Edexcel GCSE Physics

Your notes

States of Matter & Thermal Capacity

Contents

Density

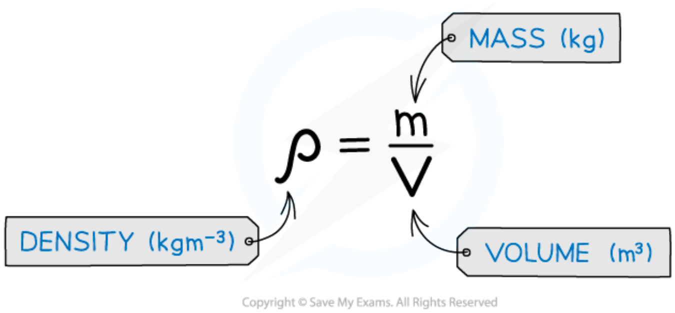
Your notes

Density

- Density is defined as:

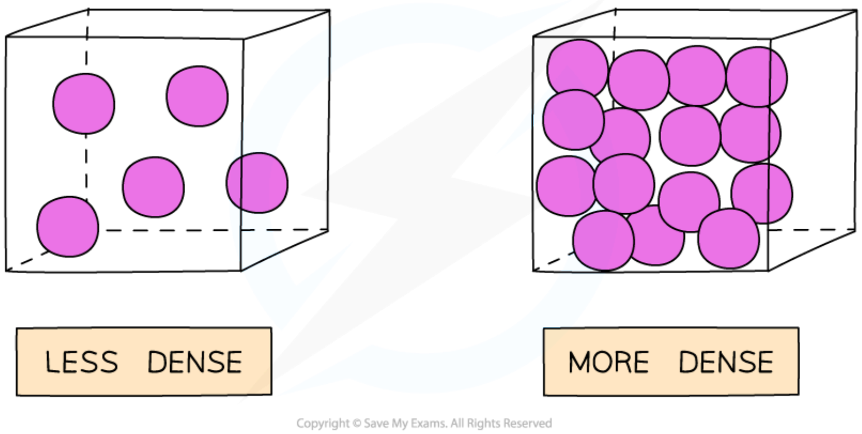
  The mass per unit volume of a material

- Objects made from **low density** materials typically have a **low mass**
- Similarly sized objects made from **high density** materials have a **high mass**
  - For example, a bag full of feathers is far lighter compared to a similar bag full of metal
  - Or another example, a balloon is less dense than a small bar of lead despite occupying a larger volume
- Density is related to mass and volume by the following equation:



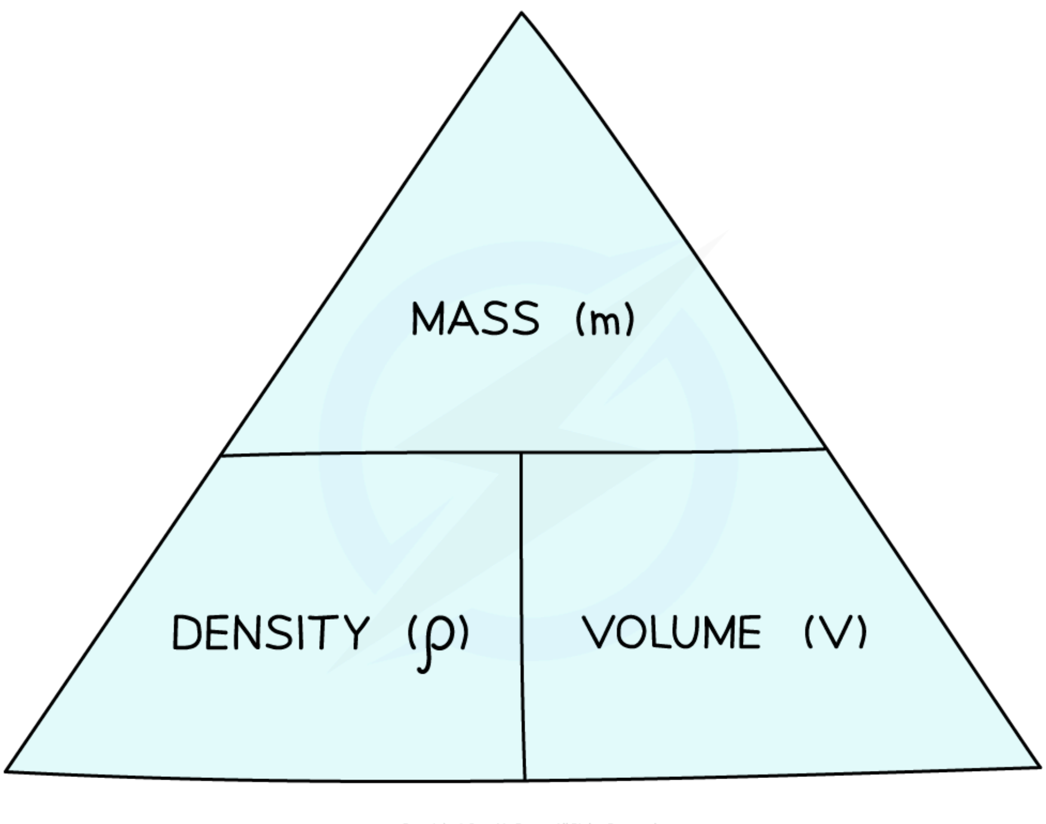
- Gases, for examples, are less dense than solids because the molecules are more spread out (same mass, over a larger volume)

Your notes



Gases are less dense than solids

- This equation can be rearranged with the help of the formula triangle:



Density, mass, volume formula triangle

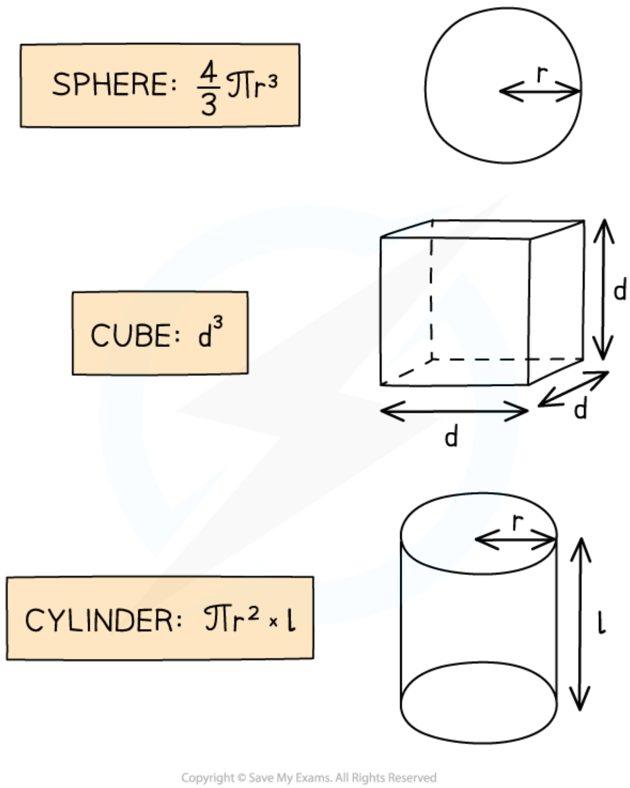
- The units of density depend on what units are used for mass and volume:
  - If the mass is measured in g and volume in cm^3, then the density will be in **g/cm^3**
  - If the mass is measured in kg and volume in m^3, then the density will be in **kg/m^3**
- This table gives some examples of densities on common materials
  - If a material is more dense than water (1000 kg/m^3), then it will sink

Approximate Densities of Materials Table

Material	Approximate Density (kg/m^3)
Air	1.3
Wood	300–800 (depending on species)
Water	1000
Granite (stone)	2700
Lead	11300

- The volume of an object may not always be given directly, but can be calculated with the appropriate equation depending on the object's shape

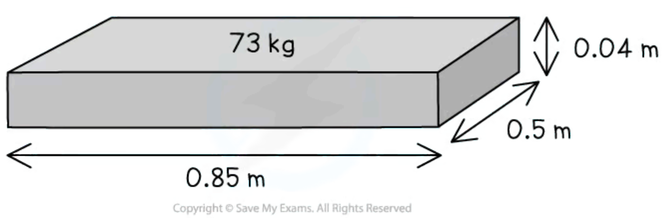
Your notes



Volumes of common 3D shapes

Worked Example

A paving slab has a mass of 73 kg and dimensions 0.04 m × 0.5 m × 0.85 m.



Calculate the density, in kg/m^3, of the material from which the paving slab is made.

Your notes

Answer:

Step 1: List the known quantities

- Mass of slab, m = 73 kg
- Volume of slab, V = 0.04 m × 0.5 m × 0.85 m = 0.017 m^3

Step 2: Write out the equation for density

$$\rho = \frac{m}{V}$$

Step 3: Substitute in values

$$\rho = 73 \div 0.017 = 4294 \text{ kg/m}^3$$

Step 4: Round the answer to two significant figures

$$\rho = 4300 \text{ kg/m}^3$$

Examiner Tips and Tricks

Make sure you are comfortable converting between units such as metres (m) and centimetres (cm) or grams (g) and kilograms (kg).

- When converting a **larger** unit to a **smaller** one, you **multiply (×)**
  - E.g. 125 m = 125 × 100 = 12 500 cm
- When you convert a **smaller** unit to a **larger** one, you **divide (÷)**
  - E.g. 5 g = 5 ÷ 1000 = 0.005 or 5 × 10^{-3} kg

Solids, Liquids & Gases

Your notes

Solids, Liquids & Gases

- Matter can exist in one of three different states: **solid**, **liquid**, or **gas**

Solids

- In a solid:
  - The particles are **closely packed**
  - The particles **vibrate** about fixed positions
- Solids have:
  - A definite **shape** (they are **rigid**)
  - A definite **volume**

Liquids

- In a liquid:
  - The particles are **closely packed**
  - The particles can **flow** over one another
- Liquids have:
  - No definite shape – they are able to **flow** and will take the shape of a container
  - A definite **volume**

Gases

- In a gas:
  - The particles are **far apart**
  - The particles move **randomly**
- Gases have:
  - No definite shape – they will take the shape of their container
  - No fixed volume – if placed in an evacuated container they will expand to fill the container
- Gases are highly **compressible**, this is because:

- There are large **gaps** between the particles
- It is easier to **push** the particles closer together than in solids or liquids

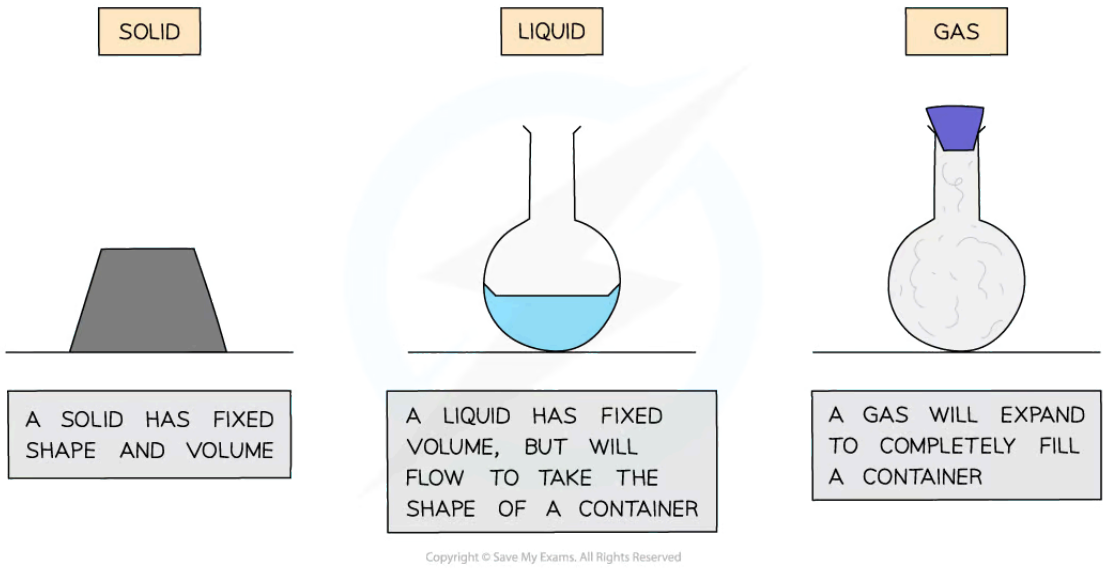
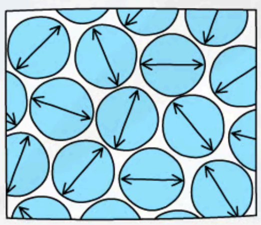
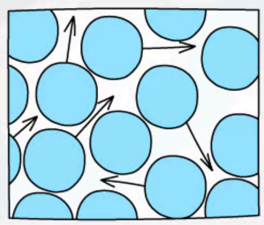
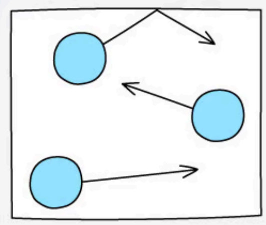


Diagram showing the three states of matter in terms of shape and volume

Solid, Liquid, Gas Summary Table

Your notes

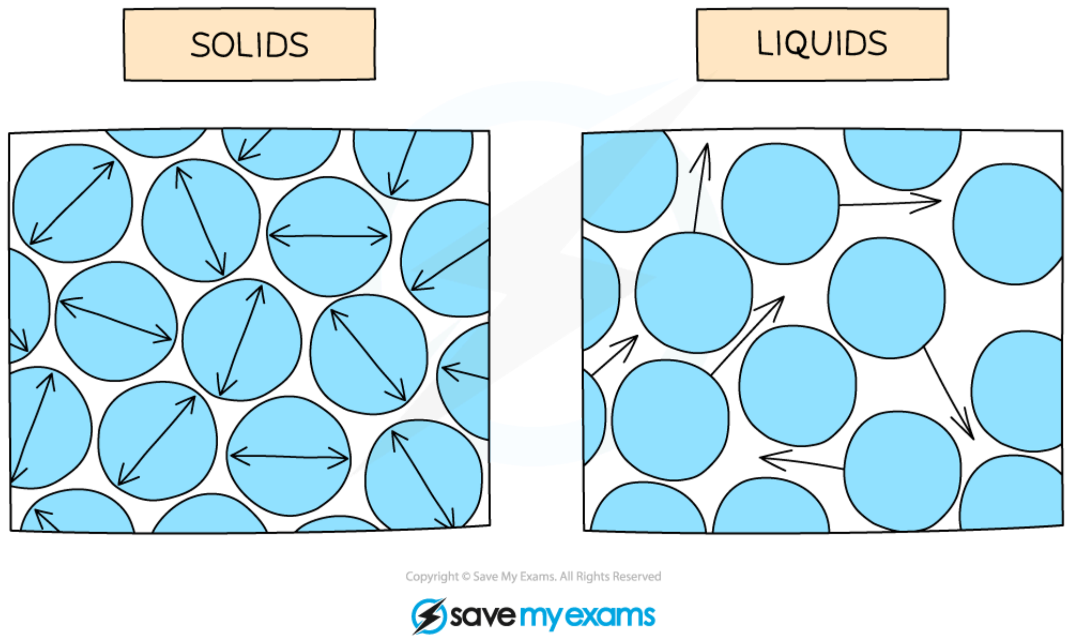
State	Solid	Liquid	Gas
Density	High	Medium	Low
Arrangement of particles	Regular pattern	Randomly arranged	Randomly arranged
Movement of particles	Vibrate around a fixed position	Move around each other	Move quickly in all directions
Energy of particles	Low energy	Greater energy	Highest energy
2D diagram			

Differences in Density

Solids & Liquids

- In solids and liquids, the molecules are tightly packed together
  - The difference is, in a liquid, the molecules have enough energy to push past each other
- As a result of this, the density of solids and liquids are roughly the same

Your notes

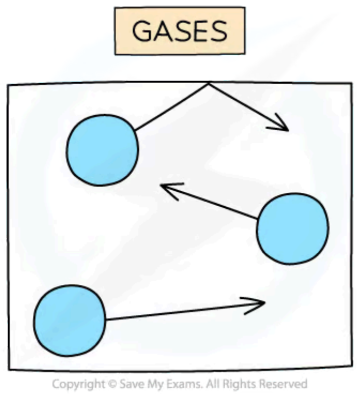


The molecules in solids and liquids are tightly packed, giving them a high density

Gases

- In a gas, the molecules are widely separated
  - As a result of this, gases have significantly **lower** densities than solids or liquids
- At room temperature, the distance between molecules in a gas is roughly ten times (in each direction) the distance between molecules in a solid or liquid
- As a result, the density of a gas is typically around one-thousandth (1/1000) of the density of a solid or liquid, for example:
  - The density of water is 1000 kg/m^3
  - The density of air at sea level and room temperature is 1.3 kg/m^3

Your notes



The molecules in a gas are widely spaced, giving it a much lower density

Core Practical: Determining Density

Your notes

Core Practical 5: Determining Density

Equipment List

Apparatus	Purpose
Regular and irregular shaped objects	Objects to use to determine the density of
A suitable liquid (e.g. sugar or salt solution)	Liquid to use to determine the density
A 30 cm ruler	To measure objects up to 30 cm in length
Vernier caliper	To measure objects up to around 15 cm in length
Micrometer	To measure objects up to around 3 cm in length
Digital balance	To measure the mass of the objects
Displacement "Eureka" can	To measure the displacement of water of irregular objects
Measuring cylinders	To measure the volume of liquid

- Resolution of measuring equipment:
  - 30 cm ruler = 1 mm
  - Vernier calipers = 0.01 mm
  - Micrometer = 0.001 mm
  - Digital balance = 0.01 g

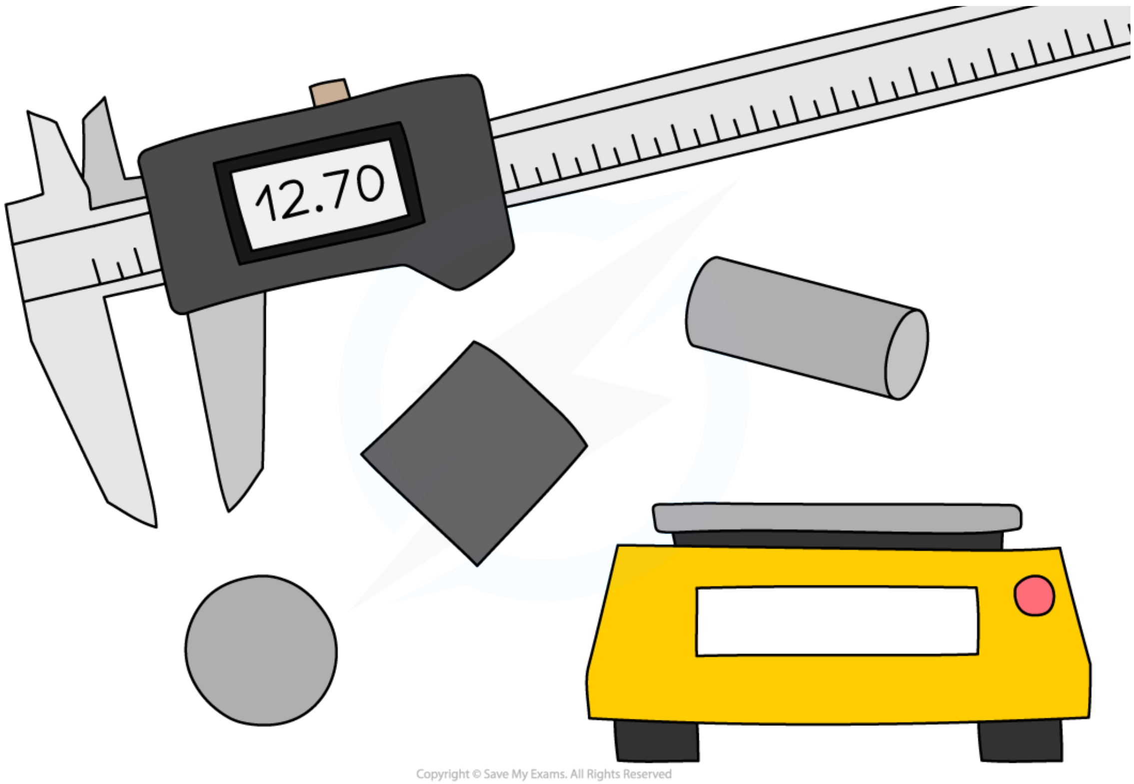
Experiment 1: Measuring the Density of Regularly Shaped Objects

Your notes

Aim of the Experiment

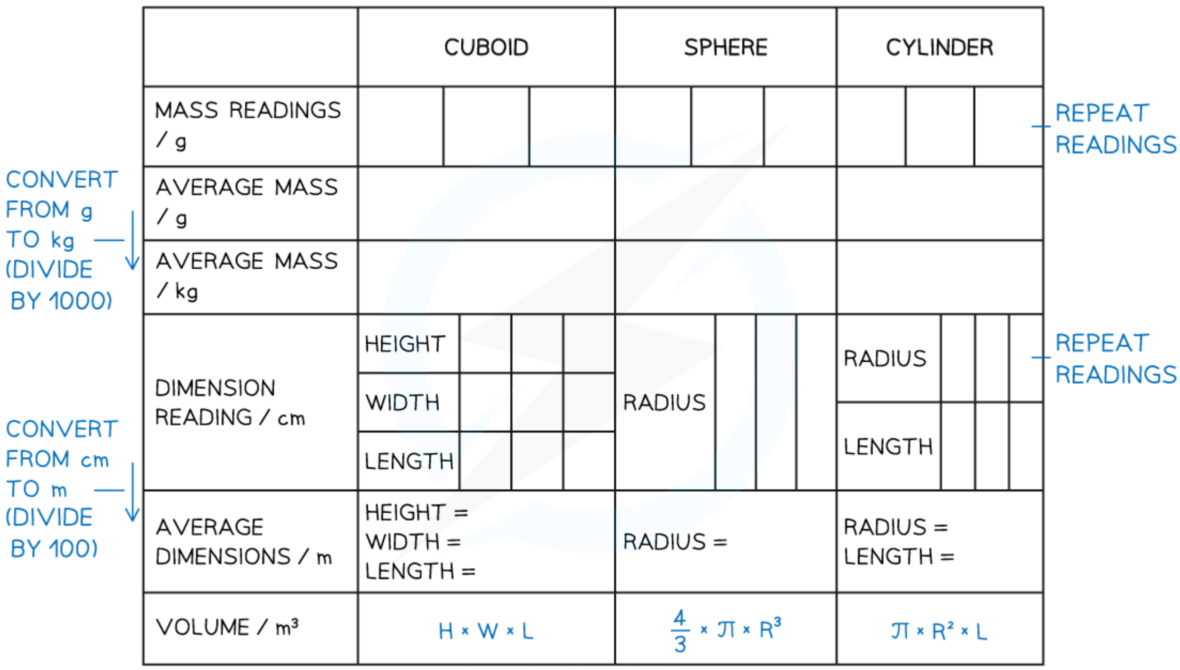
- The aim of this experiment is to determine the densities of regular objects by using measurements of their dimensions

Method



1. Place the object on a digital balance and note down its mass
2. Use either the ruler, Vernier calipers or micrometer to measure the object's dimensions (width, height, length, radius) – the apparatus will depend on the size of the object
3. Repeat these measurements and take an average of these readings before calculating the density

- An example of a results table might look like this:

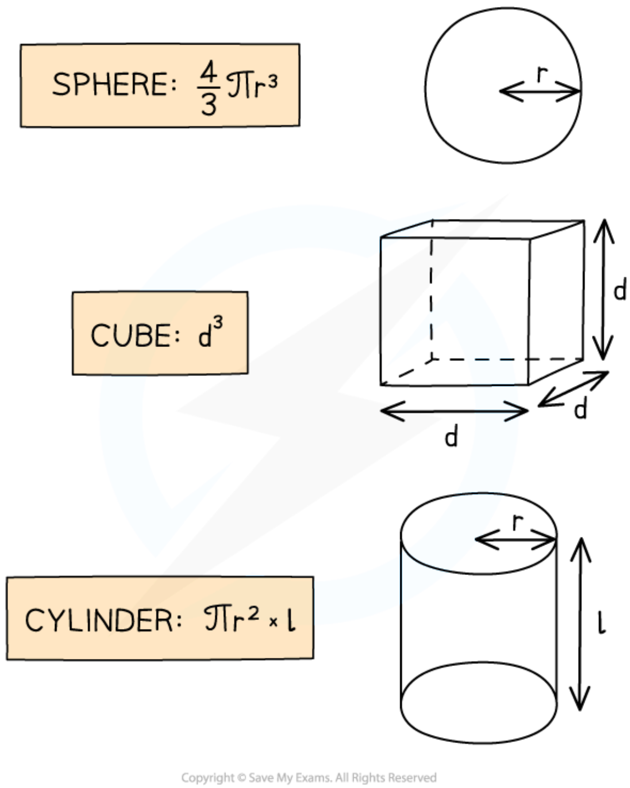


Your notes

Analysis of Results

- Calculate the volume of the object depending on whether it is a cube, sphere, cylinder (or other regular shape)

Your notes



Calculating the volume of an object depends on its shape

- Remember to convert from **centimetres (cm)** to **metres (m)** by dividing by 100

1 cm = 0.01 m

50 cm = 0.5 m

- Using the mass and volume, the density of each can be calculated using the equation:

$$\rho = \frac{m}{V}$$

- Where:
  - ρ = density in kilogram per metres cubed (kg/m^3)
  - *m* = mass in kilograms (kg)
  - *V* = volume in metres cubed (m^3)

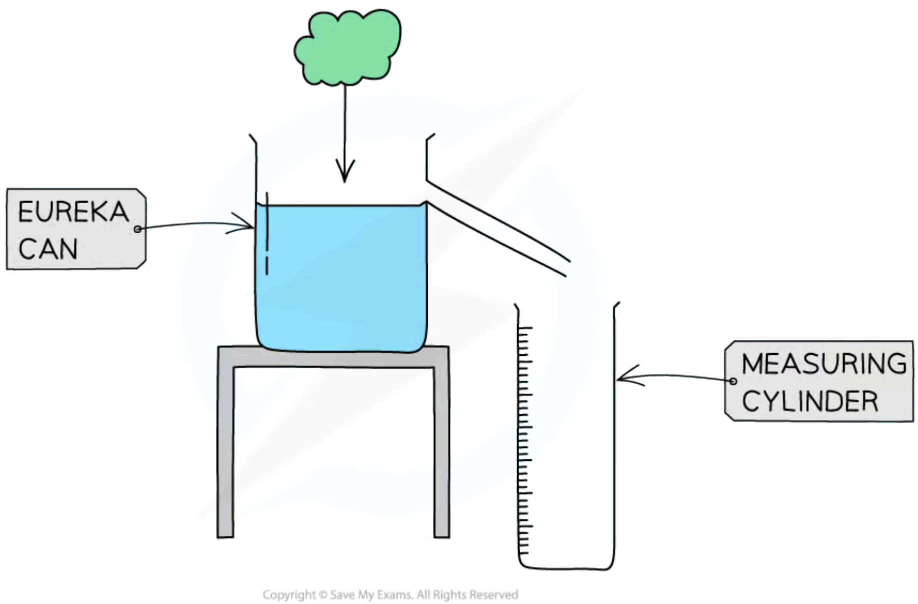
Your notes

Experiment 2: Measuring the Density of Irregularly Shaped Objects

Aim of the Experiment

- The aim of this experiment is to determine the densities of irregular objects using a displacement technique

Method



Apparatus for measuring the density of irregular objects

1. Place the object on a digital balance and note down its mass
2. Fill the eureka can with water up to a point just below the spout
3. Place an empty measuring cylinder below its spout
4. Carefully lower the object into the eureka can
5. Measure the volume of the displaced water in the measuring cylinder
6. Repeat these measurements and take an average before calculating the density

- An example of a results table might look like this:

OBJECT	MASS OF OBJECT / g			AVERAGE MASS / kg	VOLUME OF WATER DISPLACED / m^3			AVERAGE VOLUME OF WATER DISPLACED / m^3
	1	2	3		1	2	3	
1								
2								
3								

Analysis of Results

- The volume of the water displaced is equal to the volume of the object
- Once the mass and volume of the shape are known, the density can be calculated using:

$$\rho = \frac{m}{V}$$

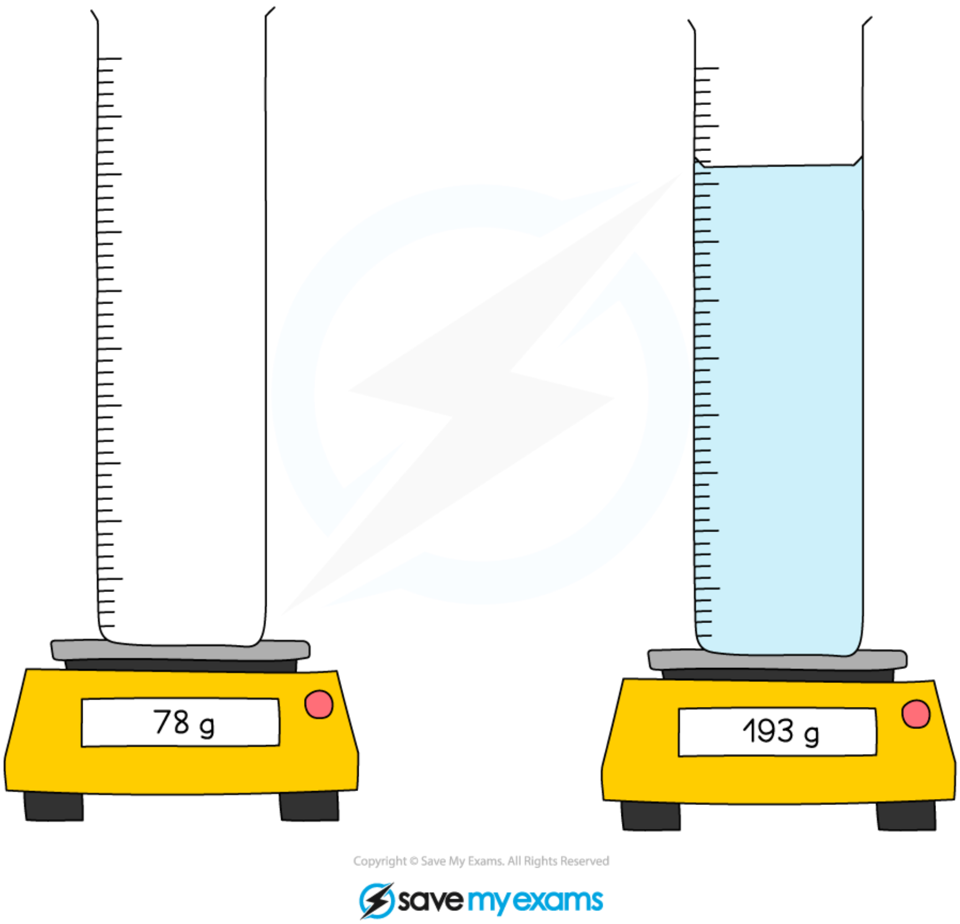
Experiment 3: Measuring Density of Liquids

Aim of the Experiment

- The aim of this experiment is to determine the density of a liquid by finding a difference in its mass

Method

Your notes



Apparatus for determining the density of a liquid

1. Place an empty measuring cylinder on a digital balance and note down the mass
2. Fill the cylinder with the liquid and note down the volume
3. Note down the new reading on the digital balance
4. Repeat these measurements and take an average before calculating the density

- An example of a results table might look like this:

Your notes

MASS OF CYLINDER BEFORE / g			AVERAGE MASS / kg	VOLUME OF WATER ADDED / m^3	MASS OF CYLINDER WITH WATER / g			AVERAGE MASS OF CYLINDER WITH WATER / kg
1	2	3			1	2	3	

Analysis of Results

- Find the mass of the liquid by subtracting the final reading from the original reading

Mass of liquid = Mass of cylinder with water – mass of cylinder

- Remember to convert between **grams (g)** and **kilograms (kg)** by dividing by 1000

1 g = 0.001 kg

78 g = 0.078 kg

- Once the mass and volume of the liquid are known, the density can be calculated using the equation:

$$\rho = \frac{m}{V}$$

Evaluating the Experiments

Systematic Errors:

- Ensure the digital balance is set to zero before taking measurements of mass
  - This includes when measuring the density of the liquid – remove the measuring cylinder and zero the balance before adding the liquid

Random Errors:

- A main cause of error in this experiment is in the measurements of length
  - Ensure to take repeat readings and calculate an average to keep this error to a minimum

- Place the irregular object in the displacement can carefully, as dropping it from a height might cause water to splash which will lead to an incorrect volume reading

Safety Considerations

- There is a lot of glassware in this experiment, ensure this is handled carefully
- Water should not be poured into the measuring cylinder when it is on the electric balance
    - This could lead to electric shock
- Make sure to stand up during the whole experiment, to react quickly to any spills

Examiner Tips and Tricks

There is a lot of information to take in here! When writing about experiments, a good sequence is as follows:

- If you need to use an equation to calculate something, start off by giving it as this will give you some hints about what you need to mention later
- List the apparatus that you need
- State what measurements you need to make (your equation will give you some hints) and how you will measure them
- Finally, state that you will repeat each measurement several times and take averages

Your notes

Changes of State

Your notes

Changes of State

- When a substance changes state, the number of molecules in that substance **doesn't change** and so neither does its mass
  - The only thing that changes is its **energy**
- Unlike chemical changes, changes of state (a type of physical change) are **reversible**
- In a **solid**:
  - The molecules are very **close** together and arranged in a **regular** pattern
  - The molecules **vibrate** about fixed positions
- In a **liquid**:
  - The molecules are still **close** together (no gaps) but are no longer arranged in a regular pattern
  - The molecules are able to **slide past each other**
- In a **gas**:
  - The molecules are **widely separated** - about 10 times further apart in each direction
  - The molecules move about **randomly at high speeds**
- There are six changes of state that can occur between solids, liquids and gases:
  - **Melting** - When a solid turns into a liquid (e.g. ice to water)
  - **Boiling** - When a liquid turns into a gas (evaporating)
  - **Condensing** - When a gas turns into a liquid
  - **Freezing** - When a liquid turns into a solid
  - **Subliming** - When a solid turns into a gas

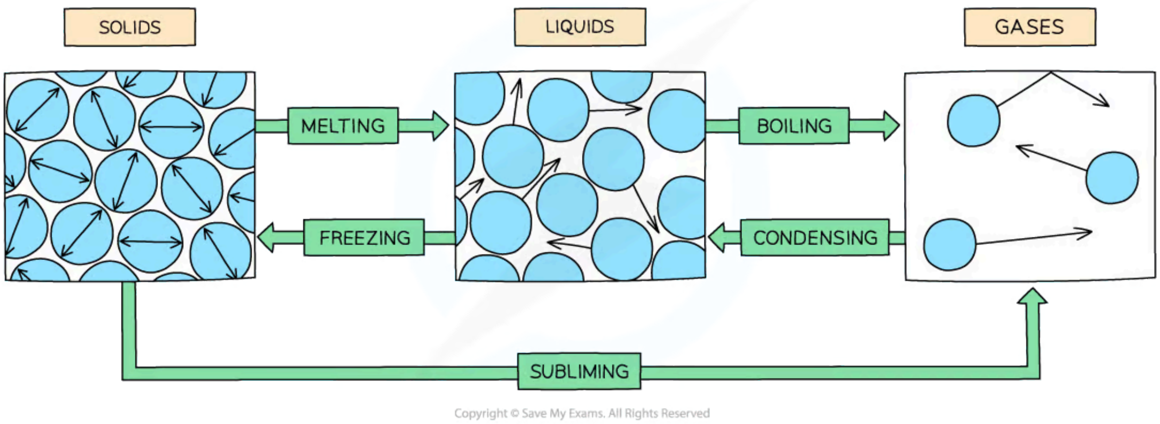
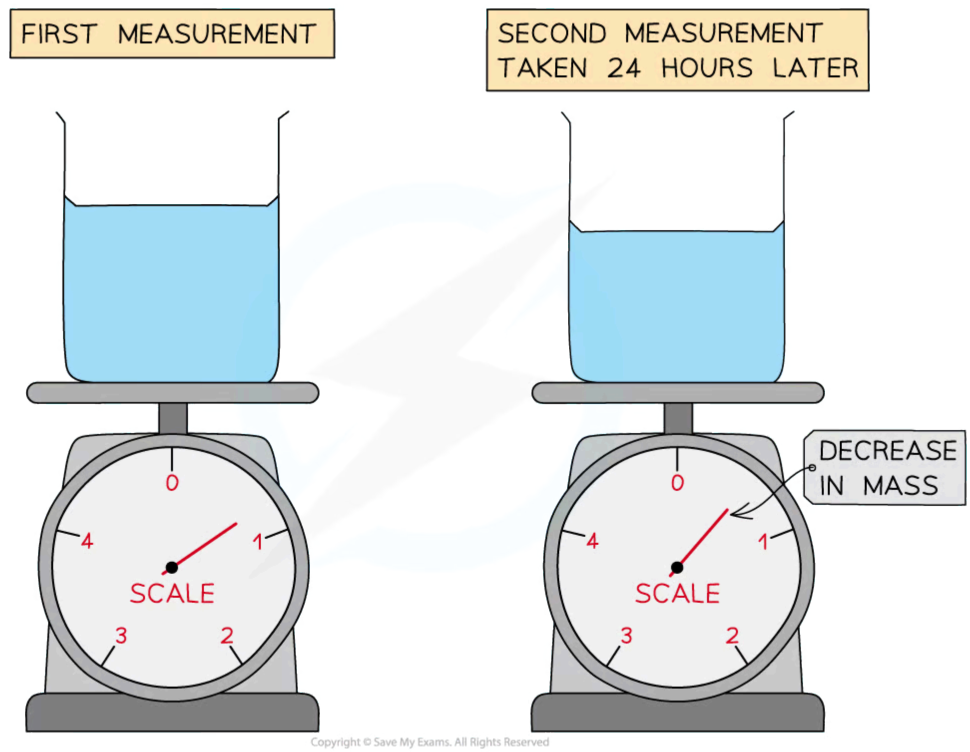


Diagram showing the arrangement and motion of different states of matter

Worked Example

A student measures the mass of a beaker of water twice, leaving 24 hours between the readings. The temperature in the room remained constant between readings, however, they notice a decrease in the mass of the beaker of water.



Which of the following is **not** a correct conclusion that can be drawn from the experiment?

A. The difference in mass is equal to the mass of the water that evaporated

B. The total energy within the beaker decreased

C. The density of water in the air increased

D. The total number of water molecules in the air and water decreased

Answer: D

- **A** is **true** because the mass lost from the beaker is due to those water molecules evaporating
- **B** is **true** because evaporation causes the most energetic particles to leave the beaker
    - The total number of particles in the beaker decreased
- **C** is **true** because additional water molecules were added to the air, without a significant change in the volume of the air
- **D** is **not true** because no mass is lost during evaporation - it is only changed from a liquid to gas state

Thermal Energy

Your notes

Energy, Temperature & Changes of State

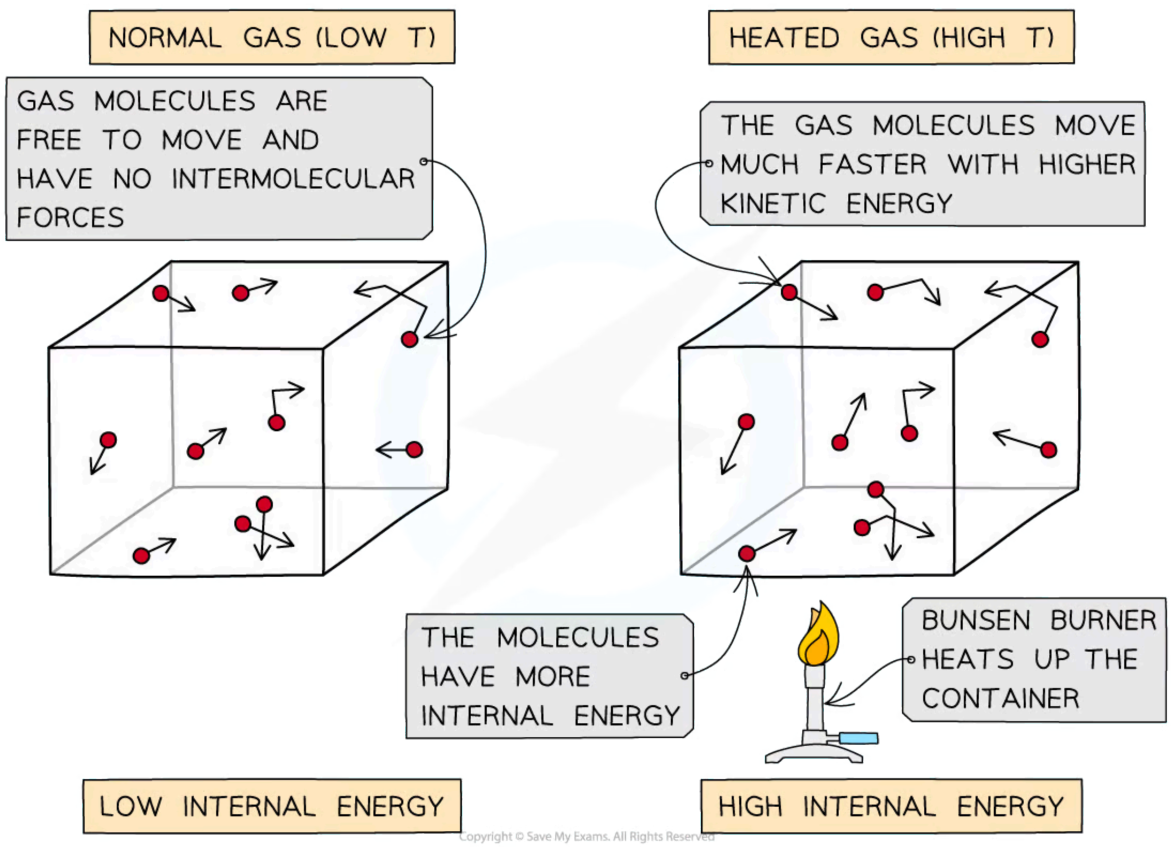
- The molecules within a substance possess two forms of energy:
  - **Kinetic energy** (due to their random motion / vibration)
  - **Potential energy** (due to their position relative to each other)
- Together, these two form the total energy that makes up the internal energy of the system
- Internal energy is defined as:

  The total energy stored inside a system by the particles that make up the system due to their motion and positions

Heating and Temperature Change

- Heating a system changes a substance's internal energy by **increasing the kinetic energy** of its particles
  - The **temperature** of the material, therefore, is related to the average kinetic energy of the molecules
- The higher the temperature, the higher the kinetic energy of the molecules and vice versa
  - This means they move around **faster**
- This increase in kinetic energy (and therefore internal energy) can:
  - Cause the **temperature** of the system to increase
  - Or, produce a **change of state** (solid to liquid or liquid to gas)

Your notes



As the container is heated up, the gas molecules move faster with higher kinetic energy and therefore higher internal energy

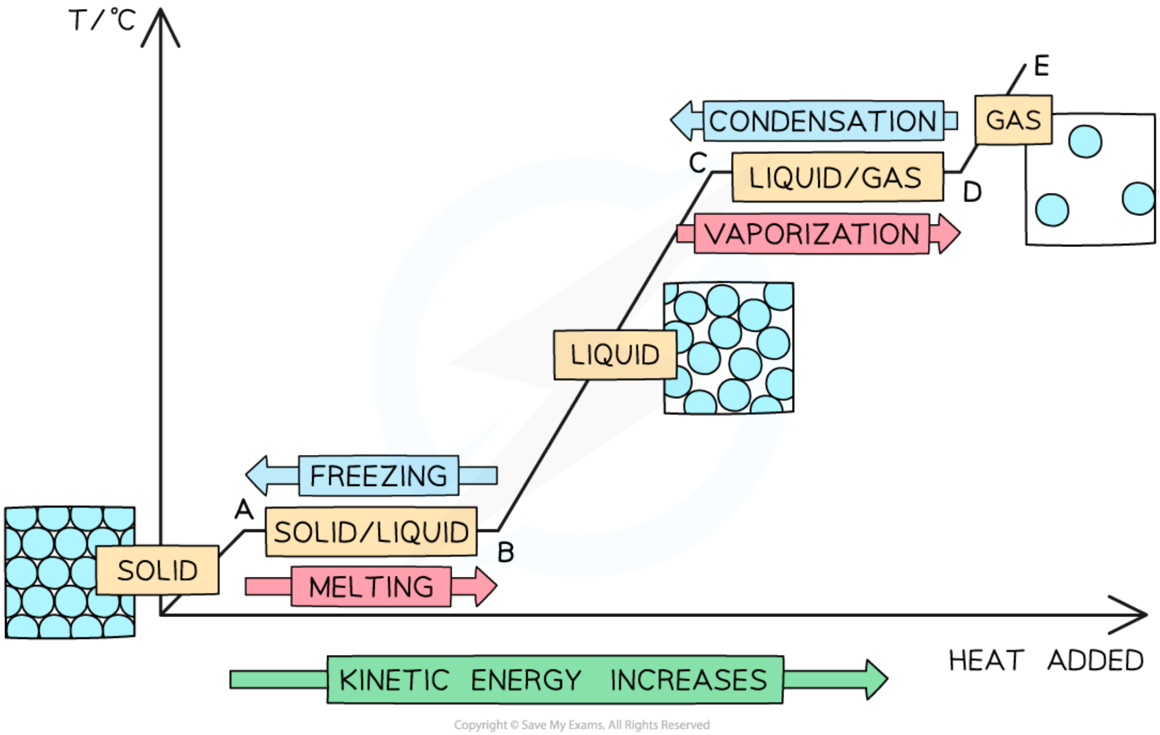
Heating and Changes of State

- When a substance reaches a certain temperature, the kinetic energy of the molecules will stop increasing and the energy will go into increasing its potential energy instead
- This breaks the bonds between the molecules, causing them to move further apart and leads to a **change of state**
  - For example, liquid to gas
- When a substance changes its state:
  - The **potential energy** of the molecules **increases**, breaking the bonds between them and becoming further apart
  - The **kinetic energy** remains the **same**, meaning that the **temperature** will remain the same, even though the substance is still being heated

Your notes

Heating Curve

- This graph shows how the temperature of a substance changes with time as it is heated
- The substance is heated until it has melted to become a liquid, and then boiled to become a gas



Heating curve of a substance showing the energy changes as temperature is increased

The different sections of the graph show:

- **ORIGIN to A**: Added heat energy is being used to increase the kinetic energy of the particles while it is a solid
- **A to B**: Added heat energy is being used to break the bonds between the solid molecules, increasing the potential energy and melting the substance
- **B to C**: Added heat energy is being used to further increase the kinetic energy of the particles while the substance is a liquid
- **C to D**: Added heat energy is being used to break the bonds between the liquid molecules, further increasing the potential energy and boiling the substance
- **D to E**: Added heat energy is being used to further increase the kinetic energy of the particles while the substance is a gas

Your notes

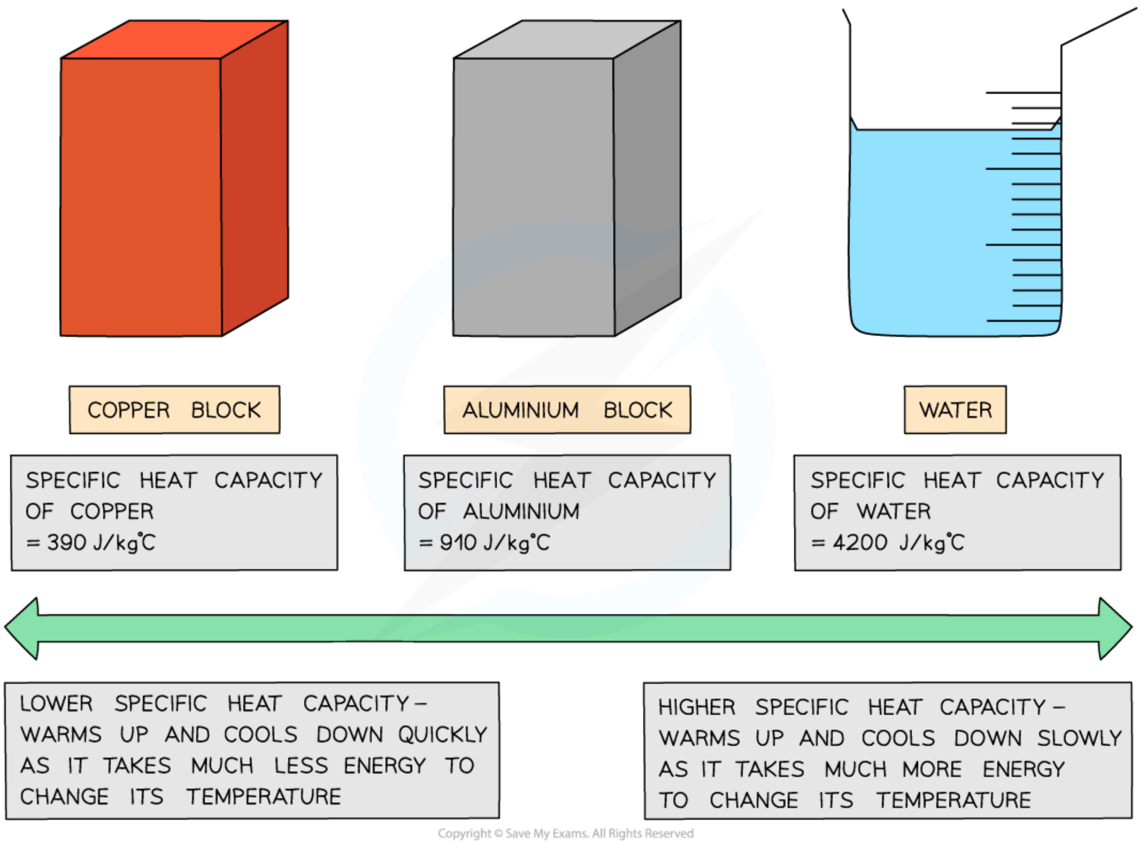
Specific Heat & Latent Heat

Specific Heat Capacity

- If the temperature of the system increases, the increase in temperature of this system depends on:
  - The mass of the substance heated
  - The type of material
  - The energy input to the system
- The specific heat capacity of a substance is defined as:

  The amount of energy required to raise the temperature of 1 kg of the substance by 1 °C
- Different substances have different specific heat capacities
  - If a substance has a **low** specific heat capacity, it heats up and cools down quickly (ie. it takes less energy to change its temperature)
  - If a substance has a **high** specific heat capacity, it heats up and cools down slowly (ie. it takes more energy to change its temperature)

Your notes



Low v high specific heat capacity

- Specific heat capacity is mainly used for **liquids** and **solids**
- The specific heat capacity of different substances determines how **useful** they would be for a specific purpose eg. choosing the best material for kitchen appliances
  - Good electrical conductors, such as copper and lead, are **excellent conductors of heat** due to their **low** specific heat capacity
  - On the other hand, **water** has a **very high** specific heat capacity, making it ideal for **heating** homes as the water remains hot in a radiator for a long time
- The specific heat capacity of some substances are given in the table below as examples:

Table of values of specific heat capacity for various substances

Your notes

Substance	Specific heat capacity / J/kg°C
Aluminium	910
Copper	390
Lead	126
Glass	500–680
Water	4200
Mercury	140

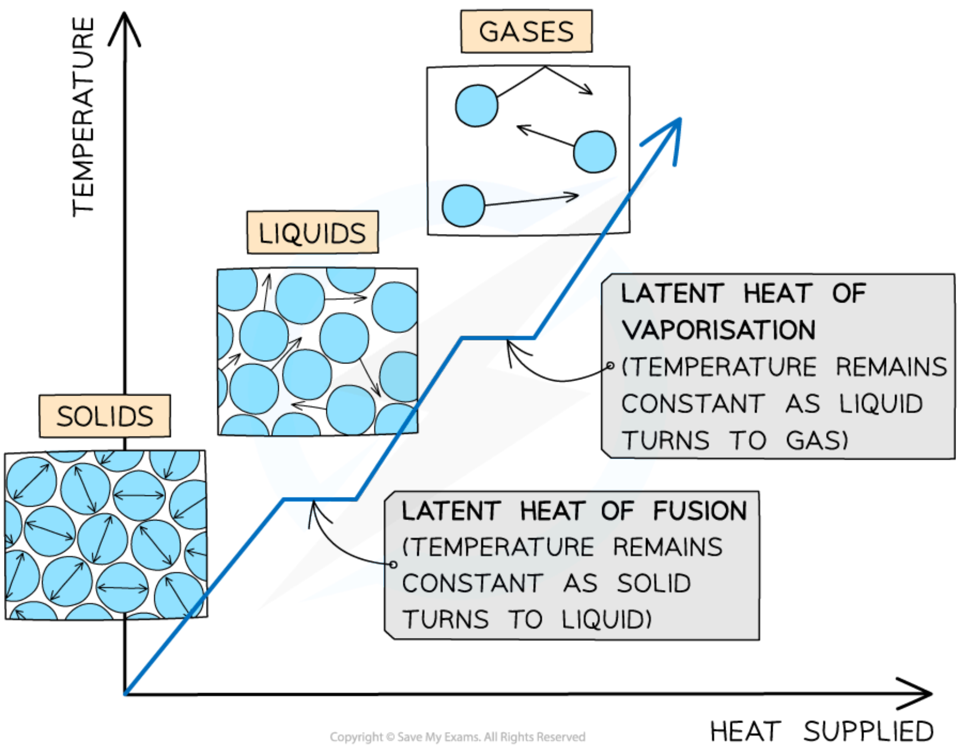
Specific Latent Heat

- Energy is required to change the **state** of a substance
  - This energy is known as **latent heat**
- The **specific latent heat** is defined as:

  The amount of thermal energy required to change the state of 1 kg of a substance with no change in temperature

- There are two types of specific latent heat:
  - Specific latent heat of **fusion** (solid to liquid and vice versa)
  - Specific latent heat of **vaporisation** (liquid to gas and vice versa)
- Latent heat is represented by the symbol ***L*** with units **joules per kilogram (J/kg)**

Your notes



The changes of state with heat supplied against temperature

- The **specific latent heat of fusion** is defined as:

  The thermal energy required to convert 1 kg of solid to liquid with no change in temperature

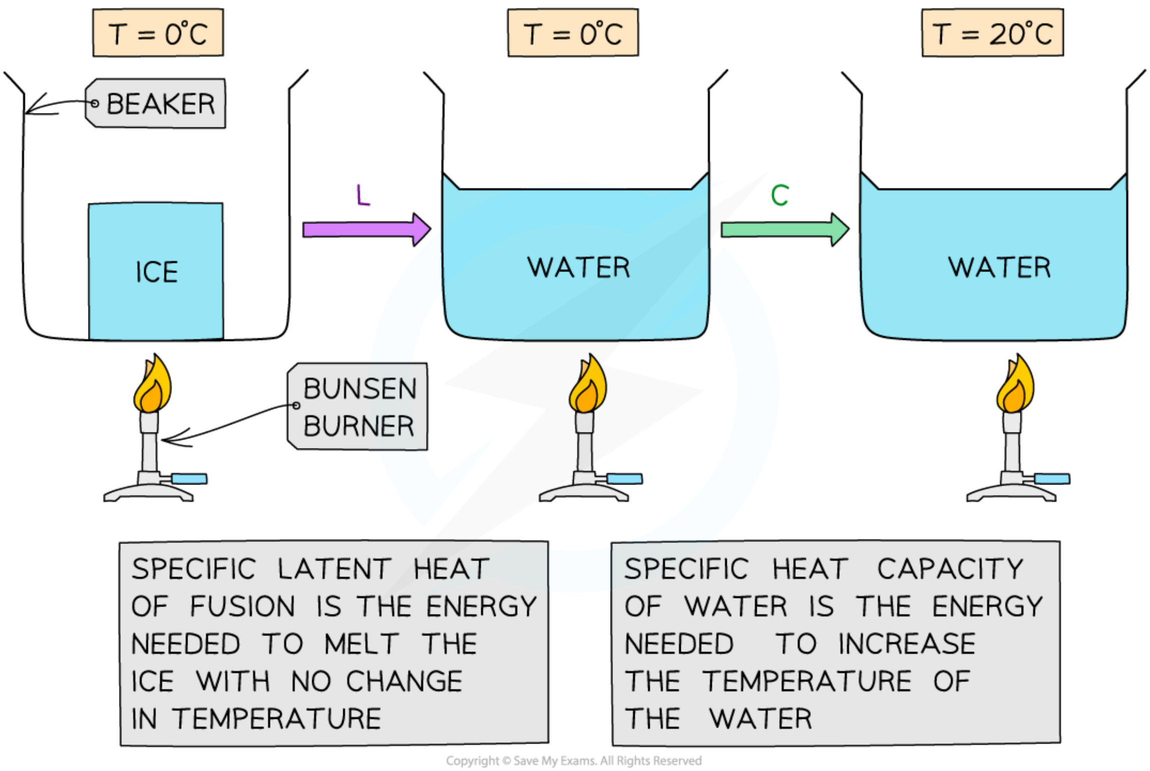
- This is used when **melting** a solid or **freezing** a liquid
- When a solid substance is melted, its temperature stays **constant** until all of the substance has melted
- The latent heat of fusion is the energy needed to break the bonds between the molecules
- The specific latent heat of **vaporisation** is defined as:

  The thermal energy required to convert 1 kg of liquid to gas with no change in temperature

- This is used when **vaporising** a liquid or **condensing** a gas
- When a liquid substance is heated, at its boiling point, the substance boils and turns into vapour
- The latent heat of vaporisation is the energy needed by the particles to break away from their neighbouring particles in the liquid
- Specific heat capacity and specific latent heat are slightly different

Your notes

- Specific heat capacity is used for a change in **temperature** in the **same** state
- Specific latent heat is used for a change in **state** but **no** change in temperature



Difference between specific latent heat and specific heat capacity

Examiner Tips and Tricks

The specific latent heat of fusion and vaporisation value of all substances will be provided for you in the exam question, so you do not need to memorise the value of any. However, make sure to include '*with no change in temperature*' in your definition of specific latent heat to be awarded full marks.

Use these reminders to help you remember which type of latent heat is being referred to:

- Latent heat of fusion = imagine 'fusing' the liquid molecules together to become a solid
- Latent heat of vaporisation = "water vapour" is steam, so imagine vaporising the liquid molecules into a gas

Specific Heat Capacity

Your notes

Specific Heat Capacity

- The amount of thermal energy needed to raise the temperature of a given mass by a given amount can be calculated using the equation:

Change in thermal energy = Mass × Specific heat capacity × Change in temperature

$$\Delta Q = mc\Delta\theta$$

- Where:
  - ΔQ = change in thermal energy, in joules (J)
  - m = mass, in kilograms (kg)
  - c = specific heat capacity, in joules per kilogram per degree Celsius (J/kg °C)
  - $\Delta\theta$ = change in temperature, in degrees Celsius (°C)

Worked Example

Water of mass 0.48 kg undergoes an increase in temperature of 0.7 °C. Calculate the amount of energy transferred to the water during this temperature rise.

The specific heat capacity of water is 4200 J / kg °C.

Answer:

Step 1: Write down the known quantities

- Mass, m = 0.48 kg
- Change in temperature, $\Delta\theta$ = 0.7 °C
- Specific heat capacity, c = 4200 J / kg °C

Step 2: Write down the relevant equation

$$\Delta Q = mc\Delta\theta$$

Step 3: Calculate the energy transferred by substituting in the values

$$\Delta Q = (0.48) \times (4200) \times (0.7) = 1411.2$$

Step 4: Round the answer to 2 significant figures

$\Delta Q = 1400 \text{ J}$

Your notes

Examiner Tips and Tricks

This equation will be given on your equation sheet, so don't worry if you cannot remember it, but it is important that you understand how to use it. You will always be given the specific heat capacity of a substance, so you do not need to memorise any values.

Specific Latent Heat

Your notes

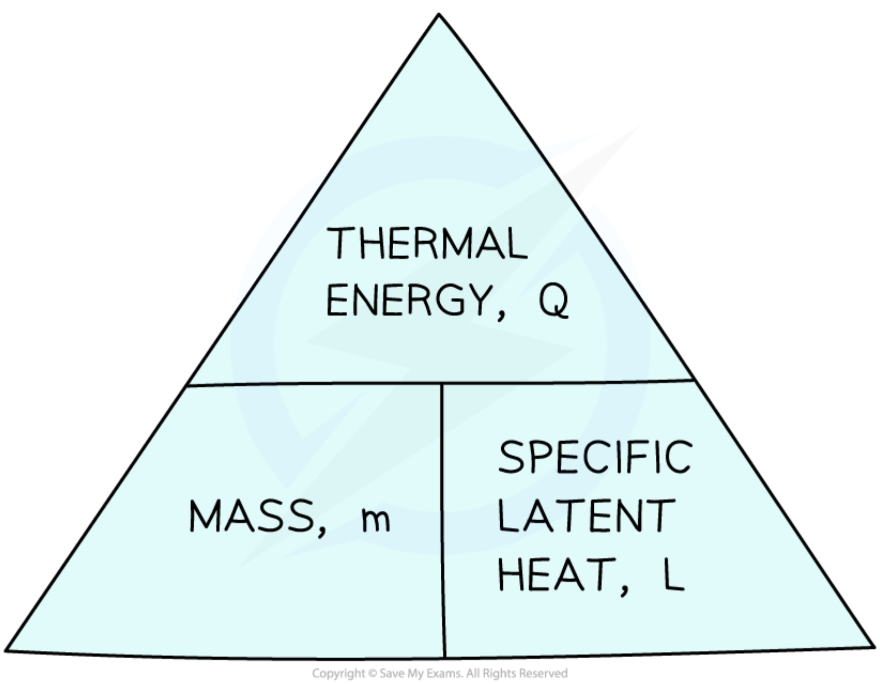
Specific Latent Heat

- The amount of energy Q required to melt or vaporise a mass of *m* with latent heat *L* is:

Thermal energy required for a change of state = Mass × Specific latent heat

$$Q = mL$$

- Where:
  - Q = thermal energy required for a change in state, in joules (J)
  - *m* = mass, in kilograms (kg)
  - *L* = specific latent heat, in joules per kilogram (J/kg)
- This equation can be rearranged with the help of a formula triangle:



- For context, the values of latent heat for water are:
  - Specific latent heat of fusion = 330 kJ/kg
  - Specific latent heat of vaporisation = 2.26 MJ/kg

- Therefore, evaporating 1 kg of water requires roughly **seven times** more energy than melting the same amount of ice to form water

Your notes

Worked Example

Calculate the energy transferred to the surroundings as 0.60 kg of stearic acid changed state from liquid to solid. The specific latent heat of fusion of stearic acid is 199 000 J/kg.

Answer:

Step 1: List the known quantities

- Mass, m = 0.60 kg
- Specific latent heat of fusion, L = 199 000 J/kg

Step 2: Write down the relevant equation

$$Q = mL$$

Step 3: Substitute in the values

$$Q = 0.60 \times 199\,000 = \mathbf{119\,400\ J}$$

Examiner Tips and Tricks

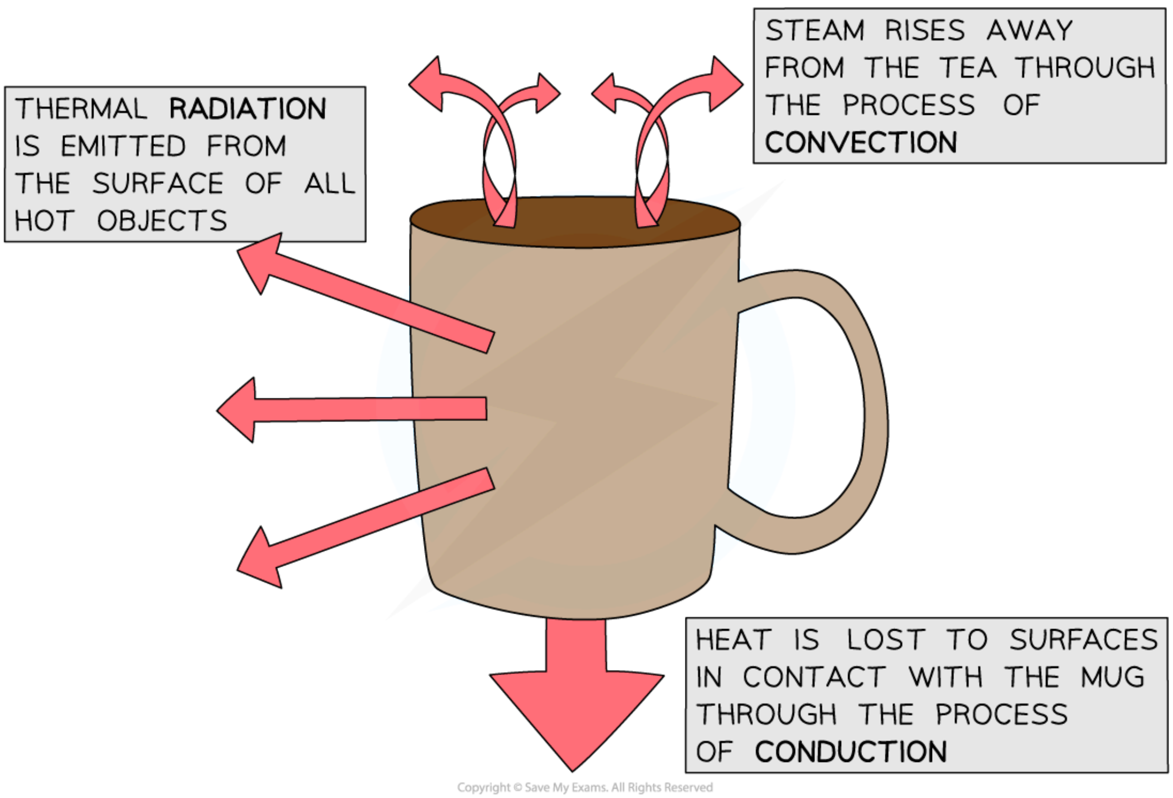
Remember that L is used as the symbol of specific latent heat of fusion **or** vaporisation. This equation will be given on your equation sheet, however, it is important you know how to use it!

Thermal Insulation

Your notes

Thermal Insulation

- Thermal energy transfers from hotter areas to cooler areas by the processes of:
  - Conduction
  - Convection
  - Radiation



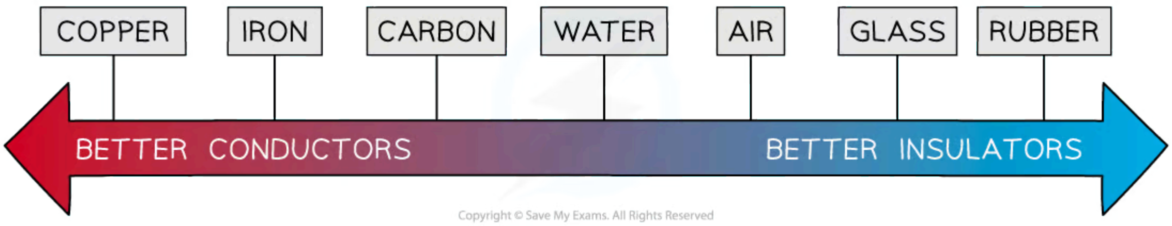
Conduction, convection and radiation demonstrated in a mug of hot tea

- Objects will **always** lose heat until they are in **thermal equilibrium** with their surroundings
- Thermal equilibrium is reached when objects have cooled to room temperature
- **Insulation** can be used to reduce the rate at which heat transfers

Reducing Conduction

Your notes

- Insulators are materials that are poor conductors of heat
- Fabrics, such as wool and cotton, are good insulators



Different materials have different properties of conductivity

- These materials are usually **low density** and often contain pockets of **trapped air**
  - This makes them very effective because **air is a poor conductor**
- Surrounding a warm object with a material that contains trapped air will **reduce the rate at which it loses heat**
- Likewise, surrounding a cold object with such a material will reduce the amount of heat reaching the object

Reducing Convection

- Insulating materials that contain trapped air are also effective at reducing convection
- Trapped air is unable to move around, forming convection currents
- By placing a lid on a hot drink, or saucepan, convection can be further reduced

Reducing Radiation

- Infrared radiation is emitted from all hot materials
  - It is a wave of electromagnetic radiation
- Shiny materials are poor emitters of radiation
- By covering the material with a shiny (non-metal) coating the rate of heat loss can be further reduced

Core Practical: Investigating Specific Heat Capacity

Your notes

Core Practical 6: Investigating Specific Heat Capacity

Equipment List

Equipment	Purpose
400 ml beaker	To hold the water that is to be heated
Thermometer	To measure the temperature of the water
Immersion heater	To heat the water
Voltmeter	To measure the potential difference across the immersion heater
Ammeter	To measure the current flowing through the immersion heater
Power supply	Providing energy for heating
Digital balance	To measure the mass of water
Stopwatch	To time the heating
Crushed ice (roughly 200 grams)	Used to plot a heating curve
Bunsen burner or hotplate	Providing energy for heating curve experiment

- Resolution of measuring equipment:
  - Thermometer = 0.1 °C
  - Voltmeter = 0.1 V
  - Ammeter = 0.1 A
  - Stopwatch = 1 s
  - Digital balance = 1 g

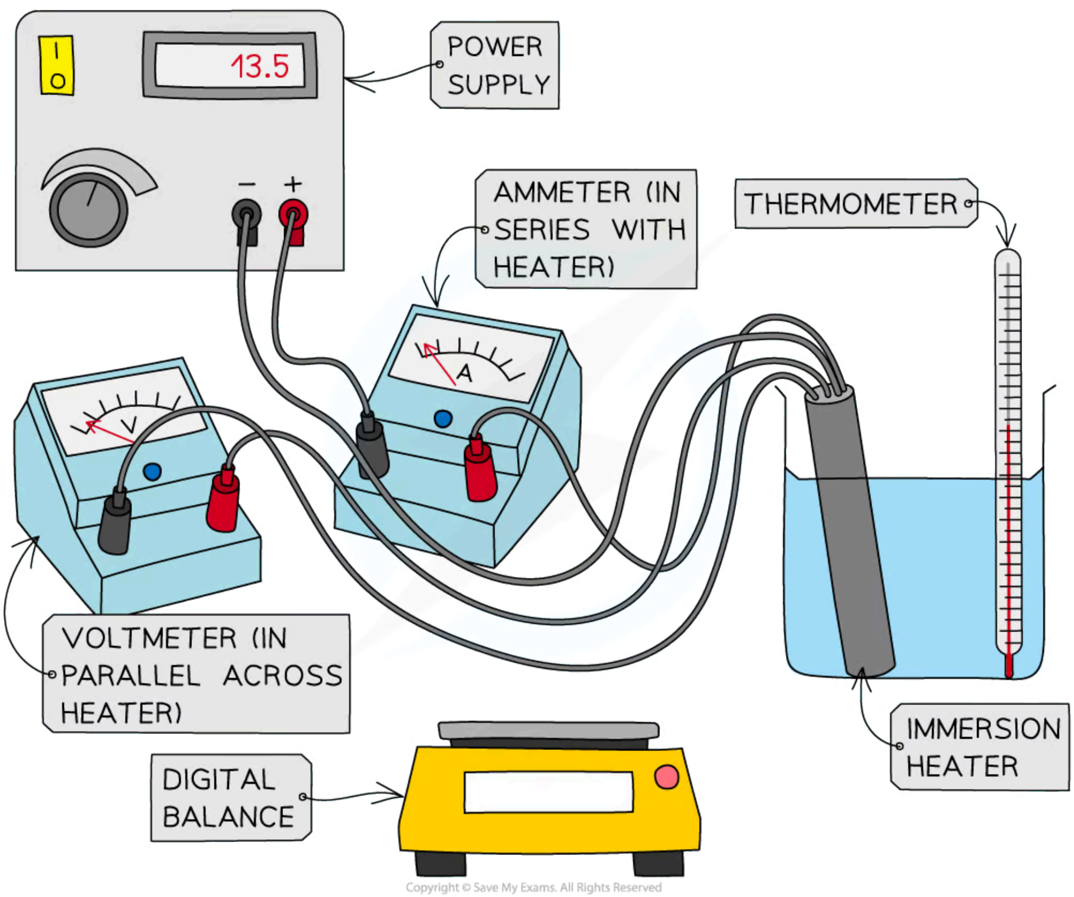
Your notes

Experiment 1: Determining the Specific Heat Capacity of Water

Aim of the Experiment

- The aim of this experiment is to determine the specific heat capacity of water by measuring the energy required to increase the temperature of a known amount by 1°C

Method



Apparatus for heating water and measuring energy supplied

1. Place the beaker on the digital balance and press 'tare'
2. Add approximately 250 ml of water and record the mass of the water
3. Place the immersion heater and thermometer in the water
4. Connect up the circuit as shown in the diagram, with the ammeter in series with the power supply and immersion heater, and the voltmeter in parallel with immersion heater

5. Record the initial temperature of the water at time 0 s

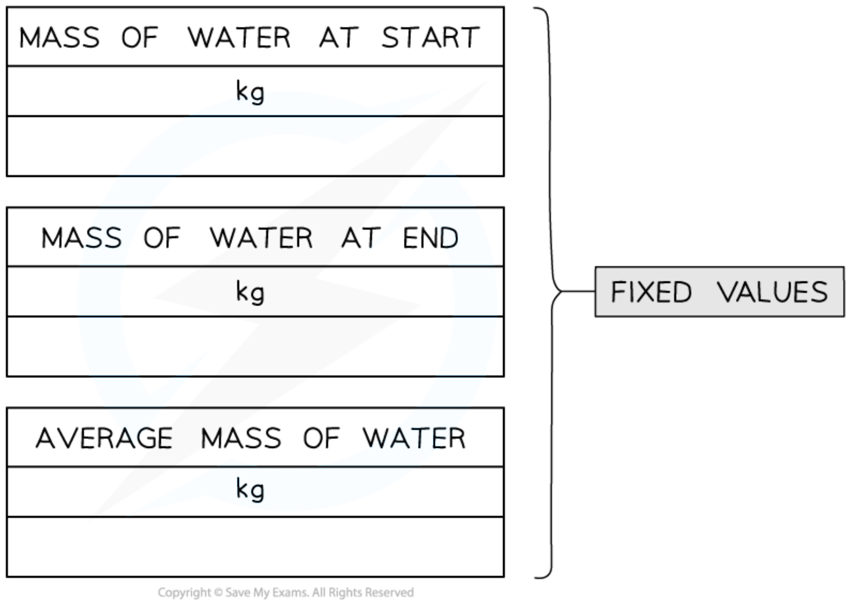
6. Turn on the power supply, set at approximately 10 V, and start the stopwatch

7. Record the voltage and current

8. Continue to record the temperature, voltage and current every 60 seconds for 10 minutes

- An example of a results table might look like this:

RAW DATA				PROCESSED DATA	
TIME	VOLTAGE	CURRENT	TEMPERATURE	ENERGY SUPPLIED	TEMPERATURE CHANGE
seconds	volts	amps	degrees C	Joules	degrees C
0				0	0
60					
120					
180					
240					
300					
360					
420					
480					
540					
600					

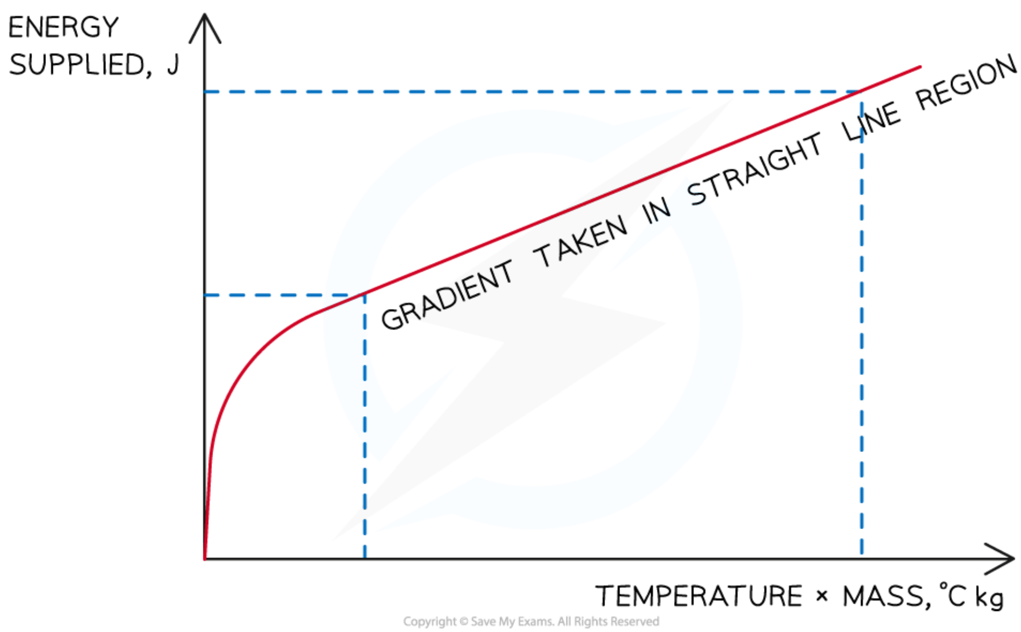


Analysis of Results

- Calculate the energy supplied each minute using the formula:

Electrical energy (J) = voltage (V) × current (A) × time (s)

- Calculate the temperature change by subtracting the temperature at time 0 s from the temperature recorded each minute
- Calculate the average mass of the water by adding the mass at the start and the mass at the end and then dividing the total by two
- Plot a graph of the energy supplied (y-axis) against the temperature change multiplied by the average mass (x-axis)
- The gradient of this graph will be the specific heat capacity of the water
- Take the gradient in the straight-line region of the graph:
  - Divide the change on the y-axis between two points on the straight line region, with the change on the x-axis between the same two points



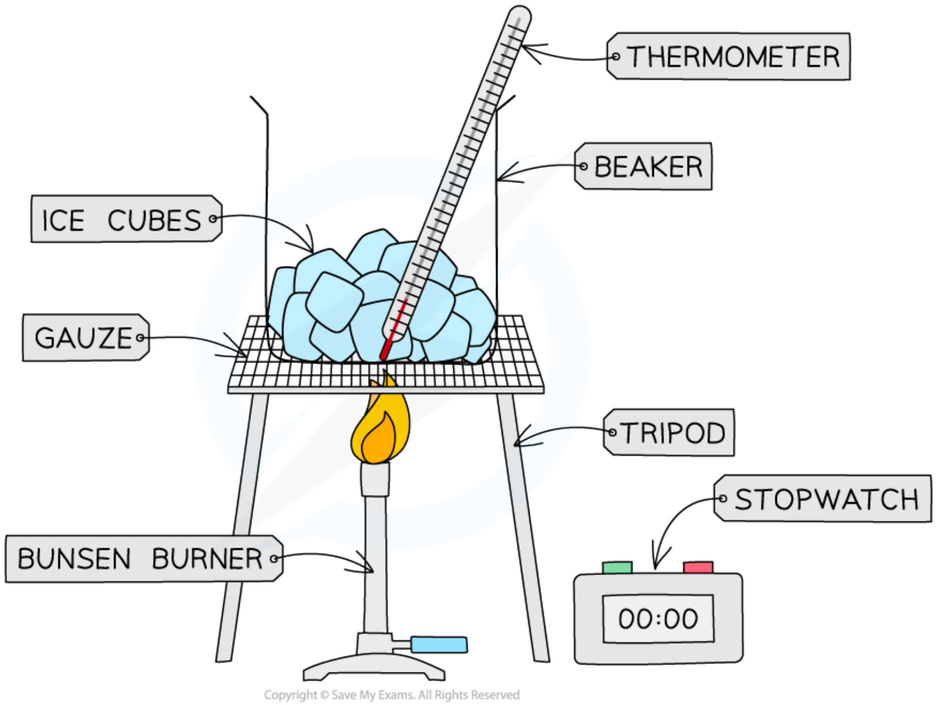
The gradient of the graph is equal to the specific heat capacity of the water, assuming a perfectly efficient immersion heater

Experiment 2: Obtaining a Temperature–Time Graph for Melting Ice

Aim of the Experiment

- The aim of this experiment is to plot a graph of the temperature of ice, against time, as it is heated to water

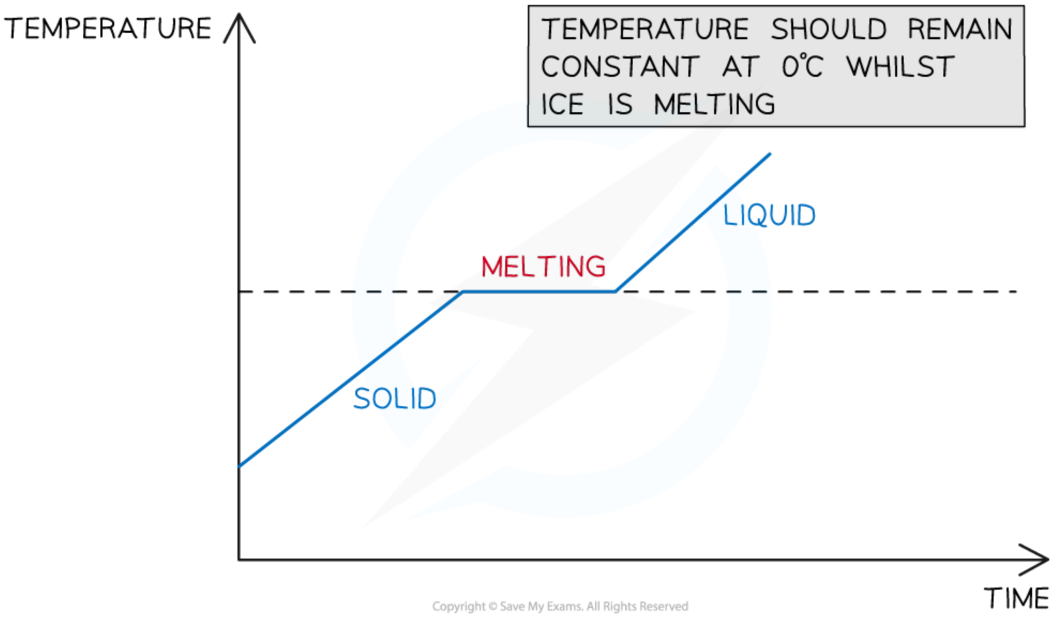
Method



Apparatus used to heat ice and measure its temperature as it melts

1. Place some ice in a beaker so it is about half-full
2. Place a thermometer in the beaker
3. Place the beaker on a tripod and gauze and slowly start to heat it using a bunsen burner
4. As the beaker is heated, take regular temperature measurements (e.g. at one minute intervals)
5. Continue this whilst the substance changes state (from solid to liquid)
6. The results can then be plotted on a graph

Your notes



A heating curve will show a flat section whilst the ice is melting

Evaluating the Experiments

Systematic Errors:

- Ensure the digital balance is set to zero before taking measurements of mass
- It may be necessary to determine the efficiency of the immersion heater before experiment 1:
  - The specific heat capacity of water has a known value of 4200 J/kg/°C
  - If the efficiency of the heater is less than 1 then the values obtained for specific heat capacity will be larger than expected
- Remember to only take gradients on the straight-line region
  - Before this point the energy supplied is being used to heat the immersion heater itself

Random Errors:

- Stir the ice water constantly whilst heating in experiment 2
- When the current or voltage values appear to be changing between two values next to one another then be consistent in choosing the higher value

Safety Considerations

- The immersion heater will get very **hot**

  - Make sure not to touch it, and have a heatproof mat ready to place it on
- Make sure that the immersion heater is connected to a **direct current** supply
- The beaker may become **unstable** with an immersion heater and thermometer resting in it
  - If you feel this is the case then use a clamp stand to hold both
- Wear goggle while heating water
- Make sure to stand up during the whole experiment, to react quickly to any spills

Your notes

Examiner Tips and Tricks

Although there is a lot of detail here, if you can begin any questions about this experiment by writing down the equation for specific heat capacity then you will have given yourself some clues about how best to proceed Taking a gradient is a more reliable way of determining an answer than just using a single value, so take time to understand the process of plotting graphs and using their gradients to make conclusions