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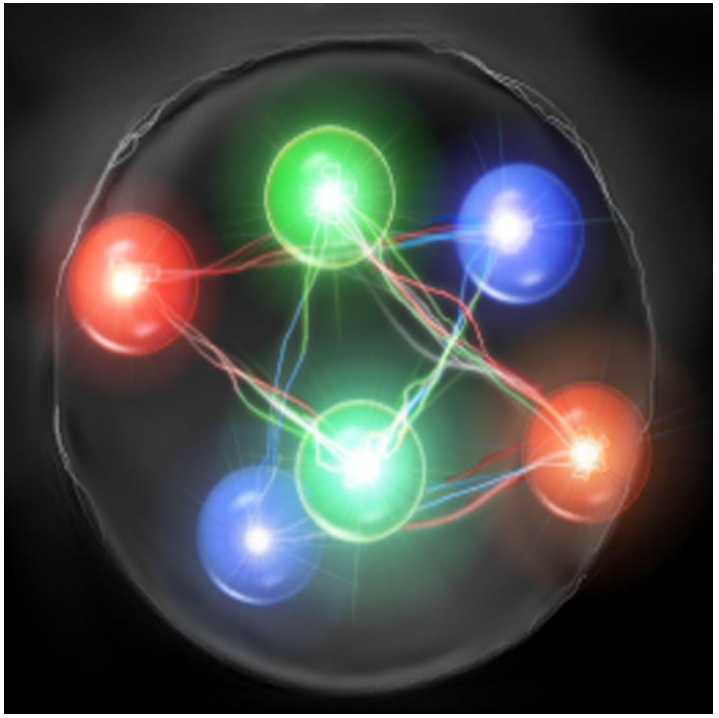
GCSE Physics

Edexcel Physics

The particle model

Overview
Edexcel Topic 14

The particle model



Part 1

- Particles and density
- Changes of state
- Energy calculations

Part 2

- Thermal (internal) energy and energy transfers
- Gas temperature and pressure
- Temperature scales
- Gas pressure and volume (physics only)

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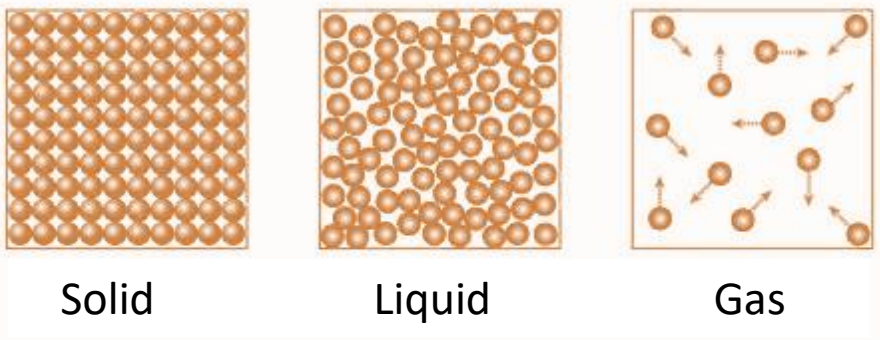
Part 1

- Particles and density
- Changes of state
- Energy calculations

Changes of state and the particle model

Density also depends on the **state** of a substance.



In solids the particles are packed close together.

In liquids the particles are free to move so the same mass takes up more space.

In gases the particles take up a much greater volume than in liquids and solids.

For any particular substance, a solid is usually denser than its liquid and the liquid is usually denser than the gas.

However, there are exceptions to this. Solid water (ice) is less dense than liquid water. This is why ice floats on water.

Density equation

Density is the mass of a given volume of a substance

The density of a substance is determined by the mass of the atoms it is made from and how closely these atoms are packed together.

Recall and use the equation:

density (kg/m^3) = mass (kg) ÷ volume (m^3)

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

substance	density (kg/m^3)
water (l)	1 000
glass (s)	3 140
iron (s)	7 700
aluminium (s)	2 800
hydrogen (g)	0.085

Density calculation

What is the density of a bar of gold if its volume is 350 cm^3 and its mass is 6.76 kg?

Solution:

Convert 350 cm^3 into m^3 = 0.00035 m^3

Equation: density (kg/m^3) = mass (kg) ÷ volume (m^3)

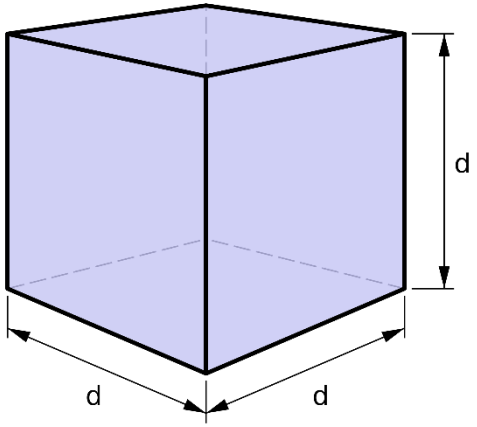
$$\rho = \frac{m}{V}$$

Substitution : $$\text{density} = \frac{6.76}{0.00035}$$

Click to reveal answer

Practical procedure: Densities

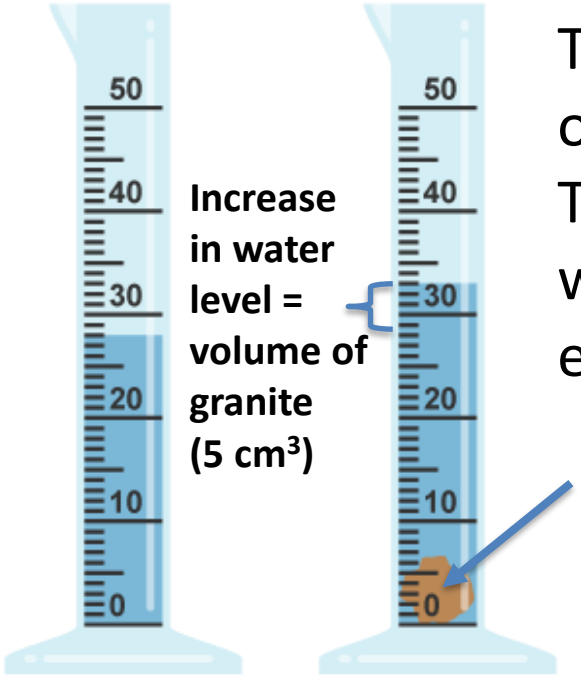
Video 1



Video 2

Video 3

Finding the density of an irregular object



To find the density of an **irregular** shaped object, you need to determine its volume. To do this, it is placed in a known volume of water and the amount of water **displaced** equals the volume of the object.

Piece of **granite** stone with a mass of 13.5 g (0.0135 kg)

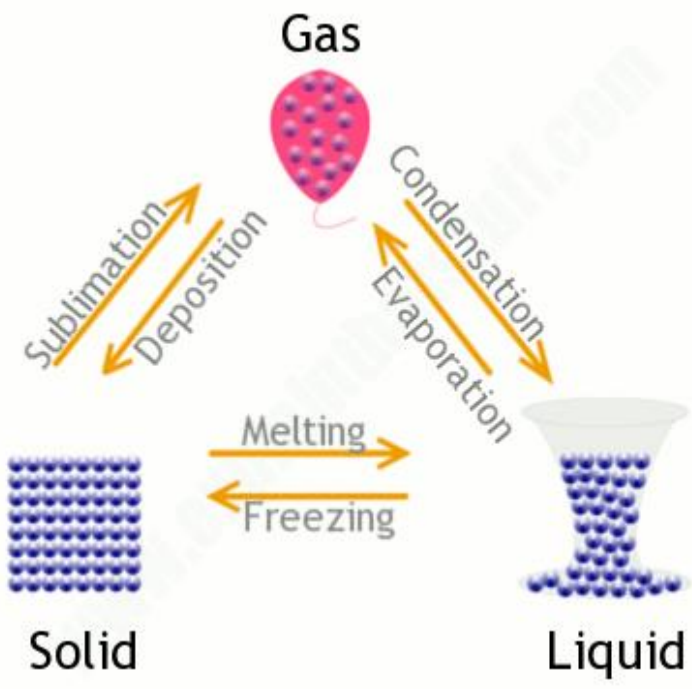
Volume = 0.000005 m^3

$$\text{density of granite} = \frac{0.0135 \text{ kg}}{0.000005 \text{ m}^3} = 2\,690 \text{ kg/m}^3$$

A change of state can be brought about by changing the **temperature** or **pressure** of a material.

If the solid shown has a mass of 1kg, then the liquid and gas will both have a mass of 1 kg.

Mass is conserved when a substance changes state, only the volume changes.



The arrows show the direction in change of state.

Changes of state are **physical changes** **not** chemical changes. The change can be **reversed** in a physical change so the material recovers its **original properties**. This does not happen with a chemical change.

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QuestionIT!

Part 1

- Particles and density
- Changes of state
- Energy calculations

Part 1 – QuestionIT

1. Why is it incorrect to say iron is heavier than wood?

2. Water has a density of 1000 kg/m³. A piece of rubber has a density of 1024 kg/m³. Explain what would happen if the rubber was put in a pool of water?

3. This “ready-mix” concrete waggon contains 9600 kg of concrete. If the density of the concrete is 2400 kg/m³, what volume of concrete does the waggon contain?

4. a. A sheet of insulating foam measures 3 m x 1 m x 0.08 m. It has a mass of 9.6 kg. Calculate the density of the insulating foam.

b. High density foam is made of the same material and can be used to give better insulation for the same thickness of foam. Describe how the arrangement of particles would differ in these two types of foam (you may draw diagrams to help your answer).

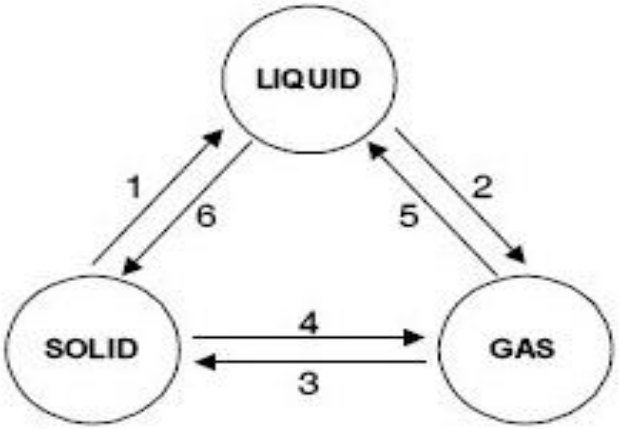
5. When copper metal is heated to 1100 ^{o}C it melts.

a. Is this a chemical or physical change? Explain your answer.

b. What will happen to the mass of the sample of copper after it has melted? Explain your answer.

6. Explain the difference between a physical and a chemical change.

7. Name the changes in state given in the diagram by the arrows 1 to 6.



8. If you wanted to find the density of a brass key, you first need to measure its volume. Describe how to determine the volume of a brass key.

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AnswerIT!

Part 1

- **Particles and density**
- **Changes of state**
- **Energy calculations**

1. Why is it incorrect to say iron is heavier than wood?

   It depends how much iron and wood you have. You should say iron is denser than wood.

2. Water has a density of 1000 kg/m³. A piece of rubber has a density of 1024 kg/m³. Explain what would happen if the rubber was put in a pool of water?

   Rubber has a higher density than water so the rubber would sink in water.

3. This "ready-mix" concrete waggon contains 9600 kg of concrete. If the density of the concrete is 2400 kg/m³, what volume of concrete does the waggon contain?

Density = $\frac{m}{v}$ $v = \frac{mass}{density} = \frac{9600\ kg}{2400\ kg/m^3} = 4$

volume of concrete in the waggon = 4 m³

4. a. A sheet of insulating foam measures 3 m x 1 m x 0.08 m. It has a mass of 9.6 kg. Calculate the density of the insulating foam.

V = 3 x 1 x 0.08 = 0.24 m^3 **Density = 9.6 / 0.24 = 40 kg/m^3**

b. High density foam is made of the same material and can be used to give better insulation for the same thickness of foam. Describe how the arrangement of particles would differ in these two types of foam (you may draw diagrams to help your answer).

Particles in the high density foam will be closer together so there are more particles in a given volume, making it denser.

5. When copper metal is heated to 1100 ^oC it melts.

a. Is this a chemical or physical change? Explain your answer.

Physical change. No new products have been formed.

b. What will happen to the mass of the sample of copper after it has melted? Explain your answer.

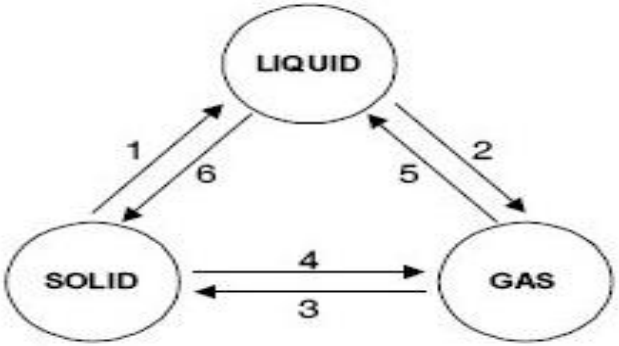
It will stay the same. Mass is conserved when state changes.

6. Explain the difference between a physical and a chemical change.

In a physical change no new products are formed and it can be easily reversed.

In a chemical change a new substance is formed which can not easily be changed back .

7. Name the changes in state given in the diagram by the arrows 1 to 6.



1. melting 2. evaporating 3. deposition

4. subliming 5. condensing 6. freezing

8. If you wanted to find the density of a brass key, you first need to measure its volume. Describe how to determine the volume of a brass key.

Drop the key into a known volume of water and measure the amount of water displaced by the key. This will be the volume of the key.

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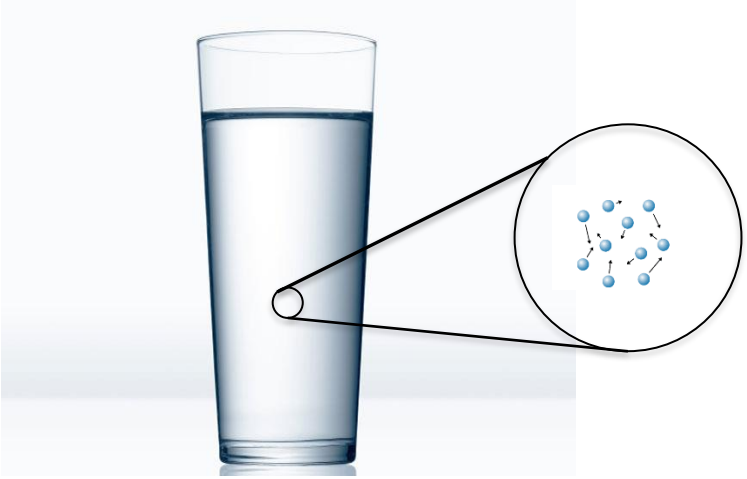
Part 2

- Thermal (internal) energy and energy transfers
- Gas temperature and pressure
- Temperature scales
- Gas pressure and volume (physics only)

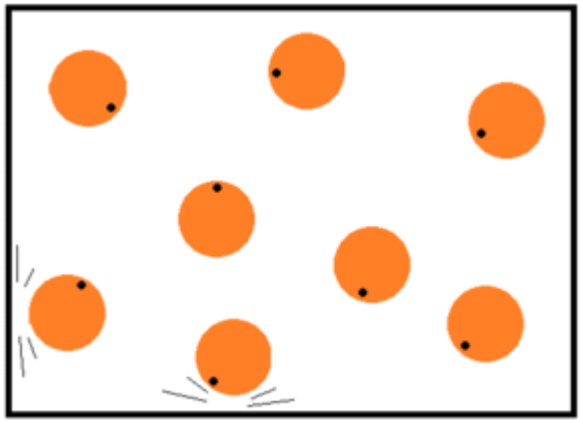
Thermal (internal) energy and energy transfers

Thermal (internal) energy is the energy stored in a system by the atoms and molecules that make up that system.



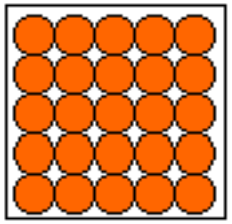
The molecules of water have kinetic (movement) energy and some potential energy. The total **kinetic (KE)** and **potential (GPE)** energy in the system make up the **thermal (internal) energy.**

The particles inside a **liquid** or a **gas** are in **constant motion**, colliding with each other and the walls of any container they are in.
In a **solid** the particles are **vibrating** around a fixed point.

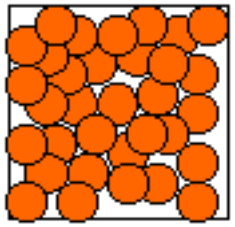


Thermal (internal) energy and changes of state

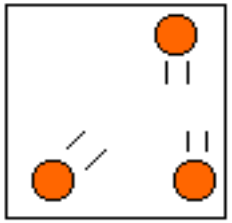
When heat is added to a system the **thermal (internal) energy** of the particles increases. This can result in the material **changing state**.



In a **solid**, particles can only **vibrate** so they cannot move relative to each other. When the solid is heated the particles gain kinetic energy and vibrate faster and faster.



In a **liquid**, the particles are **moving** fast enough to break free from the solid. They are free to move relative to each other but are held within a container.



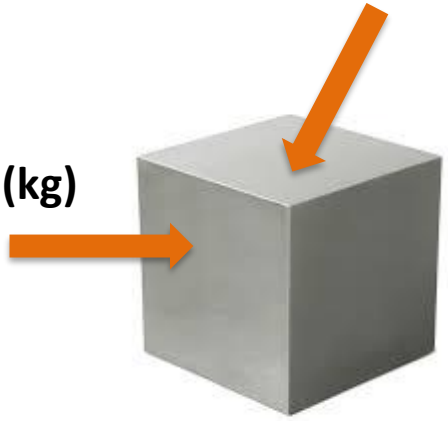
In a **gas**, the particles have sufficient energy to **break free** from their container. Gas particles can move away from their container and away from other gas particles.

Temperature change in a system and specific heat capacity

The temperature increase of an object depends on what it is made of, the mass of the object and the amount of energy put into it.

type of material (specific heat capacity) (J/kg °C)

mass of system (kg)



energy input (thermal) (J)

To calculate the temperature change, the formula for **specific heat capacity** has to be re-arranged.

Remember, specific heat capacity (***c***) is the energy required to raise the temperature of 1 kg of a substance by 1°C.

Thermal (internal) energy equation

Change in thermal (internal) energy

Change in thermal (internal) energy can be determined by using the mass, specific heat capacity and change in temperature of an object.

Use the equation:

change in thermal energy (J) = mass (kg) × specific heat capacity (J/kg °C) × change in temperature (°C)

$$\Delta Q = m \times c \times \Delta\theta$$

Thermal (internal) energy calculation

A kettle contains 1400 g of water at 12 ºC.

If temperature of the water rises by 68 ^{O}C, how heat energy is supplied to the water?

The specific heat capacity of water is: 4182 J/kg °C

Solution:

Convert 1400 g into kg = 1.4 kg

Equation:

change in thermal energy (J) = mass (kg) × specific heat capacity (J/kg °C) × change in temperature (°C)

$$\Delta Q = m \times c \times \Delta\theta$$

Substitution: $\Delta Q = 1.4 \times 4182 \times 68$

Answer: Click to reveal answer

Specific latent heat

Latent heat is the energy needed to **change the state** of a substance without a change in temperature.
The energy supplied is used to change the **thermal (internal) energy store** of the substance.

Latent heat for melting is called **specific latent heat of fusion** (L_f)
Latent heat for evaporating is called **specific latent heat of vaporisation** (L_v)

1kg of ice at 0ºC

1kg water at 0ºC

Specific latent heat of fusion for water = 336 000 J/kg
This means 336 000 J of energy are needed to turn 1 kg of ice into 1 kg of water with no temperature change.

Thermal (internal) energy for change of state equation

A kettle contains 1400 g of water at 12 ºC.

If temperature of the water rises by 68 ^{O}C, how heat

energy is supplied to the water?

The specific heat capacity of water is: 4182 J/kg °C

Solution:

Convert 1400 g into kg = 1.4 kg

Equation:

change in thermal energy (J) = mass (kg) × specific heat capacity (J/kg °C) × change in temperature (°C)

$$\Delta Q = m \times c \times \Delta\theta$$

Substitution: $\Delta Q = 1.4 \times 4182 \times 68$

Answer: Click to reveal answer

Thermal (internal) energy for change of state equation

Thermal energy for a change of state

Thermal energy for a change of state can be determined by using the mass and specific latent heat capacity.

Use the equation:

thermal energy for a change of state (J) = mass (kg) × specific latent heat (J/kg)

$$Q = m \times L$$

Thermal energy for a change of state calculation

5 g of gold is being melted to make a ring.
Once the gold reaches its melting temperature, how much heat energy is needed to melt the gold?

Specific latent heat of fusion for gold = 64 400 J/kg

Solution:

Convert 5 g into kg = 0.0005 kg

Equation:

thermal energy for a change of state (J) = mass (kg) × specific latent heat (J/kg)

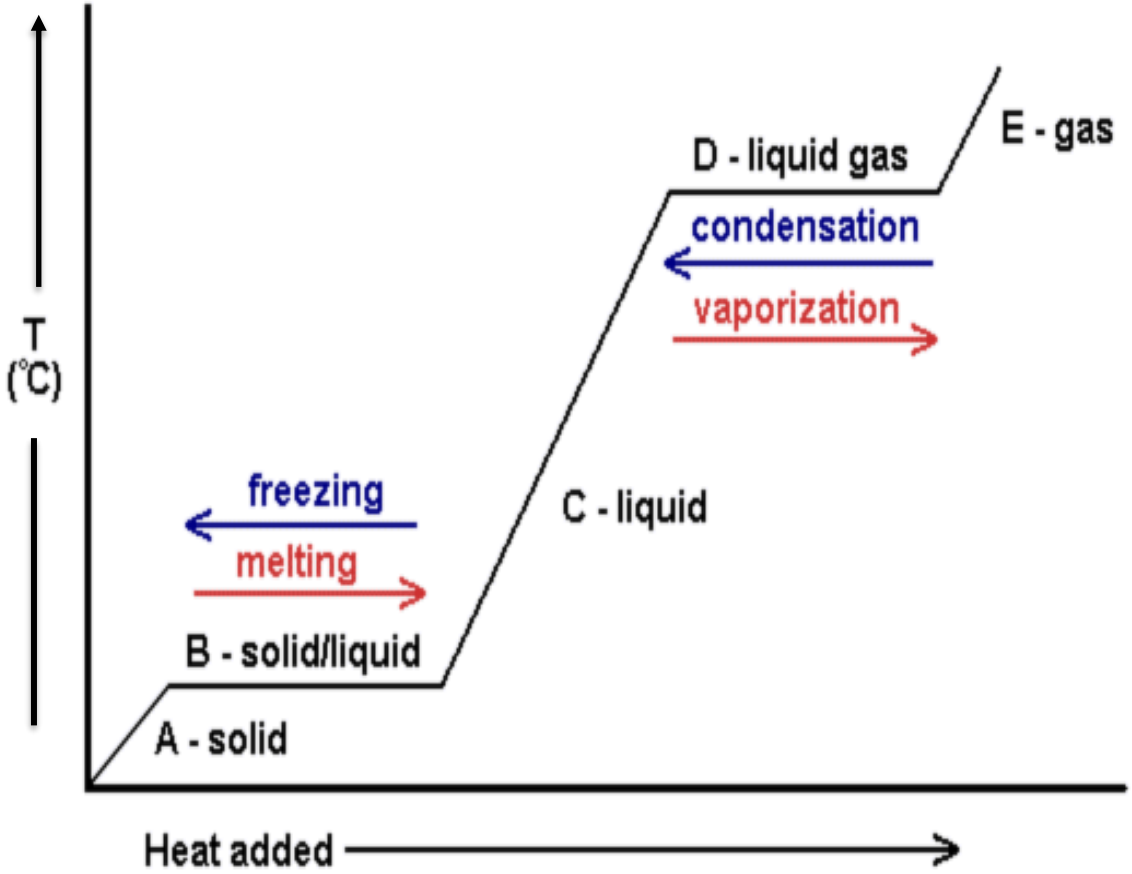
$$Q = m \times L$$

Substitution: $Q = 0.0005 \times 64\,400$

Answer: Click to reveal answer

Changes of heat and specific latent heat

Heating and cooling graphs



As heat energy is added to a solid, the temperature rises until it reaches its **melting point.**
As the substance melts, all the heat energy added is used to **change the state** of the substance with no temperature change.
When all the substance is melted, the temperature will then rise until the **boiling point** is reached.
Again, heat energy is now required to **change the state** to a gas with no temperature change.

Reducing unwanted energy transfers

Different devices have different efficiency values. No device can be more 100% efficient.

Devices can waste in many ways, for example:

- **Friction (thermal energy)** between the moving part of a car or motorbike
- **Sound energy** when a hair drier is being used
- **Electrical** circuits heating (thermal energy) up due to resisitance
- **Thermal energy** being lost from the roof or wall of a house

Mechanical devices can be made more efficient by lubrication this reduces energy transferred by friction e.g. engine oil

Having good **insulation** reduces the rate of **thermal energy transfers** e.g. loft insulation

Practical procedure: Specific Heat Capacity

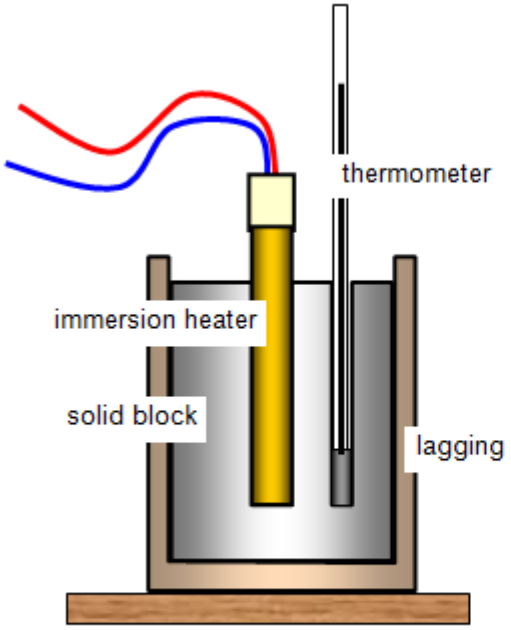


Figure 1(a)

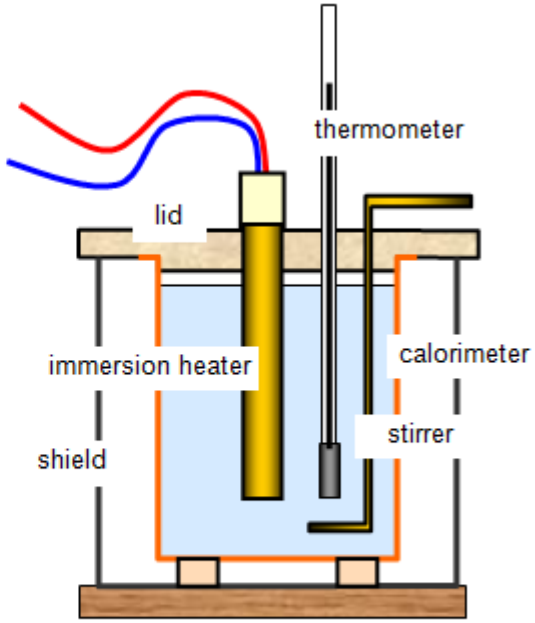


Figure 1(b)

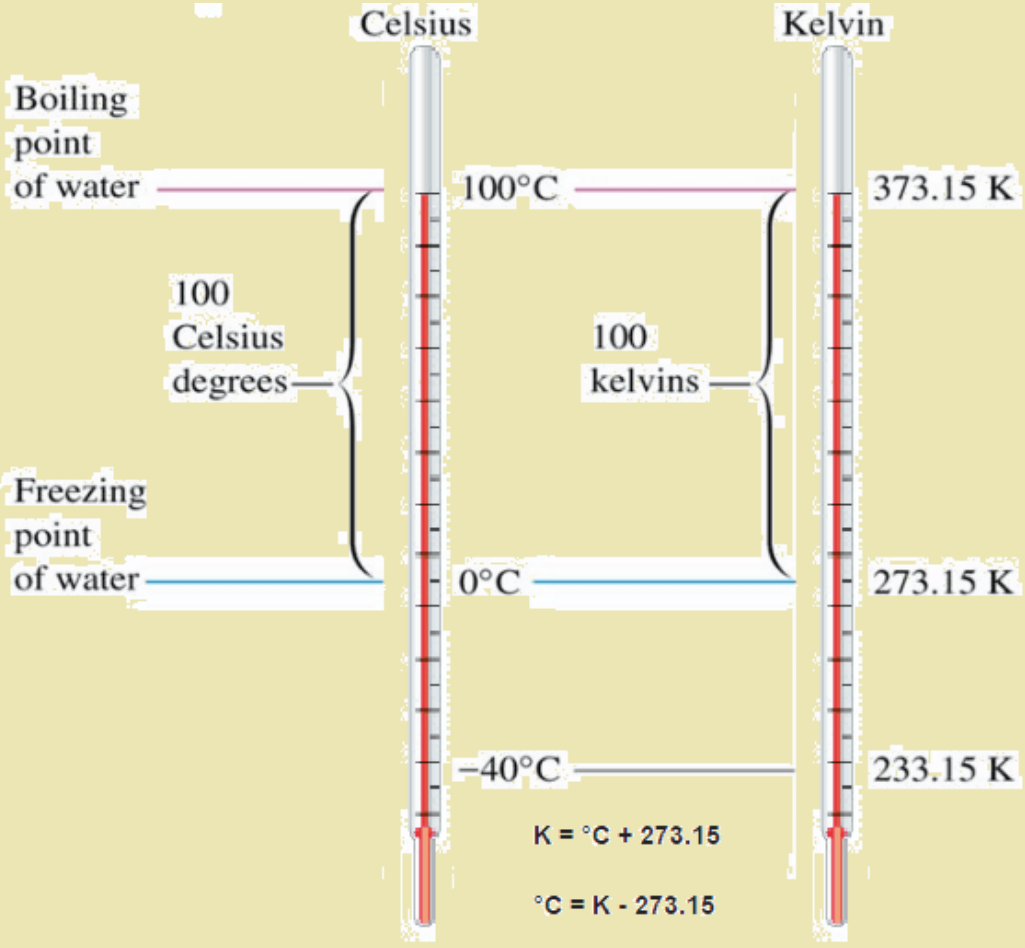
Video 1

Video 2

Image from: http://www.schoolphysics.co.uk/age16-19/Thermal%20physics/Heat%20energy/text/Specific_heat_capacity_measurement/index.html

Temperature

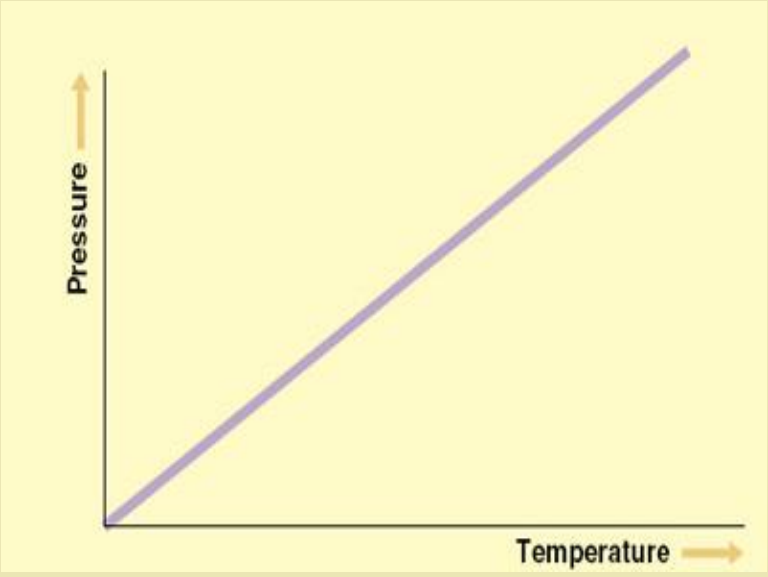
- As the **temperature** of a fixed volume gas **increases**, the **pressure increases.**
- In everyday life we usually use the **Celsius scale** to measure temperature.
- In science we also use the **Kelvin scale** to measure temperature.
- 1 °C is **equivalent** 1K.
- **Absolute zero** is the point when particles stop moving this occurs at is -273 °C and 0 K



Particle motion in gases

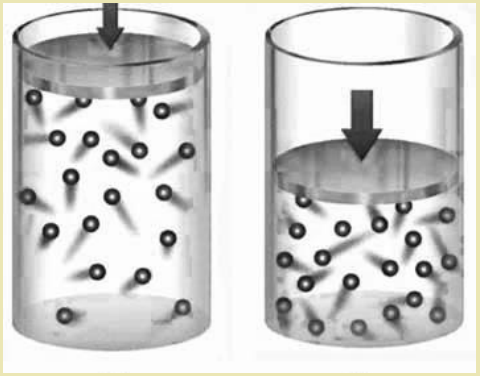
If a sealed can of air (gas) is heated, the molecules of air move faster and faster.
The collisions of these molecules on the inside walls of the container create a pressure. The hotter the molecules, the faster they move and the more pressure they exert on the wall of the can.

If the can continues to be heated, the pressure will keep rising steadily.
The graph opposite shows that **gas pressure is directly related to its temperature**, if the volume remains constant.



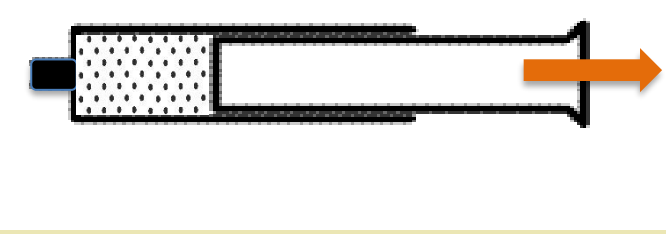
Pressure in gases (physics only)

When a gas is **compressed** inside a fixed container, there are more particles in a given volume to **strike the walls** of the container, therefore the **pressure on the container walls increases.**



The pressure produces a net force at right angles to the wall which means the pressure will act evenly in all directions.

Think about a sealed syringe with a fixed amount of gas inside. The particles will be colliding with the syringe walls creating a pressure.



If the plunger is pulled out, the same amount (mass) of gas will be occupying a greater volume.
This will result in fewer collisions over a given area of the syringe wall.

Gas pressure will be reduced

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QuestionIT!

Part 2

- **Thermal (internal) energy and energy transfers**
- **Gas temperature and pressure**
- **Temperature scales**
- **Gas pressure and volume (physics only)**

Part 2 – AnswerIT

1. Define internal energy?

2. Which of the following will change the internal energy of a stone?
   a. Lifting it to the top of a building
   b. Heating it
   c. Firing it from a catapult

3. Water and the chemical isooctane both boil at 100 ºC. When the same amount of each substance is placed on a heater, the isooctane boils first. Explain why this happens.

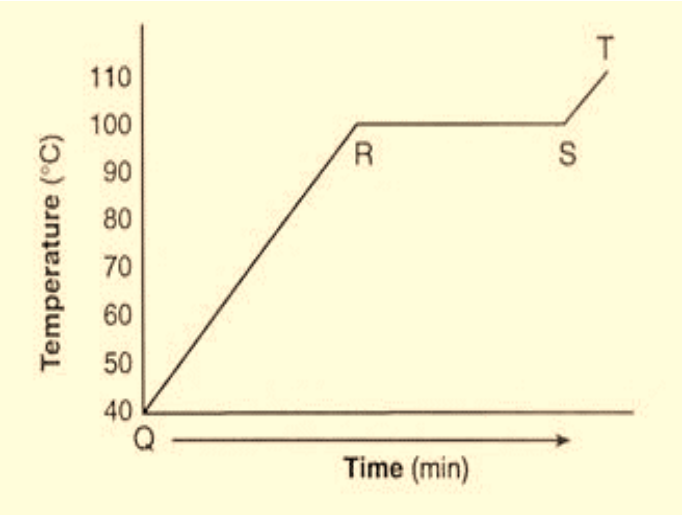
4. A hot stone is placed into a glass of water containing 200 g of cold water. If the stone transfers 25 200 J of energy to the water, what will the temperature rise of the water be?

specific heat capacity of water = 4200 J/kg °C $\Delta Q = m \times c \times \Delta\theta$

5. What is latent heat?

6. Explain the difference between latent heat of fusion and latent heat of vaporisation.

7. A boiler is being used to heat water. The graph shows the temperature of the water every 5 minutes.



a. What state is the water in between points Q and R?

b. At which point does the water begin to boil?

c. What state is the water in at 110 ºC?

8. Candle wax has a latent heat of fusion of 200 000 J/kg. If the candle is at its melting temperature, how much heat energy is needed to melt a 250 g candle?

$$Q = m \times L$$

AnswerIT!

Part 2

- **Thermal (internal) energy and energy transfers**
- **Gas temperature and pressure**
- **Temperature scales**
- **Gas pressure and volume (physics only)**

Part 2 – AnswerIT

1. Define internal energy?

   The total kinetic and potential energy of all the particles within a system

2. Which of the following will change the internal energy of a stone?

   A. Lifting it to the top of a building
   B. Heating it
   C. Firing it from a catapult

   Heating it.

3. Water and the chemical isooctane both boil at 100 ºC. When the same amount of each substance is placed on a heater, the isooctane boils first. Explain why this happens.

   Isooctane has a lower specific heat capacity than water so less heat energy is needed to raise its temperature to its boiling point.

4. A hot stone is placed into a glass of water containing 200 g of cold water. If the stone transfers 25 200 J of energy to the water, what will the temperature rise of the water be?

specific heat capacity of water = 4200 J/kg °C $\Delta Q = m \times c \times \Delta\theta$

$$\Delta\theta = \frac{\Delta Q}{m \times c} = \frac{25\,200}{0.2 \times 4200} = 30\ ^{o}C$$

Temperature rise of the water = 30 °C

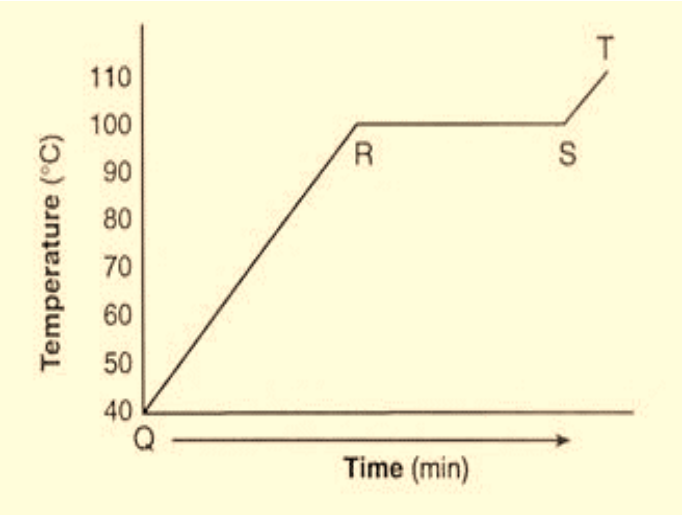
5. What is latent heat?

The energy needed to change the state of a substance without changing the temperature.

6. Explain the difference between latent heat of fusion and latent heat of vaporisation.

Latent heat of fusion is the energy needed to change between solid and liquid. Latent heat of vaporisation is the energy needed to change state between liquid and gas.

7. A boiler is being used to heat water. The graph shows the temperature of the water every 5 minutes.



a. What state is the water in between points Q and R?

Liquid

b. At which point does the water begin to boil?

R

c. What state is the water in at 110 ºC?

Gas

8. Candle wax has a latent heat of fusion of 200 000 J/kg. If the candle is at its melting temperature, how much heat energy is needed to melt a 250 g candle?

$$Q = m \times L$$

Q = 0.25 x 200 000 = 50 000 J