Energy Matters – Heat

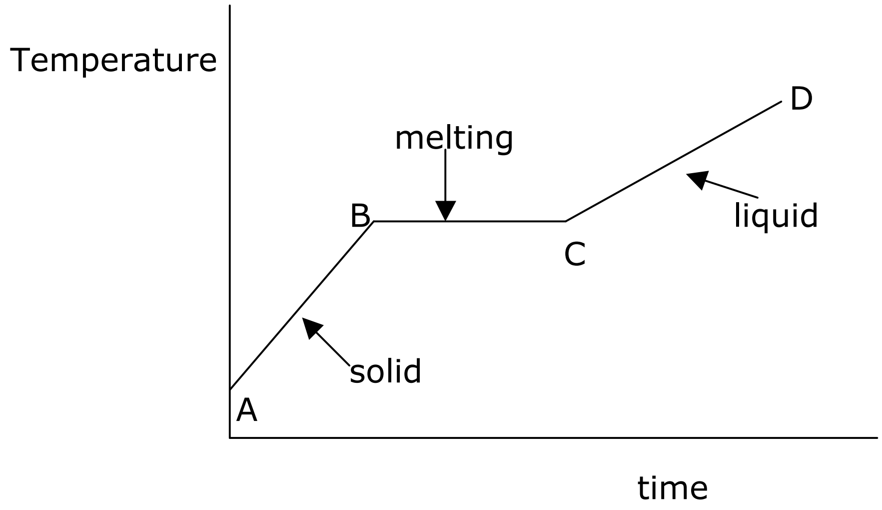
Changes of State

Fusion

If we supply heat to a solid, such as a piece of copper, the energy supplied is given to the copper particles. These start to vibrate more rapidly and with larger vibrations – the particles gain Kinetic Energy E_k. The heat supplied has been converted to kinetic energy.

If the solid is cooled, the reverse happens (the particles vibrate more slowly and these vibrations become smaller). The particles have lost kinetic energy and this lost E_k is converted back into heat energy that is lost to the surroundings.

If we heat the solid to a high enough temperature it will eventually melt to form a liquid. If we monitor the temperature of the material during heating, we would see that it varies with time during heating as shown in the graph below.



What is happening in this graph?

- Between A & B, the material is a solid. The heat supplied to the material is used to increase the E_k of the particles and the temperature rises.

- Between B & C, the solid is melting. Heat is still being supplied to the material but the temperature does not change. Heat energy is not being changed into kinetic energy. Instead, the heat is used to change the arrangement of the particles.

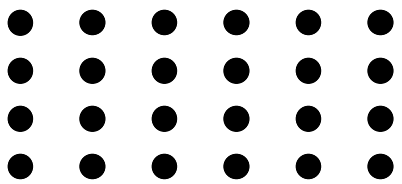
PTO

What is happening in this graph? (continued)

- At point C, all of the material has been changed to liquid.
- Between C & D, the heat supplied is again used to increase E_k of the particles and the temperature of the liquid starts to rise.

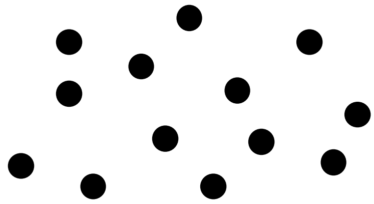
Compare the arrangement of particles in solids and liquids.

Solid



Particles vibrate but are held in fixed positions by very strong forces.

Liquid



Particles vibrate but can also move short distances. The particles are slightly farther apart than those in a solid.

The heat supplied during melting is used to set the solid particles free so that a liquid can be formed. The heat supplied is known as **latent heat of fusion** (melting) and is stored in the liquid as a kind of potential energy.

If the liquid cools and solidifies (freezes), the stored potential energy is given back out as heat energy.

A lot of heat energy is required to free the solid particles, so the latent heat of fusion is usually large. This also means that when a liquid freezes, it must give out a lot of heat energy.

Latent Heat of Fusion has the symbol $\mathbf{L_f}$.
The units of Latent Heat of Fusion are J/kg (Joules per kilogram)

$\mathbf{L_f}$ is the heat energy required to change

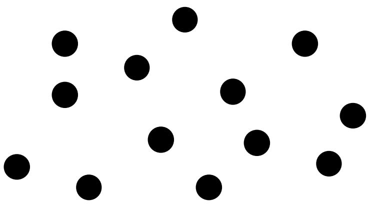
1kg of a solid (at melting point)
into
1kg of liquid (at freezing point).

Vaporisation

If a liquid is heated to a sufficiently high temperature it **vaporises** (boils). During boiling, there is no change in temperature. The heat supplied to the material is used to change the arrangement of the particles inside the liquid.

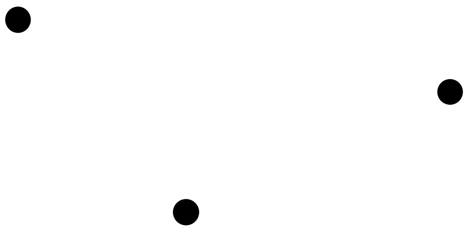
Compare the arrangement of particles in liquids and gases.

Liquid



Particles are close together, they have limited movement.

Gas



Particles are very far apart, they have complete freedom of movement.

The heat applied during boiling is used to set the particles free to form a gas. The heat energy is stored in the gas as a form of potential energy and is known as the **latent heat of vaporisation**.

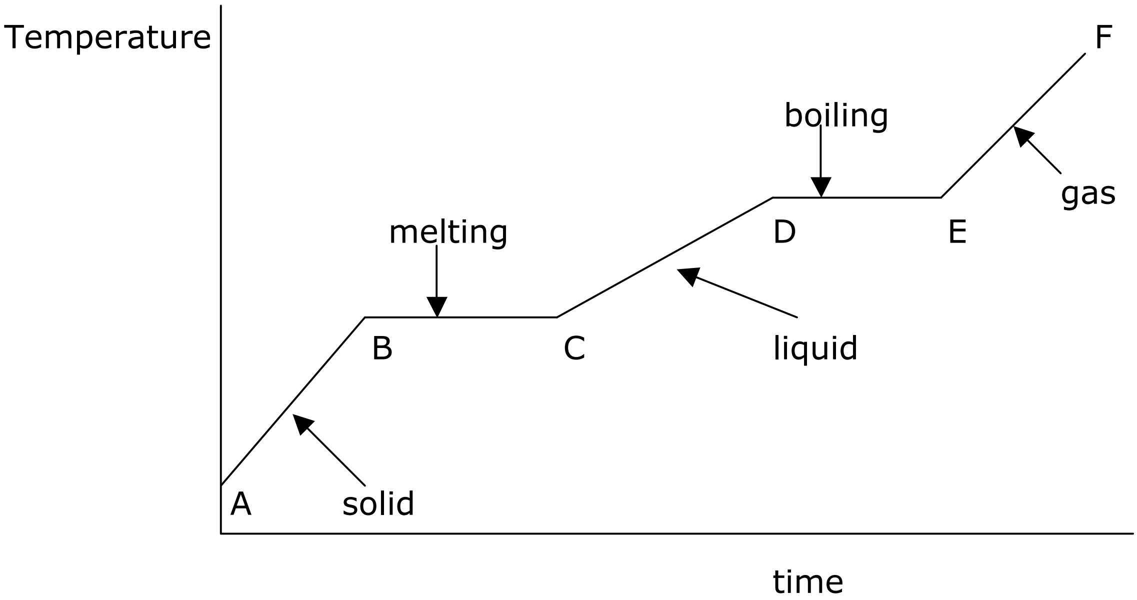
When the gas cools and condenses, the stored energy is given out as heat energy. A lot of heat is required to vaporise a liquid, so the latent heat of vaporisation is large. When a gas cools and condenses into a liquid, a lot of heat energy is given out.

Latent Heat of Vaporisation has the symbol $\mathbf{L_v}$.
The units of Latent Heat of Vaporisation are J/kg.

$\mathbf{L_v}$ is the heat energy required to change

1kg of a liquid (at boiling point)
into
1kg of gas (at condensing point).

The complete heating curve for a material is shown below.



What is happening in this graph?
(see earlier explanation for points A-D)

- Between C & D, the liquid is heated until it starts to boil.

- Between D & E, the liquid is still being heated but the extra heat energy does not change the temperature (kinetic energy) of the particles. The heat energy is used to change the arrangement of the particles to form a gas.

- At point E all of the liquid has been changed into gas.

- Between E & F, the gas is heated and the heat energy increases the E_k of particles once more, so the temperature of the gas increases.

Sample Questions on Latent Heat of Fusion/Vaporisation

Use these examples to help you see how to deal with problems involving changes of state (freezing/melting/boiling).

Example:
How much energy is required to change 2.6kg of **ice at 0˚C** into **water** at the same temperature?

Solution:
Use

$$E_h = mL_f$$

where E_h = heat energy (J)
m = mass = 2.6kg
L_f = 3.34×10^5J/kg

$$= 2.6 \times (3.34 \times 10^5)$$

so

E_h = $\underline{8.7 \times 10^5 \text{ J}}$

this is the value of L_f for water, the value will change for different materials

Example:
How much energy is required to change 2.6kg of **water** at **100˚C** into **steam** at the same temperature?

Solution:
Use

$$E_h = mL_v$$

where E_h = heat energy (J)
m = mass = 2.6kg
L_v = 2.26×10^6J/kg

$$= 2.6 \times (2.26 \times 10^6\text{J})$$

so

E_h = $\underline{5.9 \times 10^6 \text{ J}}$

this is the value of L_v for water, the value will change for different materials