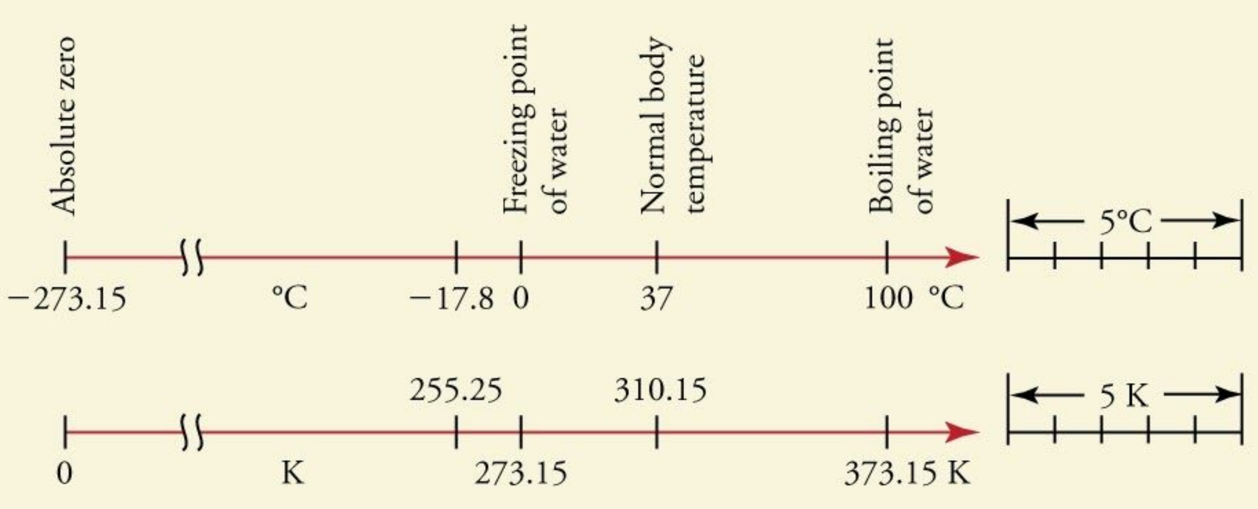
Many **physical properties** vary with temperature, meaning they can be used to measure temperature. Below are some examples:

- Change in resistance of a metallic conductor or semiconductor (such as a thermistor)
- Voltage produced across a thermocouple
- Change in volume of a liquid
- Change in volume of a gas at constant pressure
- Change in pressure of a gas at constant volume

The **thermodynamic scale** or the **Kelvin scale** is an absolute scale of temperature that does not depend on the property of any substance, whereas the Celsius scale for instance, is dependent on the melting point (0° C) and boiling point (100° C) of pure water at atmospheric pressure.
The lowest possible temperature, **absolute zero**, is represented as 0 K on the Kelvin scale. This is the temperature at which particles have **no kinetic energy** and the volume and pressure of a gas are zero.

All equations in thermal physics will use temperature measured in kelvin (K). A change of 1 K is equal to a change of 1°C , and to convert between the two you can use the formula:

$K = C + 273.15$ Where K is the temperature in kelvin and C is the temperature in Celsius.



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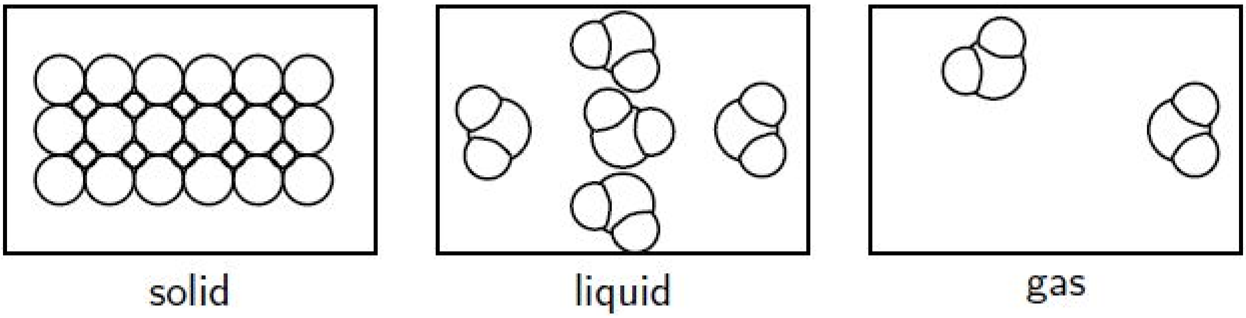
14.3 - Specific Heat Capacity and Specific Latent Heat

The **kinetic model of matter** can be used to explain the structure of solids, liquids and gases. This model is based on the following suggestions:

- Matter is formed of **particles**
- The particles can **move**
- The particles experience **intermolecular forces**

Most substances experience 3 distinct **phases**, which are determined by the energy of the substance. These phases are solid, liquid and gas, and can be explained using the kinetic model as below:

- ➔ **Solid -** Particles are fixed but can vibrate since the intermolecular forces are large. Particles are very close together.
- ➔ **Liquid -** Particles have more energy, are much more free to move and are further apart than in a solid. Intermolecular forces are smaller than in a solid but still relatively large.
- ➔ **Gas -** Particles are much further apart and can move even more freely since th intermolecular forces are very weak. Particles have more energy than in a liquid.



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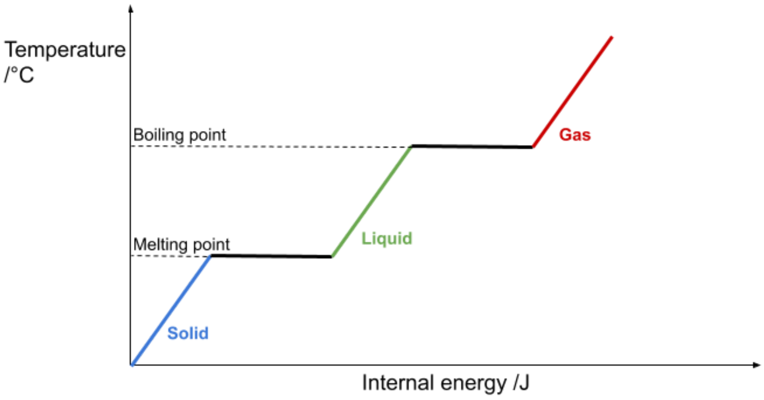
The **internal energy** of a body is equal to the sum of all of the kinetic energies and potential energies of **all** its particles. The kinetic and potential energies of a body are **randomly distributed**.

When the state of a substance is changed, its internal energy also changes. This is because the **potential energy of the system changes, whilst the kinetic energy of the system is kept constant**. This can be demonstrated by measuring the temperature of water as it boils and melts:

- **Boiling -**
  The temperature increases up until 100°C, after which the energy gained through heating the water is no longer used to increase the temperature (and therefore kinetic energy), but instead is used to break bonds between water molecules so it can change state to water vapour, and so the potential energy is increased.
- **Melting -**
  The temperature of ice increases up until 0°C, after which the energy gained through heating the water is no longer used to increase the temperature, but instead is used to break bonds between water molecules so it can change state to liquid water, and so the potential energy is increased.

Below is a graph showing how the internal energy of a substance varies with temperature:



The **specific heat capacity** of a substance is the amount of energy required to increase the temperature of 1 kg of a substance by 1 °C/1 K, without changing its state.

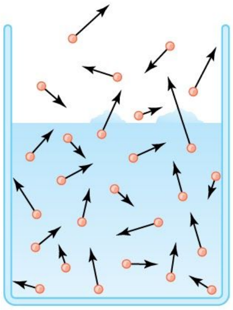
You can measure the amount of energy required to change the temperature of a substance using the following formula: $Q = mc\Delta\theta$ Where Q is energy required, m is the mass, c is the specific heat capacity, and $\Delta\theta$ is the change in temperature.

The **specific latent heat** of a substance is the amount of energy required to change the state of 1 kg of material, without changing its temperature. There are two types of specific latent heat: the **specific latent heat of fusion** (when solid changes to liquid) and **specific latent heat of vaporisation** (when liquid changes to gas).

You can measure the amount of energy required to change the state of a substance using the following formula: $Q = ml$ Where Q is energy required and l is the specific latent heat.

The specific latent heat of vaporisation is usually **larger** than the specific latent heat of fusion of the same substance as more intermolecular bonds must be broken (so more work must be done) to change a substance from a liquid to a gas, than when changing from a solid to a liquid.

As mentioned above, the kinetic energies of particles in a liquid will be random and once a particle in a liquid gains enough energy, it will leave the liquid and **evaporate**, leaving behind particles with lower kinetic energies. Therefore the kinetic energy of particles decreases and as kinetic energy is proportional to temperature, the temperature of the liquid will decrease.



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You can calculate the **specific heat capacity (c)** of a material by:

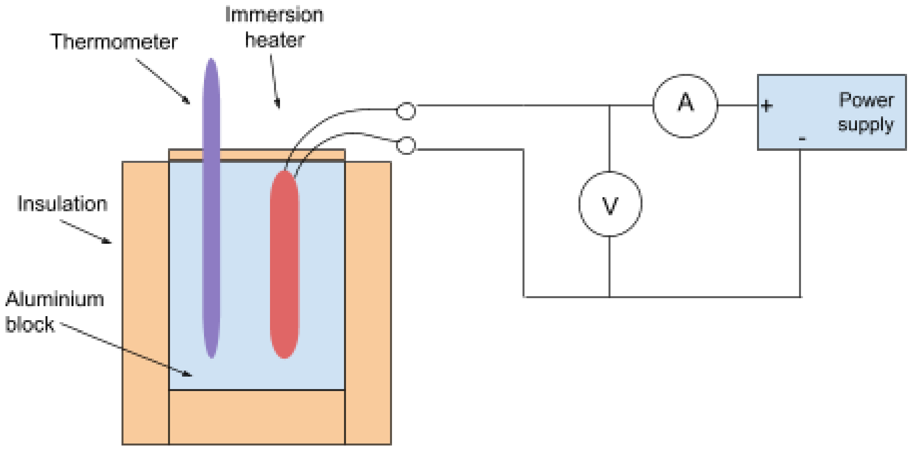
- **Measuring the mass of the material that will be heated (m)** using a top-pan balance
- **Measuring the energy input into the material (Q)** by calculating the power input by the heater (using values of voltage and current) and multiplying this by the time it is turned on
- **Calculating the temperature change (Δθ)** by finding the difference between the initial and final temperatures

And then using the following formula:

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

The calculated specific heat capacity will be **larger** than the actual value due to energy losses to the environment through resistance in the wires in the circuit, and heat being radiated away from the material. Energy losses to the environment can be decreased by insulating the material.

Below is a diagram for an experiment finding the specific heat capacity of aluminium:



You can calculate the **specific latent heat (l)** of a material by:

- **Measuring the energy input into the material (Q)** by calculating the power input by the heater (using values of voltage and current) and multiplying this by the time it is turned on.

- **Measuring the change in mass of the material (m)** - this will either be a gain in mass when calculating latent heat of fusion or a loss in mass when calculating latent heat of vaporisation. This value will give an indication of the mass of the material which has changed state.

Then use the following formula:

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

Again energy gains/losses to the environment will affect the calculated value of specific latent heat. You can reduce their effect by measuring the energy gained/lost before the heater is switched on, however this value will vary.

Below are the equipment diagrams for experiments finding the latent heat of fusion (left) and latent heat of vaporisation (right).