

Exploring



Science Extra

How Science Works

Water

8



8

Exploring Science Extra

Introduction

Welcome to our latest *Exploring Science Extra* pack. In this pack we explore a substance with some very unusual properties. It's a substance that can exist in three states of matter in a very close temperature range, its solid state is less dense than its liquid state, it has a very high boiling point for its molecular size, it acts as a solvent for a vast array of other substances and it can absorb a large amount of thermal energy. And it's probably the reason we have life on Earth. I refer, of course, to water.

The pack contains a Student Booklet, a Teacher's Guide (with suggested activities) and Activity Sheets (to support some activities). Some activities are fun extensions to existing KS3 work and some take students a little beyond KS3. However, all the activities will enable students to practice key scientific skills.

Did you know?

Do you use the Thinking Skills activities in Exploring Science? Each topic provides some ideas for activities such as Plus, Minus, Interesting (PMI), Consider All Possibilities (CAP) and Odd One Out (OOO). There's a section in the Teacher and Technician Planning Guide that introduces Thinking Skills (see pages 16 – 17 in the Year 7 TTPG).

Thinking Skills provide a great way for students to be creative in their thought processes and help students become more 'metacognitive'. That is, the activities help students to think about how they are learning (not just what they are learning).

Many of the Thinking Skills can also provide a useful framework for Formative Assessment and mini-plenaries. For example, set an OOO question and ask students to vote on the odd one out. Then ask students to work in small groups for 1 minute to explain to one another why they voted the way they

did. Then take the vote again. This not only allows students to assess themselves but will give you quick feedback on whether students have understood a certain teaching point. Many of the other Thinking Skills activities can be extended and adapted in this way.

We always enjoy hearing about how you have adapted activities in Exploring Science. So, keep all the ideas, suggestions and comments coming. You can contact us at:

www.pearsonschools.co.uk/exploringscienceextra

With best wishes for the rest of the Summer Term

Mark

Mark Levesley, Series Editor

Exploring Science Extra 2012 no 8

Picture Credits

The publisher would like to thank the following for their kind permission to reproduce their photographs:

(Key: b-bottom; c-centre; l-left; r-right; t-top)

Alamy Images: Frank Irwin 3c, Image Source 6b, Nigel Cattlin 5r; **Fotolia.com:** imageabet 1t; **Mary Evans Picture Library:** Illustrated London News Ltd 2b; **Pearson Education Ltd:** Studio 8 3b; **PhotoDisc:** Siede Preis Photography 4r, StockTrek 4br; **Veer/Corbis:** Andrey Pashkov 2t, cmfotoworks 5t, Mehmet Can 6r, mocker 5l, pixelnest 1b, Robert Paul Van Beets 3t, Sergey Korotkov 6l; **www.imagesource.com:** 4l

Cover image: Front: **Veer/Corbis:** Darren Baker

All other images © Pearson Education

Every effort has been made to trace the copyright holders and we apologise in advance for any unintentional omissions. We would be pleased to insert the appropriate acknowledgement in any subsequent edition of this publication.

1

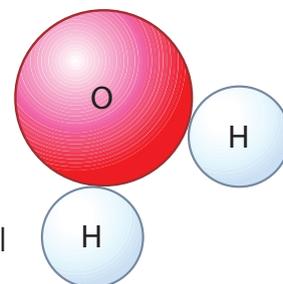
Water is strange stuff

Liquid water

Water is one of the most common molecules on Earth. It covers around 70% of the planet. A similar proportion of your body is water. We are so familiar with water that we often forget just how strange and special this chemical is.

The chemical formula for a molecule of water is H_2O . Almost every other chemical made of molecules as small as this, such as carbon dioxide or sulfur dioxide, is a gas at everyday temperatures. Water is mainly a liquid at these temperatures – something you'd expect from a compound with much larger molecules.

The reason why most water around us is liquid is that it behaves as if it had much larger molecules. The hydrogens of one water molecule are attracted to the oxygen of another molecule, forming weak bonds. These weak bonds are easily broken, but there are enough of them between all the water molecules to change the way the molecules behave.



A Each molecule of water is formed from one oxygen atom strongly bonded to two hydrogen atoms, H_2O .



B Every snowflake has the same symmetry because of the way water molecules bond weakly to each other.

Solid water

As water gets colder, weak bonds form between more of the molecules making a frame-like structure. When water freezes, the molecules fix in these positions producing crystals of ice.

There is more space between water molecules in ice than in liquid water. So ice is less dense than liquid water, and floats on the liquid. This is opposite to many other substances where the solid form is denser than the liquid form and so the solid sinks.

The Celsius scale was originally set using the melting and freezing points of pure water, because water is such a common material and behaves in a predictable way.

Solutions

Many substances are affected by the weak bonds between water molecules. When added to water, the molecules of these substances separate from each other and mix with the water. We call this dissolving. Water is one of the best solvents. You can test this by comparing how easily a spoonful of sugar or salt dissolves in water or oil.

All these strange behaviours of water are essential for life, and for many of the processes that we use in our homes and in industry.



C Water is most dense at $4\text{ }^{\circ}\text{C}$, so ice forms on the top, insulating the water beneath and protecting the organisms that live in the water.

2

Changing the properties of water

Changing freezing point

The freezing point of pure water is 0 °C. If you dissolve anything in the water, the freezing point of the solution is lowered. This is because the solute particles interfere with the water molecules and make it more difficult for them to form ice crystals. This explains why the sea rarely freezes over around the coast of the UK, although rivers and lakes may freeze in many winters.

Many cold-blooded organisms that live in polar regions, such as Arctic fish, have chemicals that stick to tiny quantities of ice as it forms. This stops the pieces of ice joining up to form lumps, which prevents their bodies being damaged by freezing.



river water flowing out into the sea

sea water

D *The air temperature is so cold that the fresh water in the river coming into the harbour is freezing. However, the sea water outside the harbour is still liquid.*

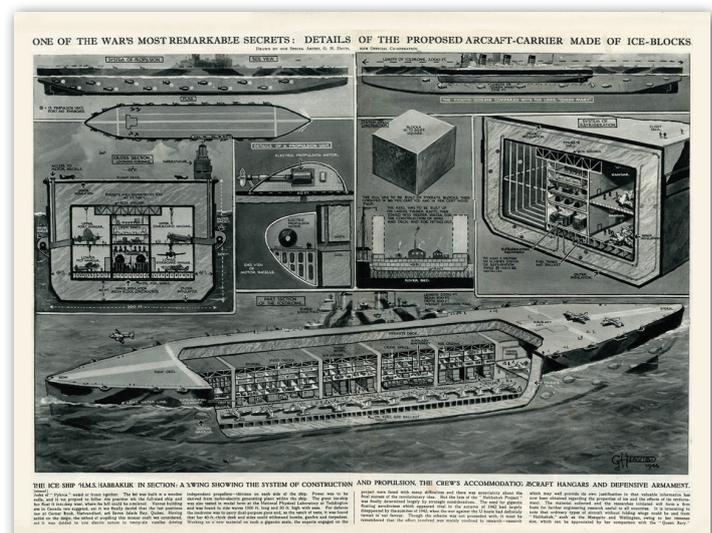
Changing strength

How does the idea of making an aircraft carrier made of ice sound? Ridiculous? This idea was suggested by Geoffrey Pyke, a British inventor, during the Second World War. He discovered that water mixed with wood shavings and then frozen was much stronger than ice.

The idea was tested by making large blocks of 'reinforced ice' that contained different proportions of sawdust. Blocks containing only 4% sawdust were as strong as concrete. A bullet from a rifle shattered pure ice, but only made a small crater in a similar block of Pykrete (the name given to the reinforced ice).

Pykrete is stronger than pure ice because it is a composite material – the sawdust holds the ice together. Pykrete also melts far more slowly than pure ice, probably because the sawdust in the outer layer helps to insulate the frozen water inside.

Project Habakkuk was a secret project in the Second World War to use Pykrete to build an aircraft carrier, because there were not enough metals. Scale models of the ship were built in Canada. However, the real thing was never built, partly due to problems with the design, but also because other solutions to fuelling planes on their Atlantic flights had been found.



E *Designs for the Pykrete aircraft carrier.*

3

Changing the properties of water continued

Changing density

Density is calculated as mass divided by volume. We can change the density of water in two ways.

- 1 The density of water increases as more solute is dissolved in it.
- 2 The density of water decreases as its temperature increases. This is because its volume increases.



F The Dead Sea contains such a high concentration of salt that it is easy to float in it.

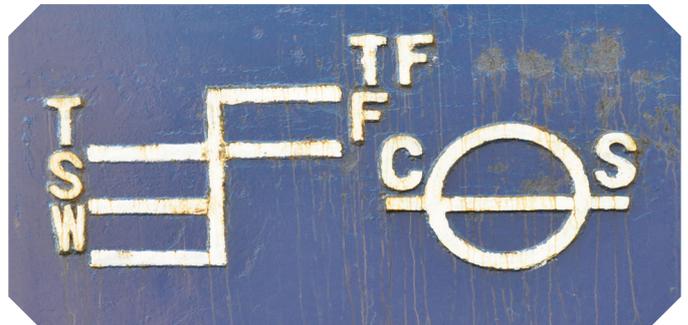
Changes in water density are important for ships that sail around the world. In the early 1800s many ships carrying goods around the world sank because they had been loaded too heavily.

In the 1860s, British MP Samuel Plimsoll introduced the Plimsoll Mark (or Plimsoll line). This mark is a circle with a line through it, which must be visible in the middle of a ship's hull, near the water. It is a permanent mark, so is visible even if the paint wears off. Ships were not allowed to be loaded beyond the point that the line was under water, as that meant the ship would be at risk of sinking.

Since its introduction, other marks have been added to the Plimsoll line, to show the different safe load levels for different types of water. These make sure that a ship loaded in water of one type will not be overloaded if it sails into water of a different temperature or salt concentration.

The density of a liquid can be measured with a piece of apparatus called a hydrometer.

H This mechanic is measuring the density of the coolant in a car using a hydrometer. The density of the coolant shows how much antifreeze has been added to the water. During winter, more antifreeze must be added to prevent the water freezing.



G A modern form of the Plimsoll line. The letters on the left refer to sea water: T means tropical, S means summer, and W means winter. The letters on the right refer to fresh water: F is fresh water and TF is tropical fresh water.



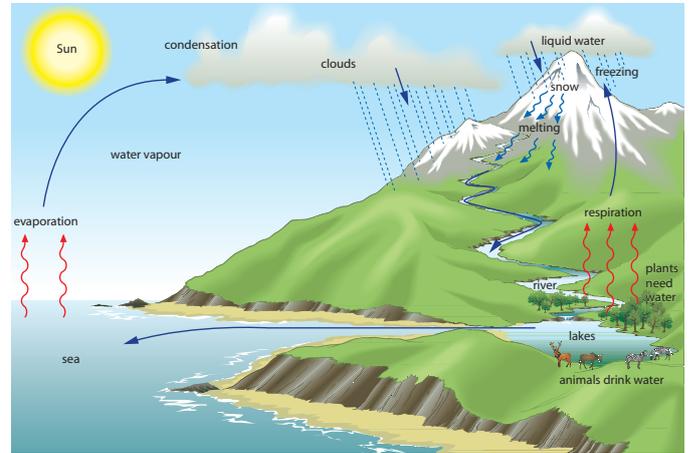
4

Water in the landscape

The water cycle

Water in the environment is continuously cycling between the land, organisms and the air. We call this the water cycle.

- Heat from the Sun evaporates water on the Earth's surface to form a gas, called water vapour.
- Water vapour rises into the air, and cools, condensing to form droplets of liquid water or solidifying to ice in clouds.
- Liquid or solid water returns to the Earth's surface in rain and snow.



I The water cycle.

Evaporation of water leaves any solutes behind. So, although much of the water that evaporates from the Earth's surface comes from the oceans, rain is always fresh water while the oceans remain salty.



K Over thousands of years, a river can carve out a canyon through mountains.

Changing the landscape

Water that moves, such as in rivers, can change the landscape around it. This is because it carries sand, gravel and even pebbles with it. The faster a river flows, the larger the stones it can move. The constant bumping of stones against the bottom and sides of the river bed changes the shape of the stones and the shape of the river bed.



J As pebbles are tumbled along a river bed, their rough edges are rounded.

When a river reaches the sea, the sand and mud in the water is dropped and can form a network of channels within low swampy ground, called a delta.



L The River Ganges delta seen from a satellite.

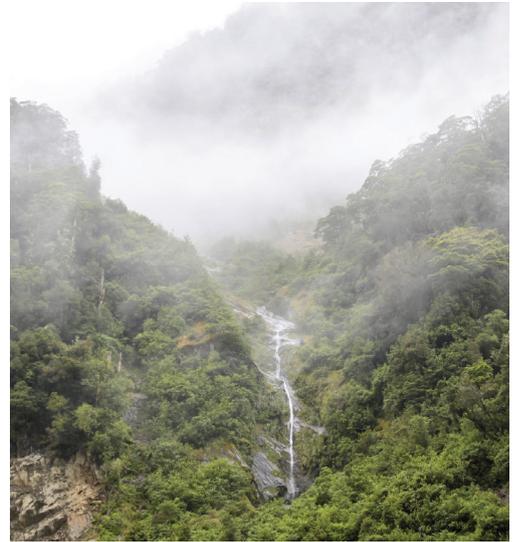
5

Water and life

All living organisms depend on water in some way or other for life, even those that don't live in it. The cytoplasm of cells is mostly water. Liquids that transport substances in organisms (such as blood in animals and cell sap in plants) are also mostly water. Many substances travel around the body in solution, and many reactions inside cells can only happen because the chemicals are in solution.

Water is very important in some key processes in living organisms.

- **Respiration:** All living organisms respire, breaking down food molecules to carbon dioxide and water. The water is used inside organisms or released into the air as water vapour.
- **Photosynthesis:** Plants need water for photosynthesis, converting carbon dioxide and water to sugar molecules. This water is mostly absorbed from the ground.
- **Transpiration:** Some of the water absorbed by the plant isn't used in photosynthesis but passes straight through the plant and evaporates from the leaves as water vapour, by a process called transpiration.



M Large areas of forest, such as rainforest, release so much water into the air through transpiration that they control the local weather, increasing the amount of rain that then falls.

A large broad-leaved tree may take as much as 150 m³ of water from the ground every day. Think how much water a rainforest needs every day!



N Oil and water don't usually mix. Humans secrete a substance that helps watery sweat spread out across oily skin rather than just dripping off. This means that more of the skin is cooled as the sweat evaporates.

- **Sweating:** Water also evaporates from the surface of animals. Mammals, including humans, have sweat glands that secrete watery sweat on to the surface of the skin when the animal is too hot. The evaporation of the water from the skin surface takes heat energy from the skin and so helps to cool the body down.

Plants also use water for support. Cells that are full of water can help to hold stems upright, and hold leaves out to capture sunlight. In a plant that has no woody stems or branches, if the cells do not have enough water, the plant will wilt and droop.

Scientists searching for life in other parts of our Solar System look for evidence of water, because without water on Earth there would be no life.



O The plant on the left has wilted. If it is given enough water quickly, it will soon recover and look like the plant on the right.

6

Water and life continued

Too little water

Some plants and animals have adaptations that help them survive where there is too little water for other organisms, such as in a desert.

Global warming might cause drought in more places, which will mean we need more water for growing our crops. As the human population continues to grow, access to enough fresh water to give us the food and drink we need could become increasingly difficult.



P Even drought-adapted plants will eventually die if there is no water in the ground.



Q Crops that need a lot of water must be irrigated during dry periods, so that they produce food for us.

Hosepipe bans during droughts may cause problems for gardeners, but they help to make sure there is enough water in rivers for farmers to irrigate crops, and for wildlife that live in the rivers.

Lack of water, or dehydration, causes problems for animals too. Not drinking enough water each day can cause headaches, confusion, constipation (hard faeces), irregular heart beat and in extreme cases even death in humans. Unless water is limited, we can usually get enough to drink, but dehydration can happen due to excess sweating (due to heat or exercise) or abnormal loss of water in diarrhoea.

Wheat yields in 2012 in the UK were over 14% less than normal, due to the wettest summer for over 100 years.

Too much water

Too much water can also cause problems. Heavy rainfall over a long period can cause flooding, which can cause millions of pounds of damage to the land and our buildings. Even on a short timescale, most plants are damaged if their roots are waterlogged.

Drinking too much water is harmful for animals too. Too much water in the body upsets the balance of water and salts, so cells don't work so well. Extreme cases produce 'water intoxication', which can cause death as the brain swells inside the skull.



R The flooded plants in this field are not growing as well as the rest of the crop because their roots cannot get oxygen for respiration.

Cell and tissue models

Exploring Science link: 7A

In this activity students make models of plant cells or tissues. Place students in groups and, depending on materials available, ask each group to make a model cell or tissue using the information below. They should compare their models with what they know about the cells or tissues in order to consider the strengths and weaknesses of the models.

Model plant cell (The original protocol for this activity was developed by Sarah Harrison at the University of Worcester. We are most grateful for their help.)

A plant cell model can be made using a plastic take-away box and lid for the cell wall. The box should be lined with cling film for the cell membrane, leaving enough extra film to cover the surface of the contents of the container. The box is then filled with jelly for the cytoplasm (the jelly should be made up to 750 cm³ rather than the usual 500 cm³ so that it remains a little runny when cold). The following can be placed in the jelly:

- a small sealable plastic bag containing sugar solution for the vacuole
- cherry tomato for the nucleus
- green sweets, buttons or pieces of green pepper for chloroplasts.

The 'cells' can be stacked together to form a 'tissue'. Then ask students to use the model to explain:

- how plant cell walls help to support the plant
- why you don't see a nucleus in every plant cell when looking at slides of plant cells.

You will need to point out that a live cell differs from the model in some important ways, including:

- there is constant movement of structures in the cytoplasm
- some materials, such as water and dissolved substances, are able to cross the cell wall and cell membrane into and out of the cell
- the cell wall is more flexible than this model would make us believe.

Ask students to consider the importance of these facts for a living cell, and suggest whether the model could be adapted to add any of these features.

Model plant tissue

Students should make at least 10 small cubes (c. 5 cm side length) from stiff paper, taping the sides together but leaving one flap open. There are plenty of templates online, which can easily be found by doing an image search for 'paper square box template'. A water bomb should be placed inside each cube. Each bomb should be carefully filled with water, making sure water doesn't spill onto the paper. The water bombs should be tied and the paper cubes sealed. Cubes are used to build 'tissue' by making a wall that is 2 cells wide and several cells high (best done in a washing up bowl or on a tray to contain spilled water).

Use a sharp pointer to burst the water bombs in a few of the lower row of 'cells'. This should show some collapse in layers above. Ask students to use the model to explain the importance of water for giving strength to plant tissue and relating this to wilting.

Xylem tissue can be modelled using bundles of drinking straws, taped together. Explain that the tissue forms part of the veins that run through all parts of the plants. Xylem cells have strong walls. Students should be able to suggest the importance of the walls to prevent the collapse of the tubes. They could also compare the strength of one straw with a bundle to explain the importance of xylem tissue in holding plants upright.

Resources (per group/student): model cell: clear plastic takeaway box + lid, cling film to line box, clear or pale yellow jelly made with twice the recommended amount of water so that it does not set, small sealable plastic bag (e.g. freezer bag), sugar solution, cherry tomato (or similar sized round object), green sweets, buttons pieces of green pepper (or similar sized green objects).
model tissue: paper, scissors, sticky tape, water bombs, water, drinking straws, large tray.

Water flow through a plant

Exploring Science link: 7A

If students have not already had the opportunity to demonstrate water flow through a plant stem using coloured dye, a suitable method is given at <http://www.nuffieldfoundation.org/practical-biology/investigating-transport-systems-flowering-plant>.

Evidence for water on Mars?

Exploring Science link: 7H

Before beginning this activity, students will need to have learnt about the effects of water on the weathering and erosion of rocks on Earth.

Activity Sheet 1 shows three photographs taken of the surface of Mars. Students are asked how each of the images provides evidence for the presence of water on Mars in the past. The images can also be found at:

http://www.nasa.gov/multimedia/imagegallery/image_feature_98.html

http://www.nasa.gov/mission_pages/msl/multimedia/pia16189.html

http://www.nasa.gov/mission_pages/msl/multimedia/gallery/pia14295-anno.html

Further information about fluvial (river) deposits can be found at:

<http://clasticdetritus.com/2008/09/24/the-accretionary-wedge-13-fluvial-deposits-on-mars/>

Resources (per student): Activity Sheet 1.

Answers:

- 1 Photo A shows a large delta feature, which could have been formed by the flow of water cutting through surrounding surface materials and depositing new sediments.
Photo B shows rounded pebbles that may be formed in moving water as they rub against the rocks through which the water flows.
Photo C shows a canyon that could be formed by the erosion of moving water such as a river. It also shows a sandy surface that could have been formed by moving water that deposited sand, which it had carried downstream to this point.
- 2 We assume they need water because that is how these features form on Earth. Other processes may also produce these features where there isn't any water, as on the surface of Mars.
- 3 All three features can be explained by the presence of water at some time in the past. Any one feature could have been produced by a process that didn't involve water, but this means we may need three different processes that don't involve water to explain all three features, which is less likely.

Developing a Plimsoll line

Exploring Science link: 7K

This practical activity supports work on floating and sinking, and can be introduced using the information on the Plimsoll line in the Student Booklet, or in relation to Worksheet 7Kc in the *Exploring Science Year 7 ActiveBook*. Activity Sheet 2 gives details of an investigation into the density of water of different temperatures and salinity.

Note that the difference in floating height may not be large, so a fine marker pen will increase accuracy of recording. You may wish to test the experiment first, to check that a measurable difference in density can be observed.

Answers:

- 3 (a) The straw should float higher in the salt water than in the fresh water, indicating that salt water is denser than fresh water.
(b) The straw should float higher in cold water than in warm water, indicating that cold water is denser than warm water.
- 4 A ship loaded in one kind of water to a safe loading level will float at a different level in water of a different kind. If the ship sails into water that is less dense than the water in which it was loaded to a safe level, it may sink.

Resources (per student or group): beaker or clear plastic cup, cold water + ice, warm tap water (c. 40 °C), 2–3 teaspoonfuls of table salt, spoon or stirrer, plastic straw, modelling clay, waterproof marker pen, small weights (e.g. ball bearings, fishing line weights) or sand, ruler, Activity Sheet 2.

Water of life

Exploring Science link: 8A, 8B

In this literacy-based activity, students should take notes from the Student Booklet, the *Exploring Science* Year 8 Student Book and any other suitable sources, about the importance of drinking sufficient water every day. Encourage students to organise their notes under headings such as:

- how water is lost from the body
- how water is gained by the body [remind students of the equation for respiration if needed]
- why the need for water by the body varies in different conditions [including body temperature and exercise]
- how much water is lost from the body in different conditions
- what effect dehydration has on the body.

They should use their notes to produce an illustrated poster that advises on how much water should be drunk each day, giving scientific reasons for their advice.

Treating ice on roads

Exploring Science link: 8G

This practical activity investigates the effect of a solute on the melting point of a solvent, specifically the effect of salt and sugar on the melting point of water. The protocol for this method is available at http://www.all-science-fair-projects.com/print_project_1151_38.

The investigation can be completed simply by comparing 2.0 mol dm⁻³ sugar solution against 2.0 mol dm⁻³ salt solution. For more able students, and if there is time, the activity could be extended to other concentrations, so that sufficient data can be generated to draw a scatter graph of freezing point against concentration for each solute. Note the tests will probably need to be carried out using one pair of concentrations at a time, because of limits on equipment.

The salty ice cubes, for chilling the water bath, will need to be made at least the day before the lesson.

Ask students to draw a table to display their results, and a chart or graph if they tested several concentrations. Then ask questions about the results such as the following:

- 1 By how much did each substance lower the freezing point of water? (Note that some students may need reminding that the freezing point of pure water is 0 °C.)

Answer: At 2.0 mol dm⁻³: sugar solution should freeze at c. -4.1 °C, salt solution should freeze at c. -7.4 °C.

For the extended activity, values should be around:

Concentration	Freezing point (°C)	
	Table salt	Table sugar
0.5 mol dm ⁻³	-1.8	-1.0
1.0 mol dm ⁻³	-3.6	-1.9
1.5 mol dm ⁻³	-5.5	-3.1

- 2 Which solution started freezing at the warmer temperature?

Answer: Sugar

- 3 Using your results, would it be better to spread sugar on roads instead of salt, to help prevent freezing. Explain your answer.

Answer: No, because salt is better than sugar at preventing water from freezing.

- 4 Ethylene glycol is the antifreeze added to water in vehicles during the winter. If mixed in equal proportions with water, the freezing point of the mixture is around -34 °C. Suggest as many reasons as you can why ethylene glycol is used in vehicles but salt is used on roads.

Answer: There are many possible reasons – here are a few:

- salt is much cheaper than ethylene glycol and you need a lot more to treat roads than to treat vehicles
- salt speeds up the rusting of metals, so would not be useful in vehicles
- ethylene glycol is a liquid, while salt precipitates out as a solid at warmer temperatures, which would cause abrasion of surfaces in an engine
- vehicles can be adapted to run on icy roads if it gets colder than the freezing point with salt, but vehicles cannot run if the water in them isn't liquid.

Resources (per student or group): 2 test tubes, large beaker, 6–8 salty ice cubes (prepared at least one day in advance – see above for details), tap water, about 100 cm³ each of 2.0 mol dm⁻³ salt solution and 2.0 mol dm⁻³ sugar solution, marker pen, 2 thermometers or temperature sensors, Activity Sheet 3.

For the extended activity: 8 test tubes, about 100 cm³ each of the following solutions: 0.5 mol dm⁻³ salt solution, 0.5 mol dm⁻³ sugar solution, 1.0 mol dm⁻³ salt solution, 1.0 mol dm⁻³ sugar solution, 1.5 mol dm⁻³ salt solution, 1.5 mol dm⁻³ sugar solution, 2.0 mol dm⁻³ salt solution, 2.0 mol dm⁻³ sugar solution; protocol from website.

The coldest Pykrete

Exploring Science link: 8I

Use the information on Pykrete in the Student Booklet to introduce this practical activity. You could also do a search on YouTube for 'WW2 2 million ton ice aircraft carriers', which brings up a 5 minute clip about the history of Pykrete and its potential use as a material for aircraft carriers.

Tell students that they will be given a form of Pykrete made from newspaper pulp and water. They are to investigate the best proportion of pulp to water to make something that melts slowly enough for use as, for example, an ice pack as a first aid treatment for injuries. Activity Sheet 3 supports this activity. Students will need to plan how to work out proportions for their mixtures, and a method for measuring how long the frozen mixtures take to melt. If preferred, this planning can be done before the investigation begins.

Shredded newspaper needs thorough mixing with the water, to separate the wood fibres, before freezing. A 'standard' paper/water mix (such as 25% paper to 75% water) should be prepared by the teacher or technician before the lesson. This can be done in several ways. Mixing by hand is slow and not very effective. The shredded paper can be boiled in the water, but that needs extra care, and the ink will remain on the container after boiling (easily removed by wiping with vegetable oil). Mixing in a blender is most effective. Leaving the paper/water mixtures to soak overnight can also help to loosen the paper fibres. Students then dilute this 'standard' paper water mix with water to produce their mixtures.

The filled freezer bags need to be placed in a freezer at least overnight, until completely frozen. Students will need to plan how to test the rate of melting. This can be done in many ways, such as by loss of mass if a hole is made in each bag and melted water allowed to drain, or by measuring the change in surface temperature over time. Students should consider how to control all other variables in order to get a fair test.

This practical work takes several hours at room temperature. Students could set up the apparatus and return to it after 3–4 hours, or they could set up datalogging for several hours, for analysis in a later lesson. Alternatively the apparatus could be set up by a technician several hours before the lesson in which students record the results.

Question 5 on the Activity Sheet may need answering as a group or class discussion. Students should consider the insulating effect of the wood fibres on the ice inside the pack.

Safety note: Students should not prepare the 'standard' Pykrete mixture.

Resources (per student or group): 'standard' paper mix made from newspaper or other soft paper prepared before the lesson, warm water, 3 bowls or basins, 3 small sealable freezer bags, marker pen, weighing balance, access to a freezer, Activity Sheet 3. Optional: temperature sensor and

datalogger or thermometer. The teacher or technician may also require access to: blender, boiling water.

Flooding and plants

Exploring Science link: 9C

This is a data-handling activity that links to the effects of the environment on the growth of plants. It can be introduced using information in the Student Booklet about how flooding can affect plants. Spreadsheet 1 contains data for analysis. Activity Sheet 4 contains instructions on how to analyse the data, and questions that can be answered using the analysis.

Some students may need help with the analysis of the data and in answering the questions.

Answers:

- 2 In all species, the above-ground parts of the plants (leaf and stem) grew more in flooded plants than in plants that weren't flooded, but the below-ground parts of the plants (roots) grew less. [If appropriate to your students, you could explain that this is because food made by photosynthesis cannot be used by many root cells when flooded (due to a lack of oxygen), so it is used in the above-ground parts of the plants which causes the increase in size.]
The biggest difference in growth between flooded and non-flooded plants was with species 1/ *Brachiaria brizantha*, which suggests this species is more affected by flooding than the other two.
- 4 In species 1, flooding reduced the rate of leaf elongation. In the other two species, flooding had less of an effect on leaf elongation, and sometimes the flooded plants grew faster than the non-flooded plants. [Students may comment that only 4 plants were used in each sample, and that more repeats would help make any differences in response to conditions more obvious, or more repeatable.]
- 5 The leaves are what the cattle eat, so the more rapid the leaf elongation rate, the more food there will be for the cattle.
- 6 Either species 2 (*Brachiaria decumbens*) or species 3 (*Brachiaria humidicola*) because leaf elongation is the least affected by flooding. These two species also respond to flooding by similar amounts in the growth of their parts.

Resources (per student): Activity Sheet 4, Spreadsheet 1: *Brachiaria* data, data analysis package.

The strength of Pykrete

Exploring Science link: 9H

This practical activity links to work on composite materials in Unit 9H of the *Exploring Science* Year 9 course. Use the information on Pykrete in the Student Booklet to introduce this activity, focusing particularly on the range of tests that have been done on the strength of Pykrete compared with plain ice. You could also do a search on YouTube for 'WW2 2 million ton ice aircraft carriers', which brings up a 5 minute clip about the history of Pykrete and its potential use as a material for aircraft carriers.

Students should then produce their own plans to test the strength of Pykrete made from different proportions of pulp and water. For example, they could drop lumps of different types of Pykrete repeatedly to see how quickly they fall apart, drop masses onto the Pykrete and measure impact depth (not very effective), or could measure the force needed to break frozen bars or cylinders of Pykrete. They will need to think how to control all the variables in their testing – the success of this can be evaluated at the end of the investigation.

The method for making Pykrete in the activity for Unit 8I above can be used, but students could freeze the mixtures in other waterproof, disposable containers to create other shapes, for example yoghurt pots or plastic piping.

It is suggested that students produce plans and then discuss them to agree on one plan that should be followed through. This could be carried out by students (see safety notes below) but it may be less risky to carry out the practical work as a teacher demonstration. One good demonstration method is to freeze the Pykrete into bars using long boxes lined with cling film (e.g. kitchen foil or cling film boxes). Don't be tempted to make the bars too thick. For testing, the frozen bar is supported a few centimetres off the ground, using wood blocks or old books and covered in a towel or rubber mat (to reduce the risk of slipping). The teacher stands on a set of bathroom scales, placed directly behind

the Pykrete bar. By then placing one foot on the supported Pykrete block and gradually shifting weight onto the bar, a measure of the force on the bar is obtained (it is the decrease in the mass measured on the scales, multiplied by 10 to convert it into newtons). Depending on the weight of the teacher, the bars may or may not break!

Safety note: Students will need to consider safety risks carefully in their plans, particularly if anything is to be dropped. If students are to break Pykrete cylinders by hanging masses on them, great care needs to be taken to avoid injury from falling masses when the cylinder fails – even relatively small diameter cylinders will take significant mass before breaking. Masses should fall a short distance only, not from more than 1 m, and into a sand tray or bin/bowl containing crumpled newspaper. The sizes of masses to be dropped should be limited to 500 g. Eye protection must be worn. There is a slip hazard for the teacher if the breaking of Pykrete bars is to be done by standing on them. Use a rubber mat or towel to prevent slipping.

Resources (per student or group): 'standard' paper mix made from newspaper or other soft paper (see instructions in 8l above), warm water, bowls or basins for mixing different proportions of water with the 'standard' paper mix, small waterproof disposable containers as moulds for freezing Pykrete (e.g. plastic pipes, long cling film/kitchen foil boxes lined with cling film, yoghurt pots), marker pen, access to a freezer; apparatus for testing strength, e.g. masses of different sizes and a method of attachment, eye protection (if impact testing used), sand trays or bins filled with crumpled newspaper. For teacher demonstration: bathroom scales, books or wooden blocks to a height of 2–3 cm, small rubber mat or towel.

Looking for water

Exploring Science link: 9J

Ask students to carry out research in books and on the internet to find out how scientists are looking for water on Mars, and why they are looking for it. [There are various answers to this, including supporting a manned base on the planet, discovering the history of Mars and how this might relate to Earth, and searching for life]. Suitable sites include

<http://www.scientificamerican.com/article.cfm?id=mars-water-rsl> and
<http://motherboard.vice.com/blog/mars-might-have-a-soggy-underground>.

They should also carry out research to find out how much money is spent on sending scientific equipment to Mars to carry out the tests for water.

Students use what they find to prepare an argument for or against the statement:

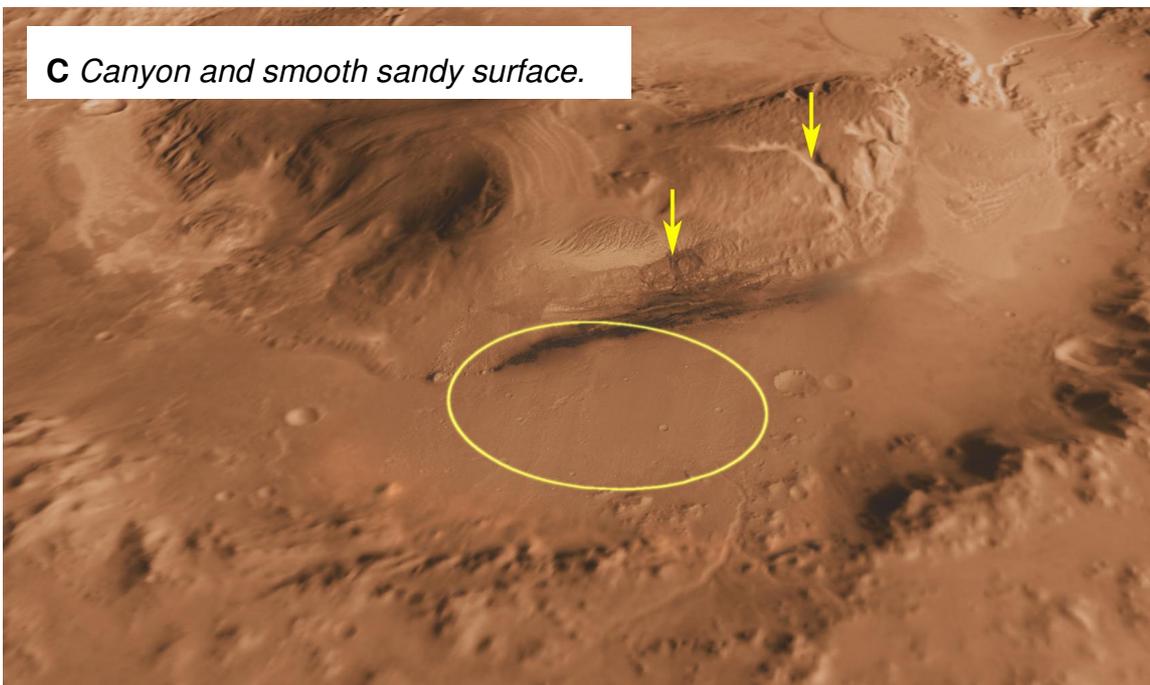
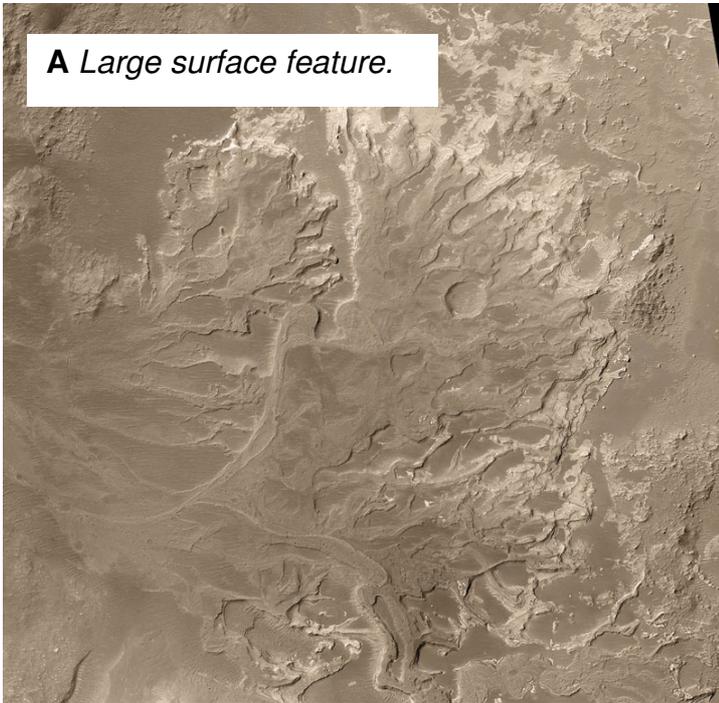
'The search for water on Mars is a waste of time and effort.'

This could be taken one step further by asking students to prepare for a class debate on 'We believe that the search for water on Mars is a waste of time and effort'.

1

Evidence for water on Mars?

These three photographs were taken of the surface of Mars. Each shows what some scientists suggest is evidence of water on the surface some time in the past.



- 1 Explain how each feature could have been created by water.
- 2 Suggest why not all scientists are convinced that each feature is evidence for water in the past.
- 3 Explain why the three photographs together provide stronger evidence for water than just one of the photographs.

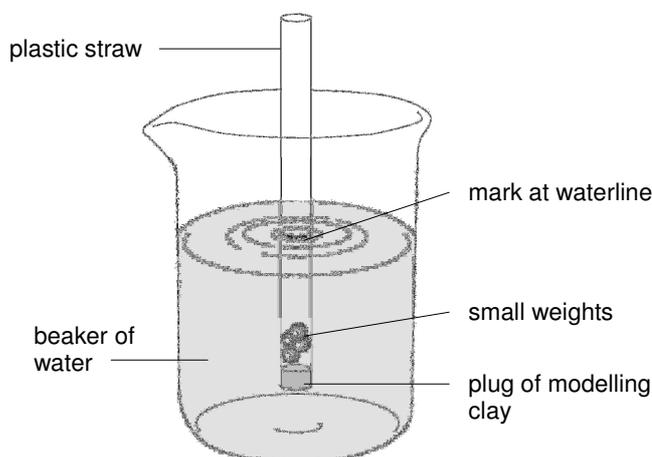
(The publisher would like to thank the following for their kind permission to reproduce their photographs: **A**: NASA/JPL/Malin Space Science Systems; **B**: NASA/JPL-Caltech/MSSS and PSI; **C**: NASA/JPL-Caltech/ASU/UA.)

Developing a Plimsoll line

The Plimsoll line is a set of lines marked on the side of a ship near the water line. These lines indicate the safe loading level for the ship in different waters. Some bodies of water are warmer than others and some are saltier than others. You will investigate the Plimsoll line using a straw as a model ship.

Apparatus

beaker or clear plastic cup
 cold water + ice
 warm tap water (c. 40 °C)
 table salt
 spatula
 plastic straw
 modelling clay
 waterproof marker pen
 small weights or sand
 ruler



Method

- A** Push one end of the straw carefully into modelling clay. Remove any clay outside the straw to leave a plug of clay about 1 cm long in the end of the straw. Place a few small weights inside the straw. Alternatively, place a little sand in the straw and tap it so that it falls down to the plug.
- B** Fill a beaker with cold water. Put the straw into the beaker, and add or remove weights or sand until it floats with about half its depth below the surface. Mark the level of the water surface on the straw using the pen. Remove the straw from the water.
- C** Add two heaped spatulas of salt to the water and stir until all the salt has dissolved.
- D** Place your straw into the salty water and mark the level of the water surface on the straw. Record the two marks on the straw by making a drawing of the straw on paper and marking the lines accurately on the drawing. Remember to note which mark is the fresh water and which is the salt water.
- E** Repeat step D with water at different temperatures, for example, water with ice added or warm water. Each time mark the position of the water surface on the straw and transfer the mark to your drawing.

Recording your results

- 1 Measure the difference in height between the marks on your straw.
- 2 Use your marks to draw your own loading level guidelines for your straw 'ship'.

Considering your results/conclusions

- 3 Using the idea of density, try to explain why the straw floated at different levels in:
 - (a) fresh compared with salty water
 - (b) cold water compared with warm water.
- 4 Explain the importance of the development of the Plimsoll line for ships that are loaded in one port, but may travel across the world before unloading at another port.

Pykrete is a material that was developed in the Second World War. It is formed by mixing sawdust with water and then freezing the mixture. The resulting solid has properties that differ from normal ice. No practical use has ever been made of Pykrete, though many suggestions have been made.

In this practical you will investigate Pykrete made from newspaper pulp and water. Your task is to find the best proportion of pulp to water to make a small ice pack that remains solid as long as possible, and so be useful in first aid treatment for sprains and bruising.

Apparatus

'standard' paper/water mix prepared from newspaper or other soft paper
warm water
3 bowls or basins
3 small sealable freezer bags
marker pen
weighing balance

Method

- A** Paper pulp is made by soaking the paper in the water and then mixing it thoroughly to separate the wood fibres. Your teacher will provide you with some 'standard' paper/water mix and explain the method used to prepare it.
- B** Pykrete is made using a mixture that is 14% sawdust and 86% water by mass. Plan how to make this mixture from the 'standard' mixture. Plan two other mixtures, one with a higher proportion of paper and one with a lower proportion of paper. Record your calculations.
- C** Prepare your three mixtures, one in each bowl. Make sure the paper fibres are separated from each other and thoroughly mixed with the water.
- D** Use the pen to label one of the bags with the proportions of one of the mixtures. Give the pulp in that mixture a final stir and then fill the bag three-quarters full with the mix. Seal the bag carefully, squeezing out as much air as possible. Measure the mass of the bag and its mixture.
- E** Repeat step D using a second mixture. Try to use exactly the same mass of mixture.
- F** Repeat step E with the final mix. Give all three bags to your teacher for freezing.
- G** Plan a way to test how long it takes each bag to melt, making the test as fair as possible. Carry out your test when the three bags are fully frozen. Wash your hands after carrying out your test.

Recording your results

- 1 Draw a table to display your results.
- 2 Display your results in a suitable table or chart.

Considering your results/conclusions

- 3 Which mixture would be the best to use in an ice pack, to keep a sprain cool for as long as possible? Explain your answer.
- 4 Did other groups in your class get similar results to yours? If not, suggest why not.
- 5 Suggest why Pykrete behaves differently to plain ice.

Flooding and plants

Different plants are adapted to grow best in different conditions. Some species can continue to grow well even if they are flooded for a little while. Some cannot grow well at all if flooded. Understanding the effect of flooding on plants is particularly important for controlling conditions in which crops are grown.

There are many species of signalgrass or *Brachiaria*. Some species are grown in tropical countries for feeding cattle. Some places where *Brachiaria* is grown are occasionally flooded by tropical storms. Planting flood-tolerant species of *Brachiaria* in these places is important, so that the grass plants continue to grow.

Spreadsheet 1 contains data about three species of *Brachiaria*. Use software to analyse the data as described below and use your analysis to answer the questions.

- 1 The 'Relative growth' table contains data about the growth of different parts of the plant, for three different species, in normal conditions and in flooded conditions. Use software to draw 3 bar charts, each chart showing the mass of one plant part for all three species. Remember to label your charts properly and to add a caption that describes what each chart shows.
- 2 Use your charts to describe the effect of flooding on each plant part. For example:
 - Did any part grow faster in flooded conditions?
 - Did all three species respond in the same way?
 - If the species responded differently, compare their responses.
- 3 There are three separate tables that show leaf elongation rate, one for each species. The rate of elongation is the speed at which a leaf gets longer. Draw separate line graphs for each species, showing both the normal and flooded results for the species on one line graph.
- 4 Use your graphs to describe the effect of flooding on leaf elongation rate. For example:
 - What effect did flooding have on leaf elongation rate in species 1, species 2 and species 3?
 - Did all the species respond in the same way to flooding?
 - If the species responded differently, compare their responses.
- 5 Explain why leaf elongation rate is an important factor for the farmer who keeps cattle.
- 6 Using your analysis, which species of *Brachiaria* would you suggest should be planted for feeding cattle in areas where tropical storms are likely? Explain your answer.