EXPLORING SCIENCE

INTERNATIONAL 11–14

7

Mark Levesley, Sue Kearsey, Iain Brand, Penny Johnson

SAMPLE UNIT

Year 7 Unit 7E: Mixtures and separation

Under the skin

The bright colour of a poison dart frog warns predators that its skin contains a lethal poison. Although just a tiny amount would be enough to kill a large animal, scientists are now investigating some of the substances in the poison to help them to design new medicines.

Pearson

7Ea MIXTURES AND SEPARATION

To remain healthy, we need water. Your body loses water all the time and you can only live for a few days without drinking. Water for drinking must be clean, because dirty water can contain harmful substances and microorganisms.

In many dry parts of the world, people struggle to get enough suitable drinking water. Even in wetter parts of the world, there is sometimes too little rain to keep water reservoirs filled. Hosepipe bans can limit the water we use and make sure enough water is left for essential needs, such as drinking.

Water is a **liquid** in which many different substances can **dissolve**. Sources of water, such as rivers and streams, may also carry **solids** such as sand, gravel or mud. To make water safe and suitable for drinking, water must be treated in different ways to remove unwanted substances.

A | Around 800 million people in the world do not have clean water that is safe to drink.

B | This reservoir in South Africa supplies water for drinking and other needs to Cape Town. Sometimes rainfall levels are so low that the reservoir is at risk of running dry.

C | Gases, such as **carbon dioxide**, can also dissolve in water. You can see this when you open a bottle of fizzy drink and the gas is released from solution.

1 a| Give an example of a solid, a liquid and a gas.

b| Describe how you can tell the difference between solids, liquids and gases.

2 A sample of water is collected from a stream. Suggest how you would separate out each of the following from the water:

a| gravel b| sand.

3 Sea water is a solution of water and dissolved substances, such as salt.

a| Explain what 'solution' means.

b| Describe how you would separate the dissolved substances from sea water.

4 a| Dissolving is a 'reversible change'. What does this mean?

b| Give one other example of a reversible change.

7Ea FORENSIC SCIENCE

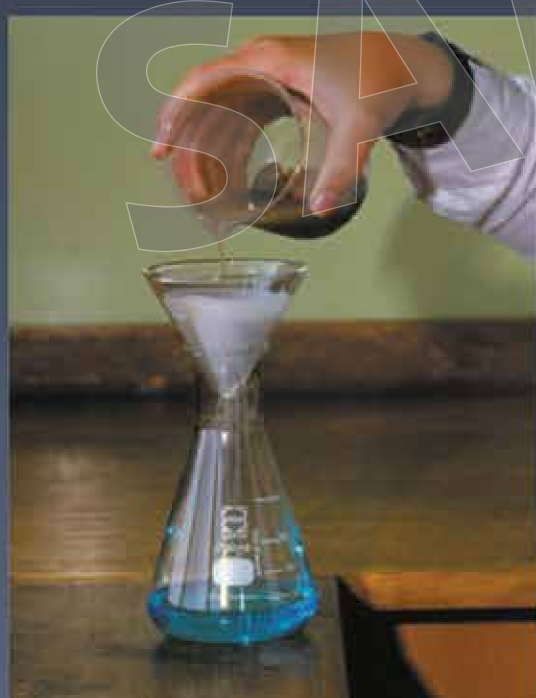
HOW DOES A FORENSIC SCIENTIST PREPARE EVIDENCE FOR A COURT?

Forensic scientists collect materials from crime scenes. They may collect soil, burnt or broken materials, hairs and body fluids. The scientists then examine and test the materials in a lab. Their results can be used as evidence in a court of law. For example, the evidence could be used to show whether a person or vehicle was in a certain place.

A | Samples of soil can be analysed to help identify where this car has been.

Using knowledge of chemistry

Most forensic scientists have a university degree in forensic science, or other science followed by forensic science training. A forensic scientist needs a good understanding of the techniques used to separate and identify small amounts of substances (samples).



B | This apparatus can be used to separate soil from water.

A common technique is **filtration**, which separates **insoluble** substances (the **residue**) from a liquid (the **filtrate**). When you filter a soil and water mixture, the filtrate contains substances naturally found in soil. These substances can be tested to find out what they are (e.g. by using chromatography, which you will learn about on page 80). The substances in a filtrate can be used to tell where some soil is from. Or the filtrate may contain substances from someone or something, such as a vehicle.

1. Write down what you think forensic science means.
2. Give a reason why a forensic scientist needs to know how to separate the different substances in a sample.
3. Explain why filtration could help analyse where a soil sample originally came from.

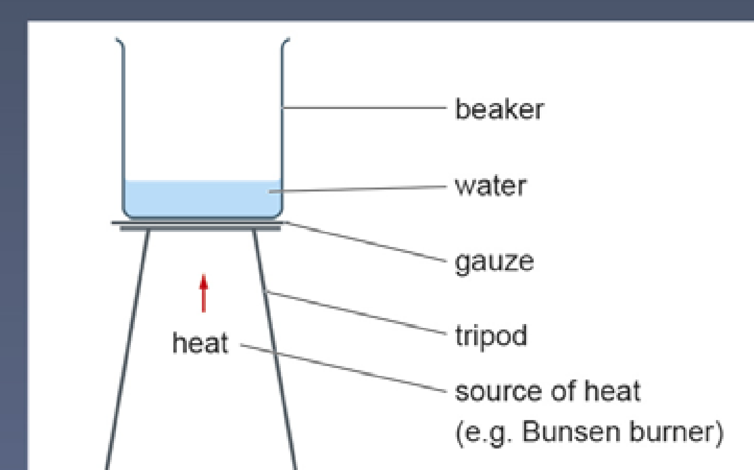
Clear communication

Forensic scientists need to explain clearly what they have done. An important part of this is their **method**, which is a set of written instructions showing how an experiment is carried out. The method may also include a diagram of the **apparatus**. A clear method lets other scientists repeat an experiment exactly, to check the **results**. It also allows people in a court to understand easily what a forensic scientist has done.

The Method on the right can be used to filter a sand (or soil) sample using the apparatus in diagram C. It is clear because:

- it is done in steps, which each have a letter
- each step describes only one action
- each step begins with a command word (also called an imperative verb). This keeps the sentence simple.

4. Why is it important for forensic scientists to describe their methods clearly?
5. 'Open' in step C is a command word because it tells you to do something. Identify three other command words in this Method. Explain your choices.
6. Suggest a part of this Method that could be made clearer by using a diagram rather than words.
7. Write a method to explain to someone how to set up the apparatus in diagram D. Use all the rules for writing a good method. Compare your method with one written by another student to see if your method could be improved to make it clearer.



D | apparatus for heating water

Method

A | Fold a circular filter paper in half.

B | Fold the filter paper in half again to form a triangular shape.

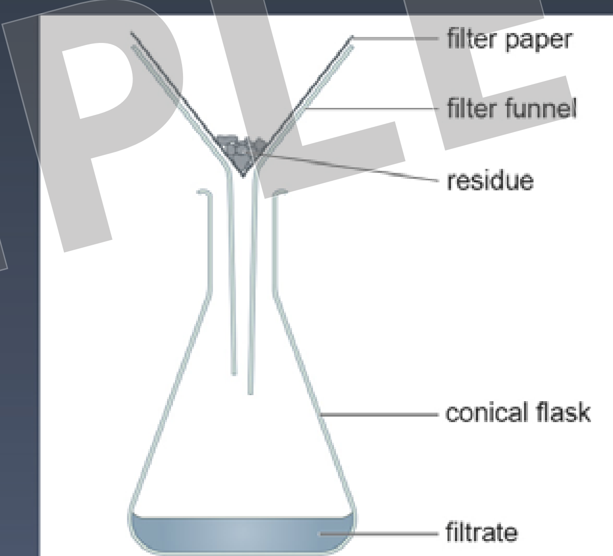
C | Open out one layer of the paper to form a cone.

D | Place the filter paper cone into a filter funnel.

E | Stir the sand mixture with water so that all the sand is suspended.

F | Place the filter funnel into the neck of a conical flask.

G | Pour the sand and water into the filter paper.



C | filtering apparatus

ACTIVITY

Use the Method above to carry out a filtering activity. As you carry out the Method, think about each instruction:

- is it written as clearly as it could be?
- is it given in the right order?

Try rewriting the method in a way you think makes it easier to carry out.

7Ea MIXTURES

WHAT KINDS OF MIXTURES ARE THERE?

Water that carries waste materials needs to be treated in a water treatment plant so that it does not harm people or the **environment**. Waste water is not a single substance – it is not a **pure** substance. It is a **mixture** of water and solid substances.

Mixtures are grouped depending on whether the substances in them are solids, liquids or gases, and on how the substances can be separated.

- A **solution** is a mixture in which the solid dissolves in the liquid. This makes the mixture clear or **transparent**.
- A **suspension** is a mixture of two substances that separate if the mixture is not stirred. These two substances are often a solid and a liquid. When they are mixed, we say that one substance is suspended in the other. An example is sand mixed with water.
- In a **colloid**, one substance is **dispersed** in another substance and the two substances will not separate easily. Either substance may be a solid, liquid or gas. A colloid is cloudy or **opaque**, so it is easy to see that it is a mixture. Milk is a colloid of different milk solids dispersed in water.

Many mixtures we use are colloids, such as hair spray, hand cream, Styrofoam™ cups, paint and gel inks. Different kinds of colloid have properties that make them useful in different ways.

FACT

Fog is a colloid of water droplets dispersed in air.

A | Waste water from homes, offices and street drains contains large solids such as leaves, rubbish and lumps of human waste, as well as smaller solids. In the first stage of treatment, waste water passes through a screen, which acts as a **sieve**.

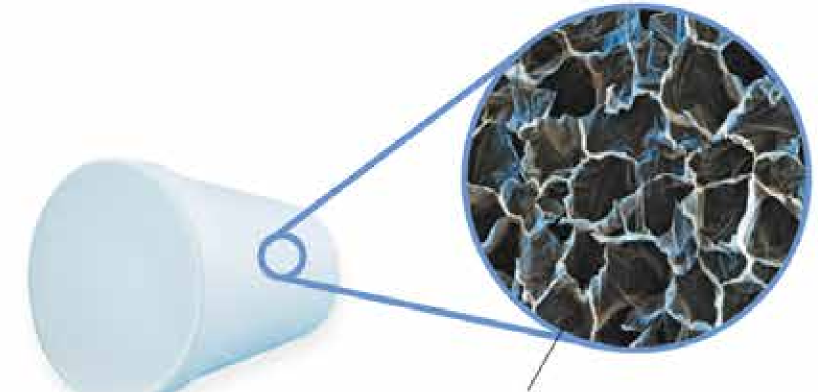
1 Why is waste water an example of a mixture?

2 a| Suggest what is removed from waste water during the first stage of water treatment.

b| Describe how this is removed.

3 Describe one difference between a suspension and a solution.

4 What kind of mixture is the waste water that enters a water treatment plant? Explain your reasoning.



B | Styrofoam™ is a solid colloid of air and polystyrene.

After waste water has been screened at a water treatment works, it is passed through fine **filters** or left to stand in large 'settlement ponds'. This stage removes smaller suspended solids that eventually settle out when the water is still.

The water from the settlement ponds is not clean because very small solids are still dispersed in it. Special substances are added to make these solids stick together to form clumps. This makes it easier to separate them from the water (using more filters or another settlement pond).

D | The beaker on the left contains water after it has left the first settlement pond. On the right is the same water after substances have been added to stick the solids together.

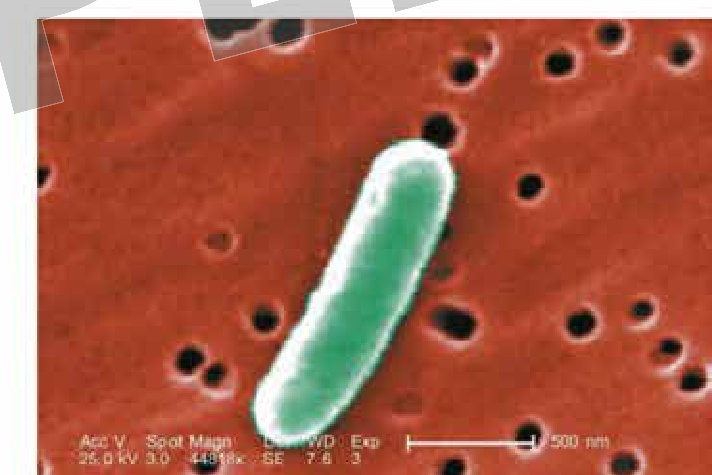
5 Explain why the Styrofoam™ cup in photo B is an example of a colloid.

6 Look at photo D. What kind of mixture is shown in the left-hand beaker? Explain your answer.

7 Suggest how waste water is cleaned after the special substances have been added to stick the remaining solids together. Explain your answer.

8 Draw a flow chart to summarise the stages of water treatment described on these pages. For each stage, give the name of the process used to clean the water.

C | Water, with fewer solids suspended in it, pours from the surface of a settlement pond. This water still contains dispersed and dissolved solids.



E | Disease-causing microorganisms are too small to be removed by filters or settlement ponds. Drinking water may be treated with chlorine to kill them.

I can ...

- classify mixtures
- describe how insoluble solids can be separated from a liquid.

7Eb SOLUTIONS

WHY DO SOME PEOPLE USE FILTERS FOR TAP WATER?

Tap water has been filtered and treated to make it safe for drinking but it does not contain only water. It is still a mixture, with many other substances dissolved in the water.

Some substances dissolve in a liquid to make a solution. In a solution, the dissolved substance breaks up into pieces so small that light passes straight through the mixture. Because of this, solutions are transparent. A solution may be coloured or colourless, depending on the substances in it.

A | A water filter, like the one in the jug, removes some substances that are dissolved in drinking water.

B | Solutions, such as these, are transparent.

1 What is meant when we say tap water is a solution?

The liquid in a solution is called the **solvent**. The substance that is dissolved is called the **solute**. Water is a good solvent because it dissolves many solids, some gases and even some other liquids.

C | This axolotl uses its gills to absorb **oxygen** dissolved in water.

FACT

Water dissolves substances in the rocks it comes into contact with. The substances in the rocks give bottled waters their different tastes. Martin Riese is a 'water sommelier' who advises restaurants on the best bottled waters to go with different foods!

2 Write down the names of two solids and one gas that dissolve in water.

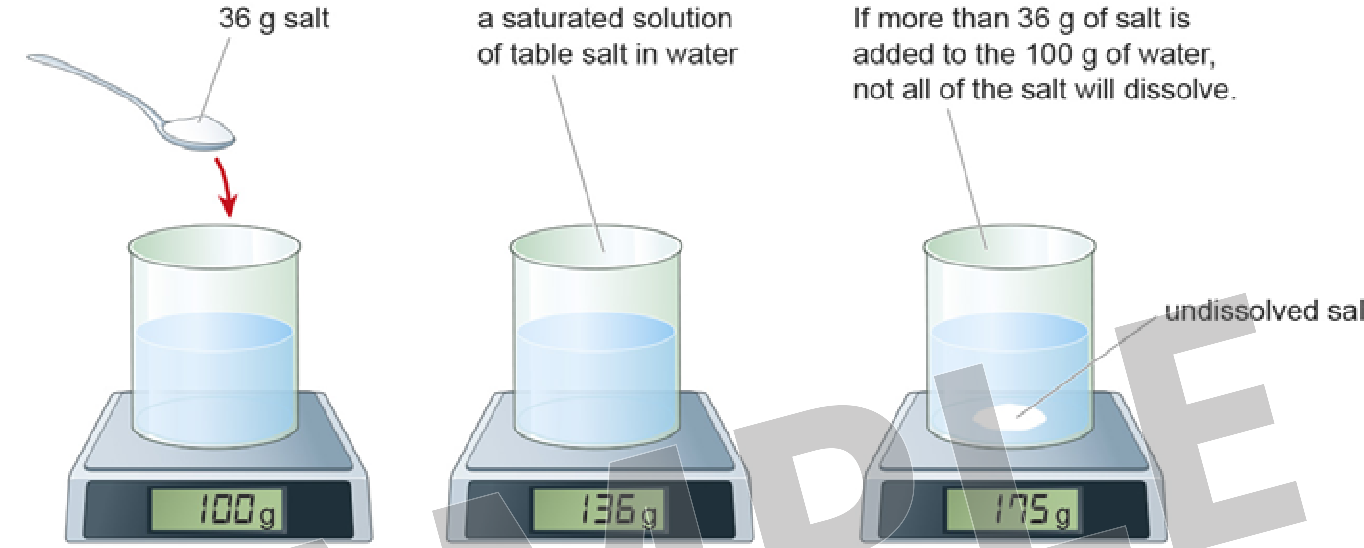
3 Suggest two ways you could tell that a liquid was a solution.

A substance that dissolves in a solvent is said to be **soluble**. Substances that do not dissolve are insoluble. Nail varnish is insoluble in water but is soluble in a liquid called **propanone**, used in nail varnish remover.

When a solution is formed, there is **conservation of mass**. This means that the **mass** of the solution is the same as the mass of the dissolved substance plus the mass of the liquid at the start.

4 When propanone is used to remove nail varnish, which substance is the solvent and which is the solute?

5 20 g of sugar is stirred into 150 g of tea. What is the mass of the solution formed?



E | The total mass of a solution is the mass of the solid plus the mass of the liquid. A saturated solution is formed when 36 g of table salt is dissolved in 100 g of water.

The mass of solute dissolved in a certain volume of solvent is the **concentration** of the solution. The higher the concentration, the more solute is dissolved. There is a limit to how much solute you can dissolve in a particular volume of solvent. If you add more solute than this, the extra will sink to the bottom and stay undissolved. This type of solution is **saturated**.

The **solubility** of a solute is the mass that will dissolve in 100 g of a solvent. The solubility depends on the solvent. For example, 36 g of table salt (sodium chloride) will dissolve in water at 20 °C but only 0.1 g will dissolve in **ethanol** at the same temperature. The solubility also depends on the temperature, usually increasing with temperature: 37 g of sodium chloride dissolves in 100 g of water at 60 °C.

When a solution is made, no new substances are formed. A solution is a mixture. Changes in which no new substances are formed are **physical changes**.

6 The solubility of blue copper sulfate is 32 g per 100 g of water at 20 °C.

a| Which has the higher solubility in water, copper sulfate or sodium chloride?

b| State the largest mass of copper sulfate that would dissolve in 500 g of water at 20 °C.

c| A saturated solution of copper sulfate at 20 °C is cooled to 5 °C. Describe what you see as the solution cools. Explain your answer.

I can ...

- describe how solutions are made
- identify the solute and solvent in a solution
- describe the effects of temperature and solvent on solubility.

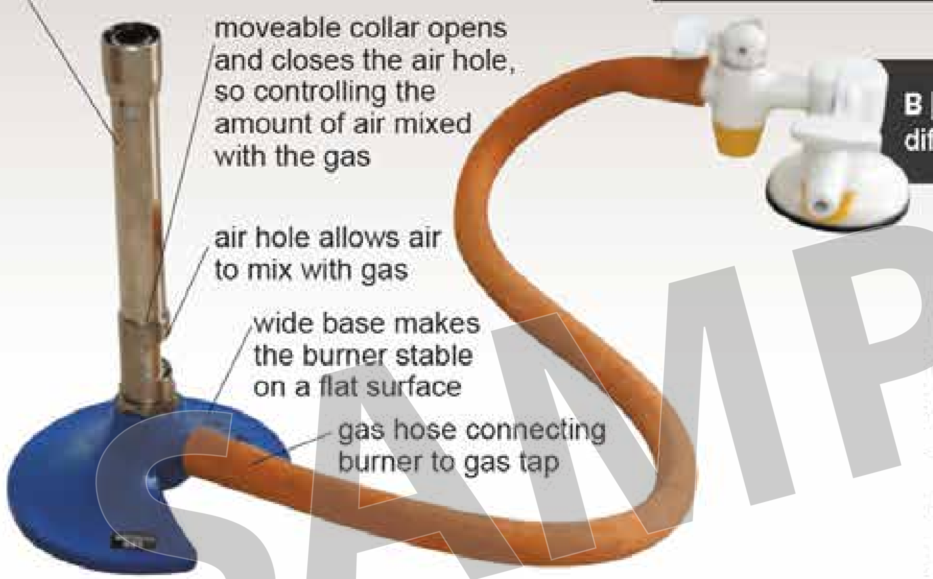
UK NC, iLS, CEE

7Ec SAFETY WHEN HEATING

HOW DO YOU HEAT TO DRYNESS SAFELY?

If a solution is left to stand, the solvent will slowly evaporate leaving the solids behind. If the solution is heated, the solvent will evaporate faster.

A | When the solvent in a solution evaporates, the solid is left behind.



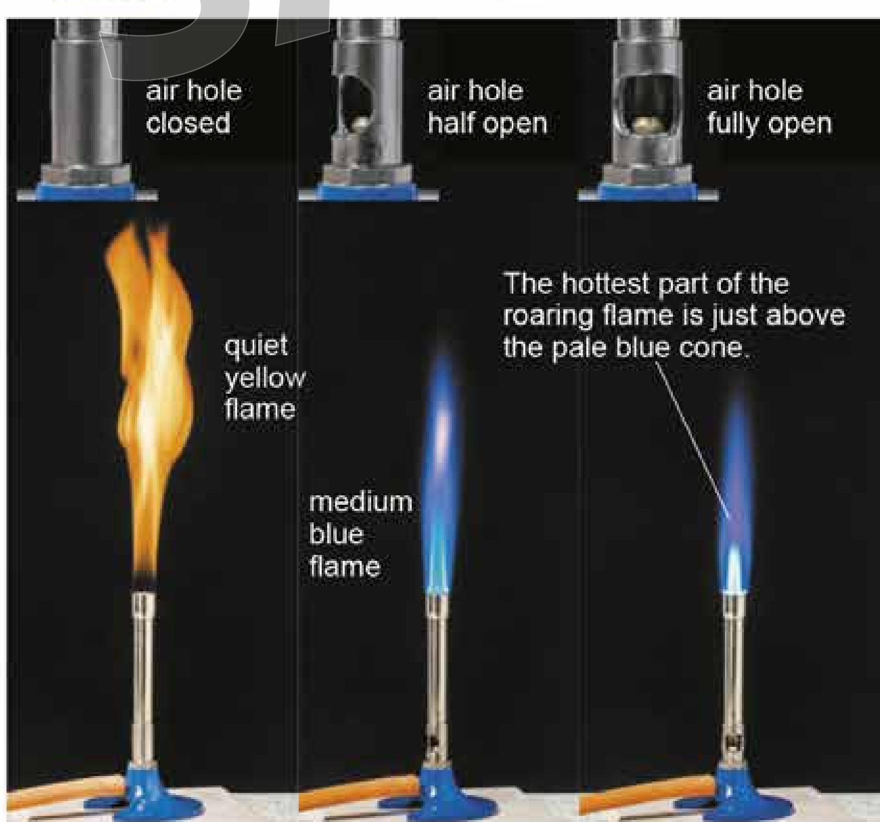
B | The parts of a Bunsen burner have different functions.

Heating a solution until all the solvent has evaporated is known as 'heating to dryness'. In the lab, a Bunsen burner is usually used to heat a solution.

Turning the collar of a Bunsen burner allows different amounts of air to mix with the gas. This changes the temperature of the flame.

Using a Bunsen burner can be hazardous. A **hazard** is anything that could cause harm. When using a Bunsen burner you could burn yourself or others.

A **risk** is the chance that a hazard will actually cause harm. When working with a Bunsen burner you should plan to reduce the chances of burning yourself or others.



C | The 'quiet yellow flame' is a 'safety flame' – it is not used for heating because it leaves a sooty layer on surfaces. The 'medium blue flame' is generally used for heating, especially tubes of liquid. The 'noisy blue flame' or 'roaring flame' is used for heating quickly.

Using a Bunsen burner safely

Bunsen burners must be used with care. Always follow the Method below to light a Bunsen, so that you work safely.

Method

A | Check the gas hose for breaks or holes. If it is damaged, return the burner and tubing to your teacher.

B | Tie back loose hair and any loose clothing, such as a tie or scarf. Remove everything from your working area except what is needed for the experiment.

C | Wear eye protection.

D | Place the burner on a heat-resistant mat, 30–40 cm from the edge of the bench.

E | Make sure the air hole of the Bunsen burner is closed.

F | Hold a lit splint about 2 cm above the top of the Bunsen burner.

G | Turn on the gas at the gas tap to light the burner.

H | When you have finished, close the air hole so that the flame is yellow. Then switch off the gas.

Heating to dryness safely

Heating to dryness increases risks because, when it has lost a lot of solvent, a solution often spits drops of very hot liquid.

The following safety rules help reduce these risks.

- Use a medium flame to heat the solution.
- Wear eye protection while heating.
- Do not fill an evaporating basin more than half-full with solution.
- If heating the liquid in a tube, make sure the open end of the tube does not point towards anyone.
- Always use tongs to hold or move hot things.
- When most of the liquid has evaporated, turn the burner off. Let the rest of the liquid evaporate more slowly.
- Always set the Bunsen burner to a safety flame when not in use and just before turning off.

1 What is a Bunsen burner used for?

2 Explain why the air hole of a Bunsen burner should be closed before the gas is lit.

3 Give two reasons why a medium blue flame is used for heating to dryness.

4 Look at photo E.

a| Identify the hazards in this experiment when the Bunsen burner is lit.

b| How could you reduce the risks of these hazards?

5 Plan an experiment to separate salt from salty water by heating to dryness. Include instructions that ensure the experiment is safe.

D | Hot equipment is a hazard when heating to dryness.

E | Working safely in an experiment reduces the risks from hazards.

I can ...

- describe how a Bunsen burner is used
- identify hazards and describe how to reduce risks.

7Ec EVAPORATION

HOW DO YOU GET SOLIDS OUT OF A SOLUTION?

During **evaporation** of a solution, the liquid turns into a gas which escapes into the air. The evaporating liquid leaves behind the solids that were dissolved in it.

Evaporation can happen at any temperature, even when it is cold. However, the rate of evaporation increases as temperature increases.

A | Stalactites and stalagmites form from the water solution that slowly drips through the roofs of caves. Each drop of water that evaporates leaves behind a tiny amount of solid.

Producing salt

The table salt we use in food is a substance called sodium chloride. In some places, sodium chloride is found in thick layers of rock underground. This is called rock salt.

Rock salt can be dug up or mined, or water can be pumped into the layers of salt in the ground, dissolving the sodium chloride. The salt solution is called brine and this is pumped to the surface where it is heated to evaporate the water, leaving behind the sodium chloride.

Table salt can also be made by evaporating sea water.

FACT

Mined rock salt is spread on icy roads in cold countries in winter. The salt helps prevent ice forming and the bits of rock give extra grip for vehicle wheels.

B | rock salt being mined

C | Sea water is left in shallow ponds to form sea salt.

1 Look at photo C. The sea water is left in the ponds for a week or more.

a| Describe what happens to the water.

b| Explain why the salt is left behind in the ponds.

2 Would the rate of evaporation of water be greater in the cold cave in photo A or the warm salt ponds in photo C? Explain your answer.

3 Draw flow charts to show the two ways in which table salt is produced.

Boiling

Evaporation occurs when a liquid is turning into a gas at the surface of the liquid. **Boiling** is when liquid is turning to gas throughout all of the liquid. When a liquid boils you can see bubbles spread in all parts of it. These are bubbles of gas newly made from the liquid. The temperature at which a liquid boils is its **boiling point**.

Different liquids have different boiling points. For example, pure water boils at 100 °C and pure ethanol boils at about 78 °C . You can see if a liquid is pure by measuring its boiling point. You can also use boiling points to identify substances.

In the lab, we can use evaporation to recover solids that have been dissolved in a solution by heating to dryness.

4 Explain why a beaker of pure water will only boil when heated to 100 °C.

5 Explain, as fully as you can, what would happen if you heated a mixture of water and ethanol to a temperature of 80 °C.

6 How would test whether a liquid was pure water?

7 Look at photo E.

a| Suggest how the two samples were prepared.

b| Describe what these samples show.

D | This geyser shoots high into the air because water underground is heated to boiling point, forcing the water out of the ground at high **pressure**.

E | the difference between evaporation of tap water and pure water

I can ...

- describe how solutes can be separated from a solution by evaporation
- describe differences between evaporation and boiling.

7Ed CHROMATOGRAPHY

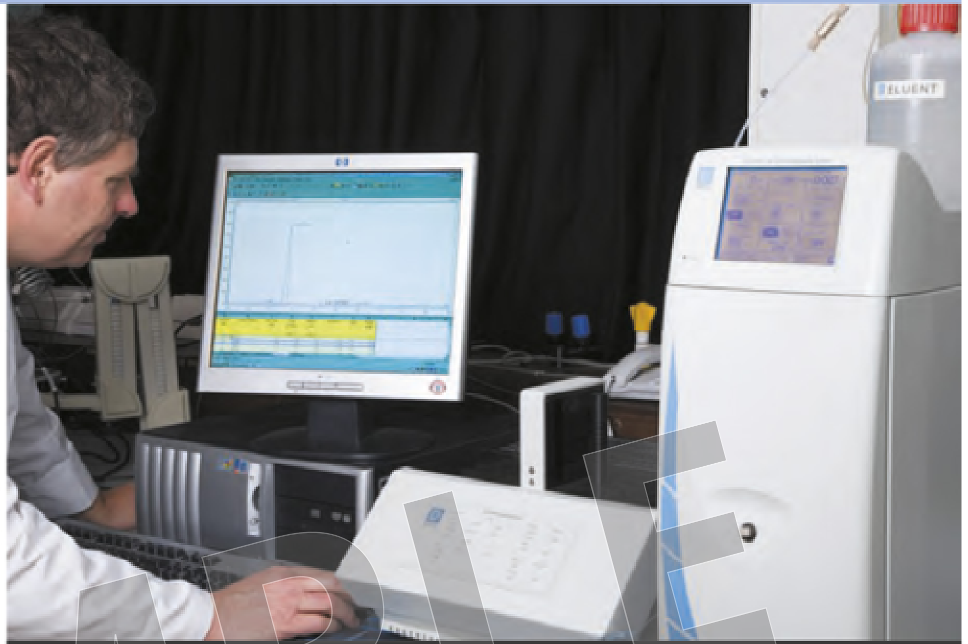
HOW CAN YOU SEPARATE SOLUTES FOR IDENTIFICATION?

After water has been cleaned at the treatment works, it must be tested before it can be used as drinking water. Tests for many different substances are carried out to make sure the water is safe.

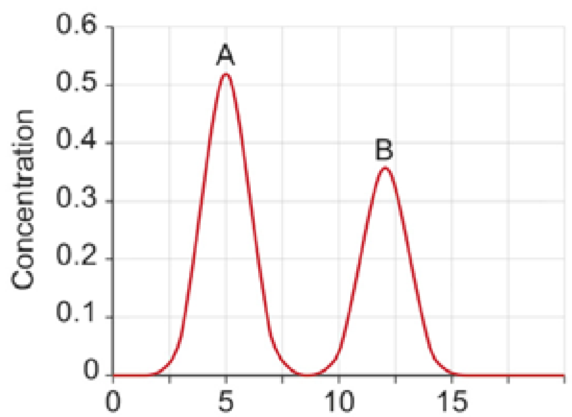
Chromatography is one technique used in water analysis. Chromatography separates substances dissolved in a mixture. This makes it easier to identify and analyse each substance.

There are many different kinds of chromatography. **Paper chromatography** is the simplest method. It can be used to find out which colours are mixed together in different paints, dyes and inks. A **concentrated** dot of the mixture is placed near the bottom of special chromatography paper. The bottom of the paper is dipped into a solvent. The solvent carries the coloured substances in the ink or paint up the paper to form a pattern called a **chromatogram**.

The basic process of chromatography is the same, whether it is done with paper or by machine. Different substances in a mixture are carried by a gas or liquid solvent. The substances are carried at different speeds, which separates them out from each other.



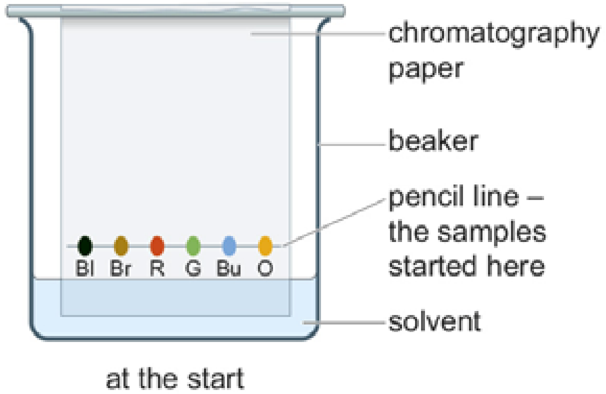
A | Chromatography is often done by complicated machines. The results of this water analysis are displayed as a graph showing a peak for each substance in the mixture. Peak height shows how much of the substance is in the sample.

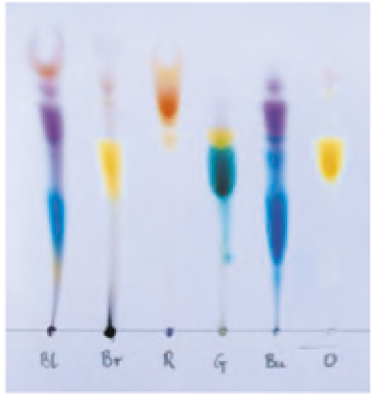


B | a sample chromatogram from water analysis

C | paper chromatography of two different inks

1. What is chromatography?
2. Look at diagram B. Which of the two substances had the higher concentration in the original sample? Explain your answer.
3. Look at photo C. Describe how this experiment was set up.





D | Six different inks were tested in this chromatography experiment: black (Bl), brown (Br), red (R), green (G), blue (Bu), orange (O).

Chromatography can be done with colourless substances. The chromatogram that is produced is then treated to make the substances coloured. Alternatively, ultraviolet light might make the substances glow. This makes the substances visible so the chromatogram can be analysed.

7. Diagram E shows the results of chromatography on three different orange drinks and some food colourings.
   a| Which food colourings are found in the three kinds of orange drink?
   b| Tartrazine is thought to make some children over-active. Which orange drink would be safe to give to an over-active child? Explain your answer.

E

8. Give two examples of how chromatography is used in industry.
9. Compare the results of paper chromatography with the results of the water analysis chromatography shown in diagram B.
   a| How are they similar?
   b| How are they different?
   c| Suggest why the method shown in photo A is used to analyse water rather than paper chromatography. (*Hint*: Think about why drinking water is analysed.)

4. Look at diagram and photo D.
   a| Identify the colours in the different inks.
   b| Which colour was carried the fastest?
5. Explain why chromatography separates the substances in the mixture.
6. Why can't you just evaporate a liquid to find out which substances were dissolved in it?

FACT

Chromatography is used to identify the contents of many kinds of mixtures, including water, food, urine, blood, sweat, soil and the atmosphere. During international athletic competitions, chromatography can be used to test blood and urine samples for banned drugs. It is also used in the forensic analysis of crime scenes to identify specific mixtures, such as colours in a lipstick or in a black ink.

I can ...

- describe how chromatography can be used to identify substances in a mixture
- explain how chromatography works.

7Ee DISTILLATION

HOW DO WE MAKE SEA WATER DRINKABLE?

In many countries, drinking water comes from rain water that collects in rivers, lakes and reservoirs. However, drier countries need to get their drinking water from other sources.

1 Why is rain water usually safe to drink?

2 Why do many parts of the world need sources of water different from the ones used in the United Kingdom?

A | Fresh rain water contains only small amounts of dissolved substances. This means it is usually safe to drink.

Over 70 per cent of the Earth's surface is covered in water. Most of this is sea water, which contains too many solutes to be safe to drink. Drinking water can be made from sea water using a process called **desalination**. Desalination removes most of the salts from the water. This requires expensive equipment and a lot of space, so it is only suitable in some places.

B | The Jebel Ali desalination plant in the United Arab Emirates produces over 800 million litres of drinking water each day.

FACT

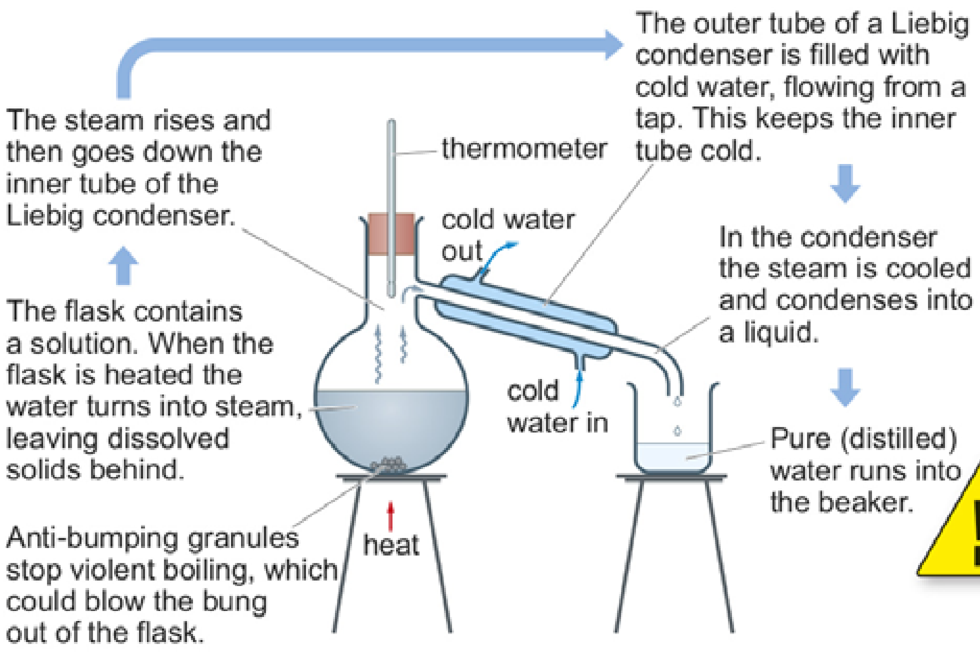
Sea water is dangerous to drink because it contains high levels of sodium chloride (table salt). In your body, sodium chloride removes water from your cells, which makes you even thirstier!

One of the ways in which sea water is desalinated is called **distillation**. The sea water is heated so that the water evaporates to form **steam**. The steam is collected and cooled so that it **condenses** back into liquid water. This distilled water is pure; it contains no solutes because the solutes in sea water cannot evaporate and are left behind.

3 What does desalination mean?

4 Explain why desalination plants are usually built next to the sea.

5 One of the products of distilling sea water is drinking water. Suggest another product from this process. Explain your answer.



C | This apparatus can be used to distil mixtures in the lab, including solutions such as salty water.

6 Use diagram C to help you draw a flow chart that describes how sea water is distilled in a desalination plant to produce drinking water. Use suitable scientific words in your descriptions.

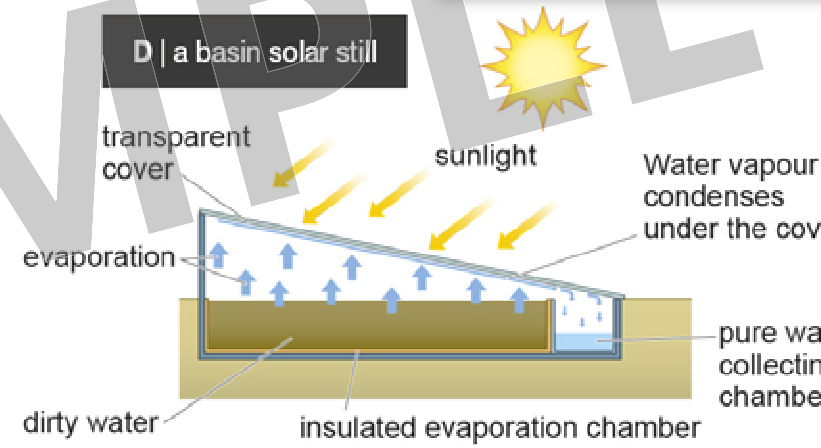
7 Describe how anti-bumping granules reduce the risk of harm from a hazard.

If the tube from the distillation apparatus is submerged in the collected liquid, it must be removed from the liquid as soon as you stop heating. Otherwise, suck-back may occur in which the cooling air in the apparatus contracts and cold liquid flows into the hot glassware. This can cause the glass to break.

The apparatus shown in diagram C is sometimes called a still. Stills can use **energy** from the Sun. In 1872, Charles Wilson invented the solar-powered water still, to supply drinking water to a large mining community in Chile, South America. The solar-powered still is a cheap way of providing clean water in poor areas of the world. Diagram D shows how it works.

Today solar-powered stills can be important for providing emergency clean water in remote places and at sea.

D | a basin solar still



8 Explain why a solar-powered water still might be useful:

a| on a ship that has broken down at sea

b| in a country where the drinking water contains bacteria that cause diseases.

9 Compare the basin solar still in diagram D with the still apparatus in diagram C.

a| Identify any similarities and differences in the way they work.

b| Suggest which still is better for getting the most pure water out of salty water. Explain your reasoning.

E | An inflatable solar still may be part of the emergency supplies on the life rafts of an ocean-going ship.

I can ...

- explain how distillation can be used to separate a solvent from a solution
- give examples of where distillation is used.

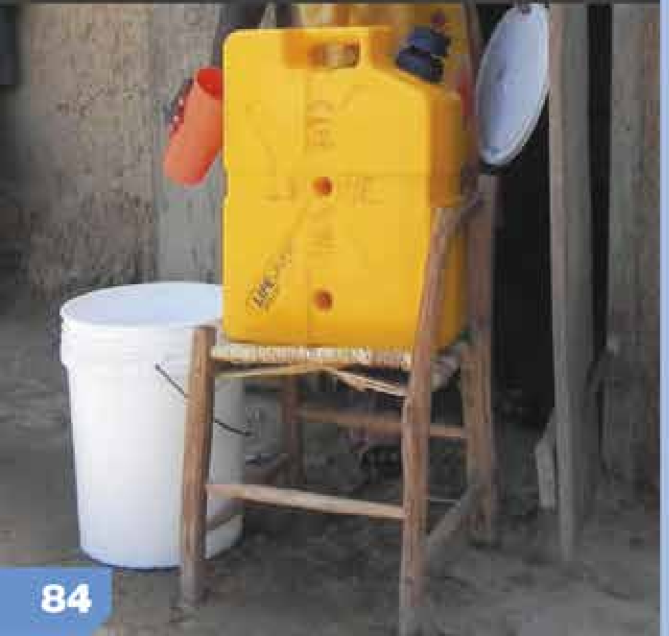
7Ee SAFE DRINKING WATER

CAN WE MAKE SAFE DRINKING WATER FOR EVERYONE?

One in eight of the world's population do not have a water supply that is free from harmful substances and disease-causing microorganisms. Climate change and increases in the number of people may make safe water supplies more difficult to access for everyone.

A | Disasters, such as flooding and earthquakes, damage water and waste pipes. Rising sea levels caused by climate change will make flooding much more common in many places.

B | In low-income countries, an average of 5 million people each month move into cities to find work. Many live in slum areas where there is no safe drinking water.



C | The filtering system in the LIFESAVER® jerrycan removes dirt and disease-causing microorganisms, and leaves water safe to drink. A smaller bottle system is ideal for emergency situations.

1 Suggest why safe drinking water could become more of a problem in more countries in the future?

2 The LIFESAVER® system uses a range of filters to clean the water.

a| Describe how the filters clean the water.

b| One of the filters in the system has extremely small holes. Suggest what this filter removes from the water to make it safe to drink. Explain your reasoning.

c| One of the filters contains a substance that can remove dissolved solids. Explain why this is needed.

3 List the different ways in which safe drinking water can be made. Briefly explain how each one works and describe where it might be most useful. Explain your answers.

HAVE YOUR SAY

Can we make sure there is safe water for everyone?