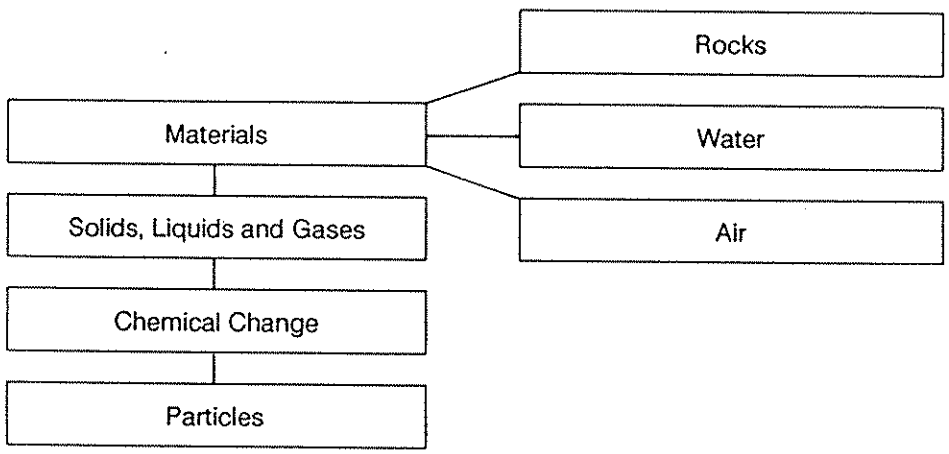
WATER

IMPORTANT NOTE

The realm of matter and materials is far too extensive to deal with as one domain, and yet it is difficult to identify clear demarcations. Any domain boundaries are necessarily artificial but seven domains have been chosen so as to focus upon the underlying structure of materials and the changes brought about by energy transfer.

This domain relates to other domains, as shown below, with 'Materials', 'Solids, Liquids and Gases', 'Chemical Change' and 'Particles' dealing with general issues and the other three domains dealing with specific important examples:



Pupils' understanding of materials will, of course, be rooted in their many first-hand experiences of what materials look and feel like and the way materials behave. Their ideas progress from understandings based on objects, through ideas of material substance of which objects are made, towards understandings in terms of chemical substances. It is therefore very important to use words carefully so as to distinguish between a material and its component chemical substances (see Introduction page 21: Material Substances). In this domain the word 'substance' is used to refer to a component (element or compound) of a 'material'.

When they have been introduced to the notion of particles, pupils can begin the long-term process of reconstructing their explantations of phenomena in terms of particles. The particulate model of matter is not only an idea to be developed in its own right: it is also a model to be used to explain the behaviour of materials in all contexts not only throughout work on inanimate materials but also in the context of thinking about living things and the processes of life. Thus the Science Maps and Learning Guides in many domains show both 'macro' and 'particulate' versions of certain ideas.

The term 'particle' is reserved for atom, molecule, ion or electron: small pieces of material are referred to as 'fragments', 'grains', 'bits' or 'droplets'.

WATER

The following sections have been designed for use in association with one another. The Learning Guides are supported by the Research Summary, the Science Map and The Teacher's View. It will also be helpful to refer to the Science Map and The Teacher's View when using the Research Summary.

CONTENTS

Science Map

This map shows those ideas which make up a sound basis for understanding Water to work towards in the early secondary years. This is proposed as a coherent framework in itself which at the same time provides an appropriate basis for development. Critical ideas around which understanding is structured are identified in the map as shaded boxes and these goals make up the right hand column of the Learning Guides.

Learning Guides

These guides are the nucleus of the materials. They are folded so that children's prior ideas from the Research Summary are set alongside goals from the Science Map and they describe the challenges pupils face when it comes to restructuring their ideas. They also suggest interventions which could be used in teaching schemes to help pupils reach the goals. Related extracts from the National Curriculum are included. The Learning Guides in this domain are:

WATER VAPOUR — DISSOLVING — WATER PRESSURE

WATER CYCLE — WATER AND LIVING THINGS — FLOATING AND SINKING

Research Summary: Children's Ideas

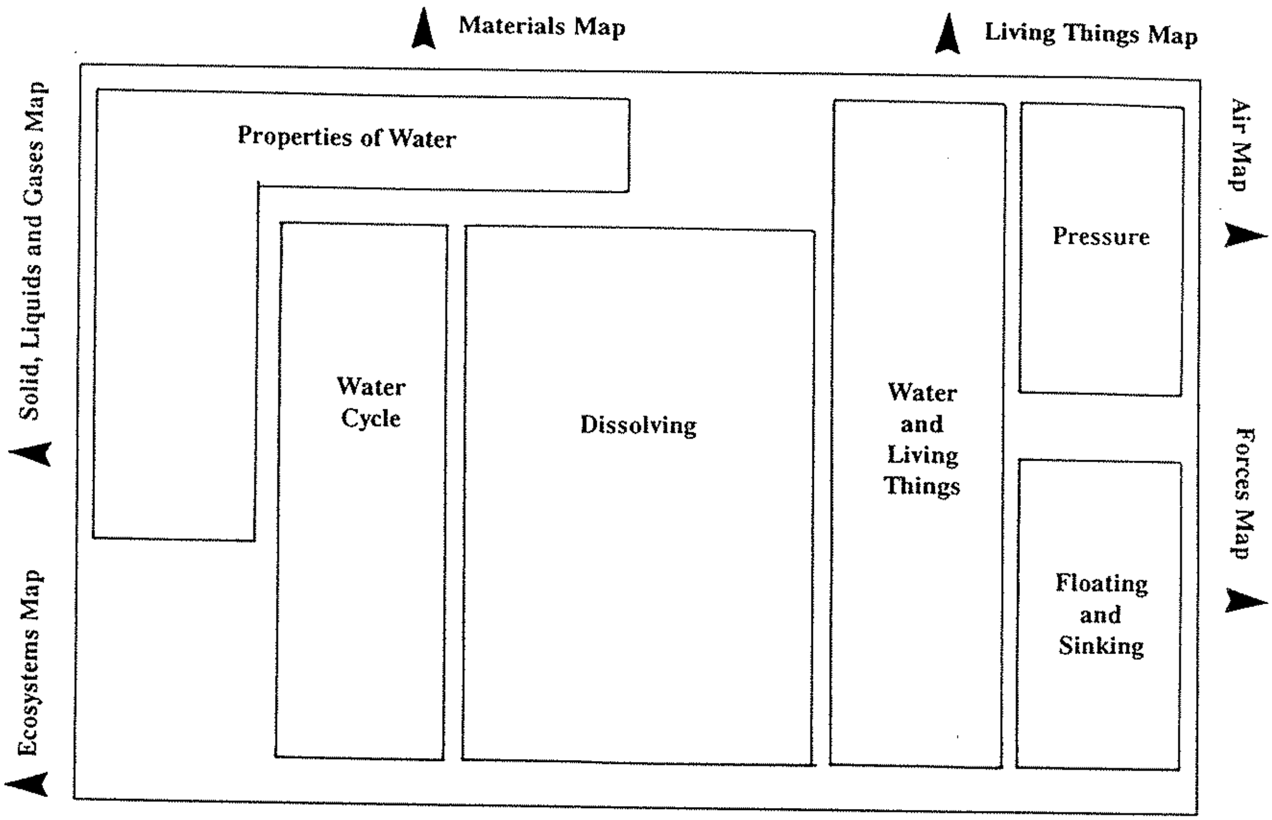
This is a brief outline of research into children's ideas, setting out the main prior ideas and understandings which teachers might expect to meet among pupils. These ideas make up the left hand column of the Learning Guides.

The Teacher's View

This section outlines those aspects of a deeper understanding which the teacher needs to have in mind whilst working with pupils.

WATER

SCIENCE MAP



Outline of the of Science Map overleaf

The map overleaf shows those ideas which make up a sound basis to work towards in the early secondary years. This is proposed as a coherent framework in itself which at the same time provides an appropriate basis for development. Critical ideas around which understanding is structured are identified in the map as shaded boxes and these goals make up the right hand column of the Learning Guides.

Aspects of a deeper understanding which the teacher needs to have in mind whilst working with pupils are outlined in The Teacher's View.

WATER

SCIENCE MAP

Water is a liquid material.

More of the Earth's surface is covered by water than by land.

Water is very important to living things.

Water is not compressible.

When objects move through water the water resists movement. There is less resistance when objects are streamlined.

Water freezes at 0°C to form ice and boils at 100°C to form water vapour.

Water expands as it freezes. Forces resulting from the expansion can break up rocks and soil.

Water is an unusual liquid because its solid form (ice) is less dense than the liquid and ice floats on water.

Because ice floats on water, ponds rarely freeze throughout and aquatic animals can live through cold winters under the ice.

Water evaporates from the surface of oceans, lakes and rivers, and plants' leaves, to form water vapour in the air. (See Learning Guide: Water Vapour)

The amount of water vapour in the air increases with the temperature of the air and when the air has passed over oceans and lakes.

Cooling causes water vapour to condense from the air to become water droplets, as clouds or dew. (See Learning Guide: Water Vapour)

Tiny drops of water in clouds collide with one another, and join together to form bigger drops which fall as rain.

Water is cycled from clouds to rain, to rivers and oceans, and back to clouds. (See Learning Guide: Water Cycle)

Many solids, some other liquids, and many gases dissolve in water: therefore water is a called 'a good solvent'. When a substance dissolves in water a solution is formed and the mixture is completely homogeneous.

When a substance dissolves in water, the particles which make up the substance become completely mixed with the particles of the water, and all the particles move around freely so that the whole solution behaves as a liquid. (See Learning Guide: Dissolving)

Only a certain amount of any substance can be dissolved in a given volume of water, at any particular temperature. When no more of a substance can dissolve the solution is saturated.

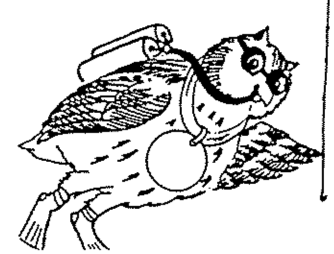
For many solids, the hotter the water the more substance dissolves in a given amount of water.

A solid which has dissolved in water can be recovered by evaporating the water.

For gases, the hotter the water the less gas dissolves in a given amount and with colder water, more gas dissolves.

The higher the pressure, the more gas dissolves in a given amount of water.

Many chemical reactions, including those in living things, take place in solution in water.



Water is the main substance of which living things are made. (See Learning Guide: Water and Living Things)

Most living things live surrounded by water. The watery environment helps to support them and supply them with dissolved substances which they use in their living processes. (See Learning Guide: Water and Living Things)

Living things which live in water and living things which live on land use dissolved oxygen for their respiration.

Because water flows easily and is such a good solvent, it is able to carry substances around the bodies of living things.

Large animals need more oxygen than can dissolve in the water part of blood and other body fluids. Haemoglobin in the blood enables more oxygen to be carried.

Plants take in water and dissolved substances through their roots.

Green plants are able, in photosynthesis, to combine water with carbon dioxide to make sugars and starch.

Because water is not compressible, it can be moved through a system of tubes. This enables it to be pumped around the bodies of living things.

In fluid materials, like air and water, there is a pressure which acts in all directions. (See Learning Guide: Water Pressure)

Some materials float in water and others sink: those materials which are less dense than water float; and those which are more dense than water sink. Many materials which sink can be made to float if they are shaped into objects, like boats, which as a whole, are less dense than water. (See Learning Guide: Floating and Sinking)

When an object floats the force acting downwards (its weight) is balanced by an upward force exerted by the water. An object sinks when its weight is greater than the upward force of the water. (See Learning Guide: Floating and Sinking)

WATER

LEARNING GUIDES APPENDIX: RELATED EXTRACTS FROM THE NATIONAL CURRICULUM PROGRAMME OF STUDY FOR KEY STAGE 3

References relating to the Learning Guides are underlined below:

Sc3 strand iv - the Earth and its atmosphere

Pupils should investigate practically, and by use of secondary sources, the properties of water, the water cycle, conservation of water resources and the effect of water on the Earth's surface. They should study the factors influencing the weather, including how different airstreams give different conditions. They should be acquainted with the meteorological symbols. Pupils should investigate, by observation, experiment and fieldwork, the properties and formation of igneous, metamorphic and sedimentary rocks, and link these to major features and changes on the Earth's surface. They should be aware of the time-scales involved in the operation of geological processes, and be able to evaluate earlier ideas about the age of the Earth. They should investigate some natural material (rock or soil) and link the properties of minerals and rocks to their uses as raw materials in construction. They should appreciate the effects of weather on buildings and on rocks, and examine soil forming processes.

Sc3 strand ii - explanations of the properties of materials

Pupils should investigate changes of state, diffusion, dissolving, and the behaviour of gases under different conditions of temperature and pressure. They should be encouraged to explain these phenomena in terms of their developing ideas of the particulate model of matter............

Sc3 strand i - the properties, classification and structure of materials

Pupils should have the opportunity to compare and study a range of physical properties, including density............

Sc2 strand iii - populations and human influences within ecosystems

Pupils should study a variety of habitats at first hand and make use of secondary sources, to investigate the range of seasonal and daily variation in physical factors, and the features of organisms which enable them to survive these changes.............

Sc4 strand iii - forces and their effects

.... They should investigate how....forces enable floating and sinking. This work should relate to the design and evaluation of structures, for example, *bridges and boats* ....

WATER VAPOUR

Children's Prior Ideas

When considering evaporation children at ages five and six are impressed by the disappearance of material. They accept that it just happens and offer no explanation.

It is not until the ages 8-10 that they are likely to attempt to conserve the (evaporated) substance by suggesting that it must go somewhere. The place is often thought of as some sort of receptacle such as the container or supporting surface, which they therefore regard as porous.

When the child develops a concept of 'static air' they may suggest that bits of water go into the (receptacle) 'air'.

It follows that the growth of the evaporation concept appears to be dependent on the development of notions of conservation, atomism and air.

When children observe a liquid changing to a gas or vapour they may construct the idea that, because material substances seem to disappear, weight and mass are lost. Alternatively those who conserve substances may generate the idea that a gas is lighter than the same amount of liquid.

Children tend to think that liquid water and/or water vapour move into leaves.

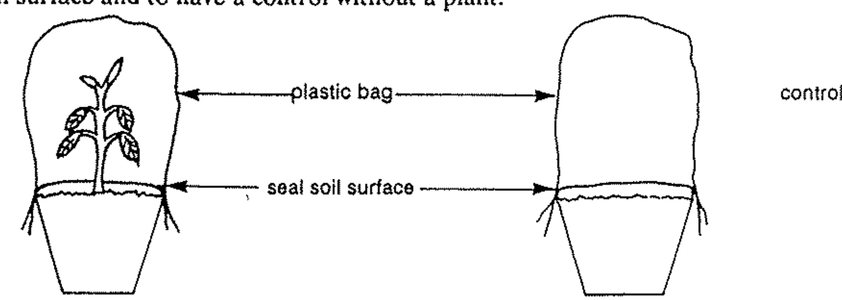
(See Water Research Summary)

The Challenge for Pupils

Children will have experience of evaporation in the context of puddles drying up and saucepans boiling dry. However, they need to recognise that the water does not just 'disappear' and a change of state occurs and it changes into a gas. (See States of Matter/Evaporating and Condensing Learning Guides in 'Solids, Liquids and Gases'.) It may help to use boiling dry as a precursor to seed ideas of water going into the air. Experience of situations where they can get the water back will help to build the idea of water vapour, for example, condensation on a cold surface.

The idea that evaporation can occur without an obvious source of heating underlies any awareness of evaporation in the environment. Moving from the idea of deliberate heating by human intervention, to the idea of energy transfer when evaporation occurs 'naturally' from puddles, rivers and lakes, presents a major challenge. The idea of water vapour in the air is not self evident to children. (See Air as a Mixture Learning Guide in 'Air'.) Even when pupils have developed the idea of evaporation as a change of state the idea of water vapour in the air is not obvious.

Once children accept that water evaporates from lakes, rivers and oceans it may be a further step to the idea of water evaporating from the leaves of plants. They will need to understand that there is water in plants (see Learning Guide: Water in Living Things) and recognise 'plants' as including trees, grass and so on, to appreciate the size of the area of leaves involved. If they grow plants in sealed systems they will see water droplets inside the bag or jar. To demonstrate that the water comes from the plants' leaves and stems it is necessary to seal the soil surface and to have a control without a plant.



In order to develop ideas about condensation of water vapour from the air pupils need to have a well established notion of water vapour in the air. Moreover, pupils need to recognise that condensation can happen at any temperature but only when cooling occurs. They also need to understand condensation is the reverse of evaporation. (See Evaporating and Condensing Learning Guide in Solids, Liquids and Gases.)

They will need to appreciate that clouds and dew are water which has condensed in areas where cooling has occurred.

Goals

Water evaporates from the surface of oceans, lakes and rivers, and plants' leaves, to form water vapour in the air.

Cooling causes water vapour to condense from the air to become water droplets, as clouds or dew.

Related National Curriculum Programme of Study Key Stage 3
Pupils should investigate practically, and by use of secondary sources, the properties of water, the water cycle.... (Sc3 iv)

Related extracts from the National Curriculum Programmes of Study: Key Stages 1, 2 and 4

Experiments on dissolving and evaporation should lead to developing ideas about solutions and solubility. (KS2 Sc3 i)

Pupils should have the opportunity to make regular, quantitative observations and keep records of weather.... This should lead to a consideration of the water cycle. (KS2 Sc3 iv)

Pupils should study, through measurement and by other means, the principles which govern the behaviour of gases in the atmosphere, and the nature of the energy transfers which drive their motion. (KS4 Sc3 iv)

Related National Curriculum Statements of Attainment

Pupils should:

Sc3 iv/5d understand the water cycle in terms of the physical processes involved.

Sc3 iv/7h understand how some weather phenomena are driven by energy transfer processes.

Goal

Water is cycled from clouds to rain, to rivers and oceans, and back to clouds.

Related National Curriculum Programme of Study
Key Stage 3
Pupils should investigate practically, and by use of secondary sources, the properties of water, the water cycle, conservation of water resources and the effect of water on the Earth's surface. They should study the factors influencing the weather. (Sc3 iv)

Related extracts from the National Curriculum Programmes of Study: Key Stages 1, 2 and 4

Pupils should have the opportunity to make regular, quantitative observations and keep records of weather and the seasons of the year. This should lead to a consideration of the water cycle. (KS2 Sc3 iv)

Related National Curriculum Statements of Attainment

Pupils should:

Sc3 iv/4d know how measurements of temperature, rainfall, windspeed and direction describe the weather.

Sc3 iv/5d understand the water cycle in terms of the physical processes involved.

Children's Prior Ideas

At ages 5-8 children do not have a connected set of ideas. They may suggest that rain falls when water reservoirs in the sky are opened. They may also think that clouds are made of smoke or cotton wool, and therefore are unrelated to rain. Others may think of clouds as bags of water which get torn or split when they collide and rain falls out. Clouds are thought to go into the sea and collect water. The clouds then move to other places and give rain.

Between ages six and nine children may start to consider clouds to be made of vapour created when the sea is heated by the Sun. The Sun goes into the water thereby heating it to a high temperature. Later the clouds open to give rain.

Slightly older children may visualise a cloud as a sponge having drops of water in it, when it rains the drops fall through little holes in the cloud, when the cloud is shaken by wind. Alternatively some children may hold that rain falls when clouds get cold or become hot.

By about age ten children children begin to appreciate that clouds may be made of water evaporated from the surface of the Earth; rain falls when clouds become cold or heavy.

By ages 11-15 children may acknowledge that clouds are created when the vapour becomes cold; the rain falls when the water drops become big and heavy.

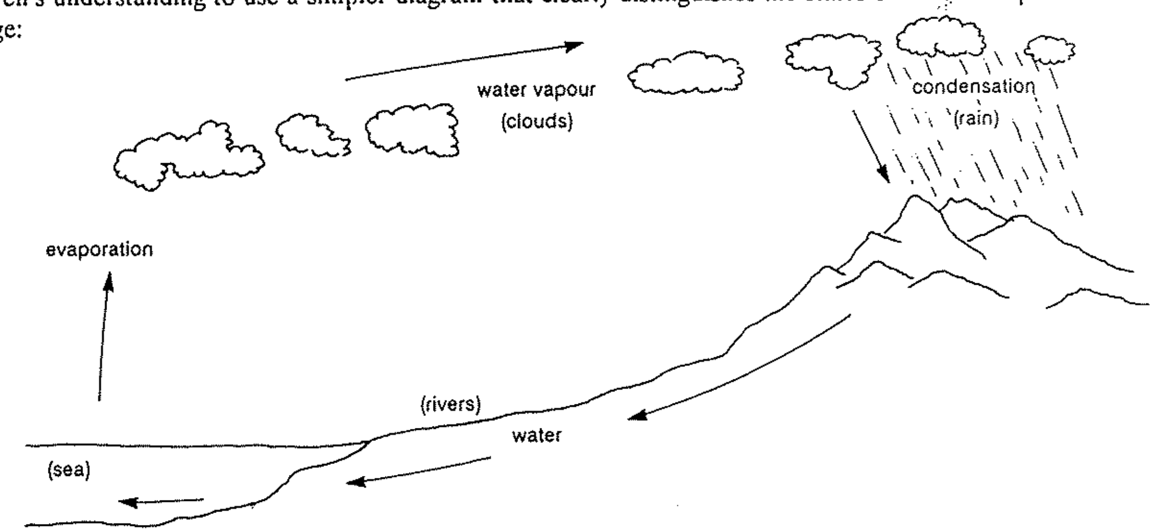
(See Water Research Summary)

The Challenge for Pupils

In order to develop the idea of the water cycle, children first need to have understood conservation of matter (see Conservation of Matter Learning Guide in 'Materials'), evaporation and condensation (see Evaporating and Condensing Learning Guide in 'Solids, Liquids and Gases') and how water evaporates from lakes, rivers and oceans and condenses as clouds and dew (see Learning Guide: Water Vapour). Each of these ideas presents a major challenge to pupils and none can be taken for granted in introducing the idea of the water cycle.

The task for pupils is to bring together the separate ideas into a dynamic cycle idea. It may help pupils to think imaginatively about 'the journey of a rain drop' as it cycles. The mere drawing of a diagram may limit thinking to an arrangement of isolated events.

Many publications often clutter their diagrams of the water cycle whereas, as a starting point, it will help the children's understanding to use a simpler diagram that clearly distinguishes the states of water and processes of change:



Once the pupils have understood the basic cycle they can then start to add in such details as domestic systems and water treatment facilities.

(For a discussion of general issues relating to cycles see Introduction: Cycles.)

WATER

DISSOLVING

Children's Prior Ideas

Many children do not distinguish between dissolving and melting and use the two words indiscriminately.

From an early age through to adulthood, individuals hold several conceptions of 'dissolving'. Up to age eight there is the tendency to focus on the solute only. Sugar placed in water 'disappears', 'melts' or 'turns into water'. This latter phrase may simply mean 'goes liquid'.

Older pupils start to imagine that as sugar dissolves 'it goes into tiny little bits' and later on, some say that 'sugar molecules fill spaces between water molecules' or 'mix with water molecules'.

About two-thirds of eight year-olds think that the dissolved substance is preserved in some form or other, although only half of these think that it weighs something.

After age eight, pupils increasingly generate more ideas about the changes that the solute undergoes.

(See Water Research Summary)

The Challenge for Pupils

Pupils are likely to find it much easier to think about the dissolving of a solid in water than to think about liquids or gases dissolving. Children usually meet both dissolving and melting in the context of water. This may well be the cause of their confusing the two processes. An initial challenge for pupils is to distinguish between dissolving and melting. They need to recognise that dissolving involves two substances and can happen without heating, whereas melting involves only one substance and also involves heating.

Some children may need to have experiences to convince them that a dissolved substance does not disappear. Weighing solvent, solute and solution may be useful, as could be getting the solute back by evaporation.

Having distinguished between dissolving and melting children will need to distinguish a solution from a pure solvent and from a suspension. Colloidal examples like milk are best excluded at this stage so that children can compare a solution and a suspension of visible fragments. Recognising the difference between a solution, a solvent and a suspension depends upon an understanding of conservation of matter when a substance is dissolved. (See Conservation of Matter Learning Guide in 'Materials'.) The pupils may consider such questions as, 'Can you see through it?', 'How many substances are there?', 'Will a substance settle out?' and 'Where is the dissolved substance?'.

Words such as solution, solvent and soluble will arise during activities, but children will need to concentrate on understanding the ideas not just remembering the words and labels.

The fact that children have embraced the idea of solids dissolving in water does not always necessarily mean that they will transfer the idea to other liquids and gases dissolving in water.

Pupils should, if possible, have experience of dissolving in contexts other than water. They need to be aware that dissolving does not occur only in water.

Pupils who can apply a particle model to substances need to begin to account for dissolving in terms of the particles of solvents and dissolved substances.

DISSOLVING

Goal

Many solids, some other liquids, and many gases dissolve in water: therefore water is called 'a good solvent'. When a substance dissolves in water a solution is formed and the mixture is completely homogeneous.
When a substance dissolves in water, the particles which make up the substance become completely mixed with the particles of the water, and all the particles move around freely so that the whole solution behaves as a liquid.

Related National Curriculum Programme of Study
Key Stage 3
Pupils should investigate....dissolving.... They should be encouraged to explain these phenomena in terms of their developing ideas of the particulate model of matter. (Sc3 ii)

Related extracts from the National Curriculum Programmes of Study: Key Stages 1, 2 and 4

They should see how some (properties) can be changed by simple processes such as dissolving, squashing, pouring, bending and twisting. (KS1 Sc3 i)

Experiments on dissolving and evaporation should lead to developing ideas about solutions and solubility. (KS2 Sc3 i)

Related National Curriculum Statements of Attainment

Pupils should:

None.

Children's Prior Ideas

Many children do not think there is one single explanation for floating and sinking and offer different explanations for different contexts.

Many children think that light objects float and heavy objects sink, or that the shape of the object determines whether it will float. Some children think that the length of material or the depth of water beneath the object affect flotation level.

Objects with holes in them are expected to sink, while those with 'air in them' may be thought to float.

Some children may think that water inside an object makes the object heavier and it sinks.

(See Water Research Summary)

The Challenge for Pupils

Pupils' everyday experiences of floating and sinking are likely to present them with all the complexities of the phenomenon. They will meet objects which float and objects which sink. They will meet materials which float and materials which sink. They will meet objects which float even though they are made of materials which sink. And they will meet small objects which 'float' due to the surface tension of water, when bigger objects of a similar shape and the same material would sink. It is small wonder that pupils have difficulty in developing a coherent understanding of the factors involved in floating and sinking when they are met in such various combinations! The first issue for pupils to face is whether they are considering an object or the material of which it is made. This distinction presents difficulties for some pupils and it may need attention at the outset of work on floating and sinking. (See All Materials Learning Guide in 'Materials'.) Pupils need to see the sense in investigating one factor at a time and this involves them in beginning to identify the possible factors affecting the floating or sinking of an object. It is helpful for pupils to begin with an investigation focusing upon materials so as to recognise that the behaviour of solid blocks of different materials is predictable. Some materials as blocks always float and others always sink. Pupils may need to clarify what counts as floating so that only materials which sink to the bottom are classed as 'sinking'. Working with a focus on materials, pupils are in a good position to ask themselves, 'Why does a floating material float?' and 'Why does a sinking material sink?'. Pupils need to compare the different materials, not only with one another, but also with water. They may think only of weight or perhaps of 'weight for size'. Embryonic versions of the notion of density can be used to try to account for floating and sinking, the challenge being that of finding a valid way of comparing the materials with water. Pupils who have a more sophisticated understanding of density (see Density Learning Guide in 'Materials') may be able to determine the densities of materials tested and predict whether a material will float or sink even when it is not easily identified as lighter (or heavier) for its size than water. When pupils try to account for the fact that a sinking material can be made into a floating object, their 'density compared with water' explanation lets them down unless all the materials in the object (including air) are accounted for.

In order to move towards an understanding of everyday experiences of floating and sinking pupils need to draw upon their ideas of forces - asking themselves what forces are acting when the object is floating. They need the idea of balanced forces. (See Resultant (Nett) Force Learning Guide in 'Forces'.) They need to understand that if the object is not moving either up or down then there must be balanced forces on it. Pupils are likely to identify the force of gravity acting downwards on an object in the air, on a table or on the floor, but when it comes to an object in water pupils are inclined to think gravity is not acting. It is only when they accept gravity acting downwards, and also the existence of balanced forces on a static object, that they are in a position to recognise that the water must be pushing the object upwards. A return to blocks of different materials may be helpful, this time using a concentrated salt solution as well as water and comparing different floaters - the different amounts of floating material which is under the water. Pupils may eventually begin to draw together their density and forces explanations of floating and sinking. This involves recognising that the upward force of the water is the same as the upward force on that volume of water which the floating object replaces. Pupils will need to draw upon a concept of proportion, recognising that the amount of floating material beneath the water depends upon its density with respect to water.

Goals

Some materials float in water and others sink: those materials which are less dense than water float; and those which are more dense than water sink. Many materials which sink can be made to float if they are shaped into objects, like boats, which as a whole, are less dense than water.

When an object floats the force acting downwards (its weight) is balanced by an upward force exerted by the water. An object sinks when its weight is greater than the upward force of the water.

Related National Curriculum Programme of Study Key Stage 3

Pupils should have the opportunity to compare and study a range of physical properties, including density.... (Sc3 i)

They should investigate how....forces enable floating and sinking. This work should relate to the design and evaluation of structures, for example, *bridges and boats*. (Sc4 iii)

Related extracts from the National Curriculum Programmes of Study: Key Stages 1, 2 and 4

They should explore floating and sinking and relate their experiences to water safety. (KS1 Sc4 iii)

They should investigate the factors involved in floating and sinking. (KS2 Sc4 iii)

Related National Curriculum Statements of Attainment

Pupils should:

Sc4 iii/4c know that more than one force can act on an object and that forces can act in different directions.

WATER AND LIVING THINGS

Children's Prior Ideas

Many children think that plants take in water as food. Many think that the plants' leaves take in water with the leaf's main function being to capture rain, water or dew.

(See Water Research Summary)

The Challenge for Pupils

Pupils need to pursue the 'what is it made of' question (see Material Substances Learning Guide in 'Materials') to recognise water as a substance in the materials which make up living things.

object —— made of —— materials —— made of —— substances
(living things) (skin, blood, leaf) (water, proteins, salt....)

Although children may think of plants and animals taking in water they still have difficulty understanding the existence of water in materials like skin which appear solid. Furthermore they might not necessarily recognise blood as largely water: they may think of it as a different liquid.

The distinction between water being present in living things and water taking part in the chemical reactions of life processes is a difficult one for pupils to make. An even more difficult idea is that the substances of living material are synthesised from simpler substances including water. (See Plant Nutrition Learning Guide in 'Nutrition'.)

In order to appreciate the significance of water for living processes, pupils need to understand dissolving and the notion of dissolved substances. (See Learning Guide: Dissolving.) Recognising the significance of water as a supplier of substances to living cells depends upon children appreciating that water is a solvent for many substances. It also depends on their appreciating the fluid properties of water which enable it to move freely between the environment and a living thing and within living things.

Goals

Water is the main substance of which living things are made.

Most living things live surrounded by water. The watery environment helps to support them and supply them with dissolved substances which they use in their living processes.

Related National Curriculum Programme of Study Key Stage 3

They should study life processes, feeding (including digestion and assimilation), respiration, removal of waste, movement, behaviour, growth, reproduction and sensitivity, particularly as they relate to human beings.... They should study respiration, growth and sexual reproduction in plants. (Sc2 i)

Pupils should study a variety of habitats at first hand and make use of secondary sources,....and the features of organisms which enable them to survive these changes. (Sc2 iii)

Related extracts from the National Curriculum Programmes of Study: Key Stages 1, 2 and 4

They should have opportunities, when possible through first hand observation, to find out about a variety of animal and plant life. (KS1 Sc2 ii)

Pupils should study plants and animals in a variety of local habitats, for example, *playing field, garden, and pond.* (KS1 Sc2 iii)

Pupils should explore and investigate at least two different habitats and the animals and plants that live there. (KS2 Sc2 iii)

They should explore how the internal environments of plants and animals are maintained, including water relations.... (KS4 Sc2 i)

Pupils should make a more detailed and quantitative study of a habitat, including the investigation of the abundance and distribution of common species, and ways in which they are adapted to their environment. (KS4 Sc2 iii)

Related National Curriculum Statements of Attainment

Pupils should:

Sc2 i/2a know that plants and animals need certain conditions to sustain life.

Sc2 iii/2c know that different kinds of living things are found in different localities.

Sc2 iii/3a know the basic life processes common to humans and other animals.

WATER PRESSURE

Children's Prior Ideas

The majority of secondary pupils think of pressure increasing with depth.

Few pupils think of pressure acting in all directions in air or water: most are inclined to think of a greater pressure acting downwards.

Changes caused by pressure differences are rarely attributed to the difference between two pressures: one pressure pushing may be recognised but more common, and tenacious, is the idea that low pressure, or a vacuum, 'sucks'.

(See Water Research Summary)

The Challenge for Pupils

Pressure in liquids and gases presents significant problems to pupils: they cannot simply extend their developing ideas about surface pressure. The first challenge for pupils at the early secondary stage is to work towards an awareness of the phenomenon of pressure in gases and liquids, and an awareness of some of its effects.

Pupils have first-hand experience of feeling water pressure when they are in water. Therefore they find the idea of pressure in water easier to accept than the idea of pressure in air. They need a variety of experiences (involving syringes, collapsing cans, drinking through a straw, using 'suction' devices....) to help them to extend their idea of pressure in water to the context of air. Because air pressure is a 'background' sensation for all of us, and the pressure can only be detected when pressure differences occur, they cannot experience it. However, they can develop from these phenomena an intellectual awareness of pressure - 'there must be a pressure in air which is collapsing the can....' and 'there must be a pressure holding it down....'.

The idea of pressure acting in all directions involves pupils thinking in terms of forces which have direction as well as magnitude. For example, in accounting for a collapsed can they will need to argue that 'there must have been a force in that direction, and that direction, and that direction....in all directions'.

Goal

> In fluid materials, like air and water, there is a pressure which acts in all directions.

Related National Curriculum Programme of Study
Key Stage 3
None.

Related extracts from the National Curriculum Programmes of Study: Key Stages 1, 2 and 4

They should investigate pressure and everyday applications of hydraulics. (KS4 Sc4 iii)

Related National Curriculum Statements of Attainment

Pupils should:

None.

Children's ideas about

WATER

RESEARCH SUMMARY

This is a brief outline of research setting out the main prior ideas and understandings which teachers might expect to meet among pupils.

Children's ideas about
WATER

Before reading this summary of children's prior ideas, it may be helpful to look at the Science Map and The Teacher's View so as to have a useful overall perspective from which to view children's understanding.

Introduction

Research into children's ideas about water is often in the context of research into ideas about solids, liquids and gases in general. Hence this summary is closely linked with that in 'Solids, Liquids and Gases'.

Research findings particularly related to water are summarised here under the following headings:

Water as a liquid
Freezing water and melting ice
Boiling
Evaporation
Condensation
Dissolving
Water cycle
Water and living things
Floating and sinking
Weathering rocks
Implications of the research findings for teaching.

Water as a liquid

In a child's view water is the exemplary liquid and all liquids tend to be regarded as 'watery', 'made of water' or 'containing water' [1].

Dow studied pupils applying a particle model to water and liquids [2]. They tended to think of the particles not as being closely packed and simply rolling over one another but rather as moving freely away from one another. As a result of this pupils saw no reason for a liquid sample to have fixed volume and they expected a liquid to be compressible.

Freezing water and melting ice

Osborne and Cosgrove [3] studied children's ideas about freezing and found that they generally do not regard freezing as taking place at a specific temperature. Pupils who tried to apply a particle model to the process of freezing tended to think in terms of the particles of water becoming more packed together and consequently they reasoned that 'ice doesn't take up as much room as when it's liquid'.

Pupils are inclined to think of a loss of mass when ice changes to water. Stavy [4] presented pupils with two samples of ice having identical weights, then melted one sample of ice and interviewed them about the relative weights of the two samples. In this case she found that the development curve of conservation was S-shaped - starting with 5% at ages five and six, it increases to about 50% at age seven and then to 75% at age ten.

Boiling

Andersson [5] set children two problems regarding what would happen to the temperature of a pan of water boiling on a stove. When asked what would happen if the water continued to be heated for a further five minutes, 40% of twelve year-olds responded that the temperature would be greater than 100°, with the majority of the group explaining that the water gets hotter the longer it is heated. The number of children offering this answer fell with age but 16% of fifteen year-olds still felt that the temperature would be greater than 100°C. Of those children suggesting that the temperature would remain at 100°C, 25% of twelve and thirteen year-olds explained their answer in terms of the switch number of the stove determining the temperature of the water. The pecentage of children offering this explanation was 35% in fourteen year-olds and 32% in fifteen year-olds.

Andersson's second problem required the children to suggest what would happen if the setting of the stove were increased. Here 90% of children aged twelve thought that the temperature would increase above 100°C. This response was also given by 63% of thirteen year-olds, 60% of fourteen year-olds and 54% of fifteen year-olds.

Even by age fifteen only 31% gave correct answers and appropriate explanations to both problems. Children appear to consider heat and temperature to be the same thing and so if you increase the amount of heat you will increase the temperature.

Bar and Travis [6] found that pupils' understanding of 'boiling' precedes that of 'evaporation' of liquids from surfaces such as floors, saucers and roads. They found that 70% of a sample of 6-8 year-olds understood that when water is boiling vapour comes from it, that the quantity of water decreases, and that the vapour is made of water. However, the same children said that when a solid object (for example, a wet saucer) dries, water just disappears or else it penetrates the solid object.

Evaporation

Development of a conception of evaporation

Several researchers have attempted to trace the development of a conception of evaporation[6 7 8 9 10 11 12]. For example, Bar [7] found that, at ages five and six, children are impressed by the disappearance of material, accept that it just happens, and offer no explanation. It is not until ages 8-10 that they are likely to attempt to conserve the (evaporated) substance by suggesting that it must go to some place. (Such a place, in their view, has the character of a receptacle.) At this age, the only 'receptacle' they can think of is the (solid) container or supporting surface; either of which they now regard as porous. When, however, they come to develop a concept of 'static air', they suggested that bits of water go into the (receptacle) 'air'. It follows that the growth of the evaporation concept appears to be dependent on the development of notions of conservation, atomism and (invisible) air so that, by ages 12-14, a conception of evaporation which links these three such notions is quite prevalent.

Particle ideas about evaporation

Osborne and Cosgrove [3] reported that of the 43 Australian 13-17 year-olds interviewed only eight mentioned particles or molecules when describing what happened to water evaporating from a plate. At least one was aware that the particles were 'getting energy from somewhere and flying off'. The possible sources of energy mentioned were: 'what they've got' or 'each other', or 'the air around.'

Evaporation and conservation of mass

When children observe a liquid changing to a gas or vapour, they may construct the idea that, because material substance seems to disappear, weight or mass is lost. Alternatively, those who conserve substance may generate the idea that a gas is lighter than the same amount of liquid.

Condensation

Development of a concept of condensation

Pupils are likely to have difficulty with condensation unless they are able to imagine that an invisible gas is changing to a liquid.

Ideas concerning the condensation of water on a vessel containing ice have been explored among Israeli children by Bar and Travis [6] and among New Zealand children by Osborne and Cosgrove [3]. Both groups of researchers used a multiple choice procedure in which the alternative choices were based on previously obtained interview responses. Israeli children, aged 10-14, most frequently chose the responses 'the coldness changed into water' and 'cold caused hydrogen and oxygen to change into water' (approximately 40% chose each alternative). Less than 20% chose the response 'the water condensed from water vapour in the air'. As a result of comparing these with other responses by the same pupils, the researchers concluded that, although pupils know that vapour can be changed to water, applying that knowledge appeared to cause some difficulty. However, 12-17 year-olds in New Zealand most frequently chose the response 'the coldness caused oxygen and hydrogen in the air to form water' (around 60% between ages twelve and fifteen, then decreasing to 30% by age seventeen). Less than 15% chose 'the coldness comes through the glass and turns to water'. The proportion who expressed the view that the condensation results from water in the air increased from 10% to 55% between ages twelve and seventeen.

The same Israeli pupils were asked about how a hand can become wet when held above boiling water. There was an almost even distribution of the two responses: 'the vapour changes into water' and 'the hand became wet from the vapour'. The frequency of the former response increased, between ages 10-14, from 20% to 55% respectively. Only a small proportion of the sample chose the responses 'the hand sweats' and 'hydrogen and oxygen changed to water' [6].

Dissolving

Development of a conception of dissolving

Several researchers [2 13 15 16 17] have found that, from an early age through to adulthood, individuals hold several conceptions of 'dissolving'. Some of these are revealed by words they use to describe what happens to sugar placed in water. Up to age eight, there is a tendency to focus on the solute only and say 'it just goes', 'disappears', 'melts away', 'dissolves away', 'turns into water', and so on [15]. When the response 'melts' is probed, many children tend to describe it as similar to ice 'going runny' (see 'Melting' above). Often, older pupils start to imagine that as sugar dissolves 'it goes into tiny little bits' and, later on, some of them say that 'sugar molecules fill spaces between water molecules' or else 'mix with water molecules'. Other ideas are described in the context of solution below.

Dissolving and conservation

Some researchers [15 18 19 20 21] have explored the conservation aspect of dissolving. Holding [15] investigated pupils' ideas about conservation (substance, weight/mass and volume) by using interviews about practical tasks, together with surveys of written tasks and children's diagrams. It would appear that about two thirds of eight year-olds think that sugar (the substance dissolved) is preserved in some form other. However, when probed about the weight of the solution, only about half of those who say the sugar is 'there' also say that 'it weighs something'. It seems the reason for this apparent discrepancy is that some children think the weight of the sugar is now 'up in the water', that is in a 'suspended' state, so that, in their view, sugar is not visualised as 'pressing down' on the bottom of a container. The gap between the proportion of pupils who conserve substance and those who conserve weight widens through ages 9-11 but then narrows in later school years. This is because a steadily increasing proportion (with age) conserve substance but a decreasing proportion conserve weight. After age eight, pupils increasingly generate more ideas about the changes that the solute undergoes (for example, 'bits' of solute, 'liquid' solute, 'atoms' of solute, and so on) but, frequently, do not regard weight as a gravitational force acting on the 'bits', 'liquid', or other imagined forms of solute. After age twelve, many pupils progressively begin to develop a gravitational view of weight and a science conception of mass so that some, but by no means all, conserve both weight and mass of solute.

Development of the conception of a solution

Eventually, pupils are expected to regard a solution as a homogeneous mixture of two or more substances. However, several studies have shown that they hold a variety of ideas about solutions [14 15 22 23 24 25]. Holding [15] found that in the early school years, some children do not regard a solution as a single phase but, instead, hold the idea that invisible gross particles of sugar remain that can be filtered out or may settle out from a sugar solution. Alternatively, because they did not see a boundary between solute and solvent, other children regarded a solution as a single substance, rather than as a homogeneous mixture.

Particle conception of solutions

After five groups of pupils, (each of over 100 pupils aged 8, 10, 12, 15 and 17 respectively) had placed some sugar in water and stirred the mixture until the sugar could no longer be seen, Holding [15] asked them to draw their idea of what was 'there' (assuming they could see the situation with 'super' eyes). The majority of children depicted 'bits of sugar' (distributed in several ways) without drawing the water; this representation peaked close to age twelve at about 65%. The next most prevalent picture of a solution was 'continuous' shading throughout; this apparently non-particulate view peaked between ages ten and twelve at just over 20%. Molecules were rarely mentioned in the earlier years, but later an appreciable proportion depicted 'molecular particles' of sugar - at age fifteen (30%) and age seventeen (50%) - but only half of these pupils depicted molecules of water also. It would appear that a continuous view of water is still quite prevalent in older pupils.

The water cycle

Bar [7] has shown that in order to understand the water cycle pupils need to understand not only the concepts of evaporation and condensation but also that water vapour and drops of water have weight and undergo free-fall. Sample populations of pupils from each of the ages between 5 and 15 were interviewed about aspects of the water cycle. The questions used were as follows: 'Where do clouds come from?', 'How do they start?', 'What are clouds made of?', 'Can you tell me how rain falls?', and 'How does it start?'. The responses indicated that particular ideas were prevalent at certain age ranges.

- At ages 5-7, the most common idea is that rain falls when somebody, possibly God, opens water reservoirs. Children may also say that clouds are made of smoke or cotton wool: it follows that clouds and rain are unrelated in their thinking. An alternative view is that clouds, regarded as bags of water, are kept above or in the sky. When clouds collide, they may explode, or open, or get torn, or split, so that rain falls out.

- At ages 6-8, the clouds are thought to go into the sea and collect ('drink') water; then they move on to other places and give rain.

- At ages 6-9, clouds are considered to be made of vapour created when the sea is heated by the sun, or they are made of vapour from kettles; eventually the clouds open to give rain. The sun is thought to go into the water thereby heating it to a high temperature; water vapour so created enters the clouds; later, the clouds open to give rain.

- At ages 7-10, a cloud may be visualised as a sponge having drops of water within it; when it rains the drops fall through little holes in the cloud; this happens when the cloud is shaken by the wind. Alternatively, some hold that rain falls when clouds get cold or become hot.

- At ages 9-10, clouds are said to be made of water evaporated from puddles; rain falls when clouds become cold or heavy.

- At ages 11-15, clouds are created when the vapour becomes cold; the rain falls when the water drops become big and heavy. (None of the sample population explained how the clouds became cold.) Above this age range weight is attributed to vapour and to small drops of water.

Water and living things

Wood-Robinson [26] summarised the findings of several papers concerning children's ideas about plants and found that many children thought plants took in water as a food. Many children thought that the plants' leaves took in water, with the leaf's main function being to capture rain, water or dew. Some also thought that water vapour moves into the leaf during photosynthesis.

In their study of children's ideas of nutrition, Wellman and Johnson [27] found that pre-school children thought that the consumption of anything, even water, would lead to body weight gain, and that differences in height as well as differences in girth are a direct consequence of the amount consumed.

Floating and sinking

Biddulph and Osborne [28] surveyed 7-14 year-old children's meanings for the term 'floating'. When they considered objects which floated on the surface or had a sizeable proportion above the surface, most children described them as floating. When only a minor portion of an object was above the surface, however, some pupils took a different view. Some thought that it was partly floating and partly sinking. Others suggested that it might be starting to sink and would eventually go down.

Some pupils who considered objects which appeared to be on top of the water thought that the objects were not floating because they were held up by the water's skin. Many children thought that objects which were completely submerged but freely suspended, such as fish or submarines, were not floating.

When asked if there was one reason why some things floated the most frequent suggestion was that things floated because they were light. Only three children qualified their answer by suggesting 'light for their size'. The majority of the children in the sample could not offer one single reason why objects float but resorted to giving different reasons for different objects.

The same study asked children aged 8-12 how a longer piece of candle would float compared with a shorter piece. The survey clearly showed that as the children got older an increasing percentage considered the longer candle would float at the same level as the smaller candle and a decreasing percentage considered the longer candle would sink or float lower. However, at age twelve, there was still a sizeable proportion of children - about 40% - who though length would affect flotation.

Although by age 9-10 years the majority of children considered that the depth of water would not affect the level at which an object floated, even at age 11-12 up to 35% of the children surveyed thought that the depth of water would affect the level the object floated at.

Few of the children correctly predicted the amount of water which would be displaced by floating objects and even when the pupils observed that reshaped plasticine displaced more water when floating than when immersed, many were puzzled by it.

Grimellini Tomasini, Gandolfi and Pecori Balandi [29] studied children's ideas about buoyancy and found four 'ways of looking' in their sample of pupils. The children offered ideas in terms of:

(i) the role played by material and weight
(ii) the role played by shape, cavities and holes
(iii) the role played by air
(iv) the role played by water.

They found that many children thought that holes in objects affected their ability to float. Despite teaching the idea was firmly held by some children, though others refined their notions to take account of cavities in objects. The part played by water in floating varied. Some children thought it made objects heavier if it went inside them, others offered ideas involving water pressure pushing either upwards or downwards.

Weathering rocks

Osborne and Cosgrove [3] found that pupils' most common underlying model, related to freezing/melting, was that volume increases as the temperature rises.

Implications of the research findings for teaching

The research findings suggest that most pupils are likely to need particular assistance with the following:

Conserving mass when water changes state

Pupils often anticipate that a change in mass occurs when materials undergo changes of state such as: solid to liquid; liquid to gas; solid to gas; and, solid (or gas) to liquid in the dissolving process. They need to be helped towards the idea that, in a 'closed system', mass is preserved although material may appear to be more dispersed in liquid/gaseous form or may even disappear in solution or gaseous form.

Appreciating that pure water changes state at a definite temperature

Research has shown that, in general, pupils do not recognise that substances have fixed melting points and boiling points. Because they observe that a substance gradually changes its state, they tend to deduce that the temperature gradually changes. They need to observe that the temperature remains constant throughout the change and does not gradually alter (unless the substance is impure). They are then in a position to ask why the temperature remains constant.

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WATER

THE TEACHER'S VIEW

This section outlines those aspects of a deeper understanding which the teacher needs to have in mind whilst working with pupils. Ideas in any aspect of science are constructed at ever increasing levels of sophistication and there are inevitably more sophisticated understandings than can be represented in these brief notes.

Water is the most common of all liquids. About two thirds of the Earth's surface is covered with water. Life on this planet began in water. Water and air together provide the conditions which support life as we know it. The average adult human body consists of 58% water and most plants consist of about 80% water.

Water and water vapour

There is an enormous amount of water spread around the surface of the Earth. Most of it is concentrated in the oceans (97.3%) and as ice in Polar regions and glaciers (2.1%). Underground aquifers account for 0.6% of the Earth's water; lakes and rivers for 0.014%; the atmosphere 0.001% and the biosphere 0.00005%. The amount of water vapour contained in the atmosphere varies. Water evaporates from puddles, and so on, into the atmosphere. This process speeds up if the temperature of the surroundings increases or the flow of air across the liquid increases.*

Warm air can hold more water vapour than cold air. When water vapour condenses in the colder air it forms clouds which often condense to form rain. Near to the ground, condensing water vapour produces mist.

During the day the temperature may warm the air enough to hold a considerable amount of water vapour. If, during the night, the temperature falls then some of the water vapour may condense and be deposited as dew. If the temperature falls enough the condensing water vapour may freeze. This is frost.

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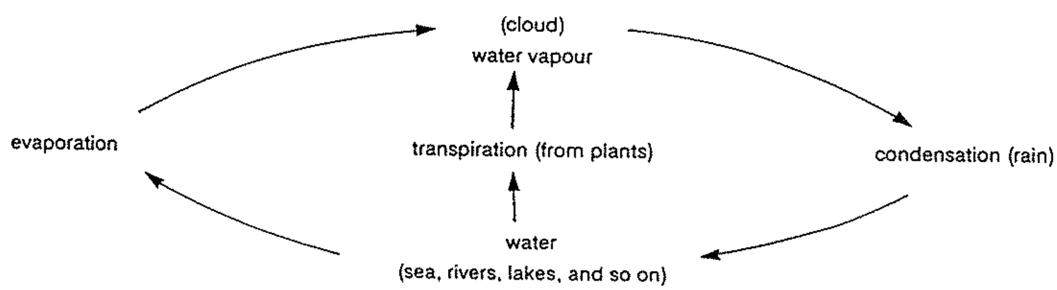
* *See The Teacher's View in 'Solids, Liquids and Gases' and 'Air'*

Water cycle

The water cycle describes the cycling and recycling that happens to water in nature. Water is evaporated by the heat from the Sun. All over the surface of the Earth millions of tons of water evaporate every second. The water vapour rises into the atmosphere where it cools and condenses into tiny droplets which make clouds. When the clouds pass over the warmer land they rise and become cooler in the colder upper atmosphere. As the air cools down it may pass through its saturation point and some of the water vapour turns to liquid water. The droplets of water get bigger and fall out of the sky as rain. The rain either soaks into the ground or runs into rivers and streams. Eventually the water reaches the sea and the cycle is repeated. Water which percolates into the ground may be taken in by the roots of plants, pass up through plants and be evaporated back into the atmosphere, by the process of transpiration.



Solutions

A solution is a uniform homogeneous mixture of two different substances. The dissolved substance is called the solute and the substance, usually a liquid, in which it is dissolved is called a solvent. The most common solvent is water and its solutions are given the name aqueous. Blood plasma, saliva and urine are three of the many solutions produced by the human body. All the processes of living depend upon the ability of water to carry substances around the body as various kinds of solutions, and all the chemical interactions of metabolism take place in solutions.

There is a limit to the amount of solute which will dissolve in a fixed amount of solvent. If further quantities of a soluble substance are added to a solvent a stage is eventually reached when no more will dissolve, at the same temperature, and the solution is said to be saturated. A saturated solution is one which contains the maximum amount of solute which can be dissolved at the temperature concerned in the presence of excess solute.

Solubility is the mass, in grammes, of a solute which dissolves in 100g of water at a particular temperature. In general, the solubility of a solid increases with temperature.

Gases dissolve in liquids although their solubilities are much lower than those of solids. Ammonia, hydrogen chloride and sulphur dioxide are soluble and all combine with water. Gases are more soluble in cold water than hot water. The presence of dissolved oxygen in water enables aquatic organisms to respire. The oxygen diffuses from the water as it passes over the general surface of specialised gills of the organism. Because of the low solubility of oxygen in warm water, thermal pollution can lead to 'suffocation'.

Suspensions and colloids

Many substances do not dissolve in a particular solvent and so they are said to be insoluble in that solvent. A mixture in which fragments are merely spread throughout a liquid, without dissolving in it, is called a 'suspension'.

The fragments may settle to the bottom if the suspension is allowed to stand. However, in some cases, where the particles are very small and when they are electrostatically charged, they may take a very long time to settle or even remain in permanent suspension. This is the case in a suspension of clay particles, for example.

A colloidal solution is one in which the fragments of the substance dispersed in a liquid are intermediate in size between those in a solution and those in a suspension. A beam of light from a strong torch is scattered by a colloidal solution.

Many natural substances are colloidal. Common colloids are glue, butter, potters' clay, ink, smoke and fog. Pastes, such as paints, putty, dough and toothpaste, are concentrated suspensions of colloidal solids in liquid solvents. (Gels or Jellies are colloidal substances even though they appear to be semi-solid.)

When the substance dispersed in water is a liquid (or when water is dispersed in a liquid), the colloidal system obtained is called an emulsion. Milk is a natural emulsion.

Change of state - a particle view

Heating a substance increases the kinetic energy of its particles, whilst cooling a substance decreases their kinetic energy (unless a change of state is involved).

If the kinetic energy of particles in a solid is sufficiently increased, the particles vibrate more vigorously until they no longer remain in a rigid array. They remain quite close together but the forces of attraction no longer hold them in rigid formation and they slide freely over one another. If ice is heated the ice becomes a water or 'melts'.

Similarly, if the kinetic energy of particles in a liquid is sufficiently increased, they escape from the attraction of neighbouring particles and move freely apart in all directions. If water is heated the water becomes a water vapour or 'evaporates'. In a liquid which is not near its boiling point an individual particle may nevertheless gain enough kinetic energy to escape from the surface of the liquid. Thus evaporation takes place continuously at temperatures below the boiling point.

Condensation is the reverse of evaporation. Some particles of water vapour may lose energy in collisions with other particles and, if they are near the surface of liquid water, they will be attracted by the particles of the water and then become part of it. Particles of a gas which lose energy as a result of collisions with a solid surface, at a lower temperature than the water vapour, may form liquid water on the solid surface. (The word 'vapour' rather than 'gas' is often used for the gaseous form of a substance which is liquid at room temperature. Strictly speaking a vapour can be liquefied by pressure alone, unlike a gas which needs to have its temperature reduced before it can condense.)

Boiling point

The boiling point of a pure substance (at a particular pressure) is a definite temperature for that substance. Hence boiling point is a characteristic that may be used to identify a particular substance. It may also be used to recognise a pure sample of it, or the presence of impurity. Pure water boils at 100°C.

Condensation can occur at any temperature at or below the boiling point of the substance. For example, water vapour condenses on cold windows, or on grass as dew.

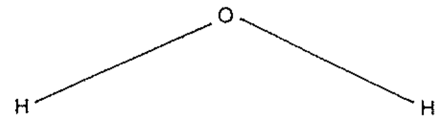
Thermal capacity

Water has a high thermal capacity. Water heats up more slowly than land, but once it has become warm it takes longer to cool down. If the Earth's surface were entirely land the temperature at night would fall quite quickly and night would be much colder than day, as it is on the Moon and as happens in inland deserts. The climate of the continents is affected by the oceans around them. Areas close to the sea have a maritime climate with rather cool summers and warm winters. Areas far from the sea have a 'continental climate' with extremely hot summers and cold winters.

The uniqueness of water

Water's maximum density is at 4°C, so ice is less dense than liquid water.

Water is a triangular molecule:



Even though it is neutral overall, there is a very slight separation of charges between the oxygen atom and the hydrogen atom. The oxygen atom becomes negative (O-) and the hydrogen atoms positive (H+). This gives rise to attractions between the oxygen atom of one molecule with a hydrogen atom of another, forming a hydrogen bond. The hydrogen bond is weaker than chemical bonds but stronger than other intermolecular attractions. These hydrogen bonds are continually being broken.

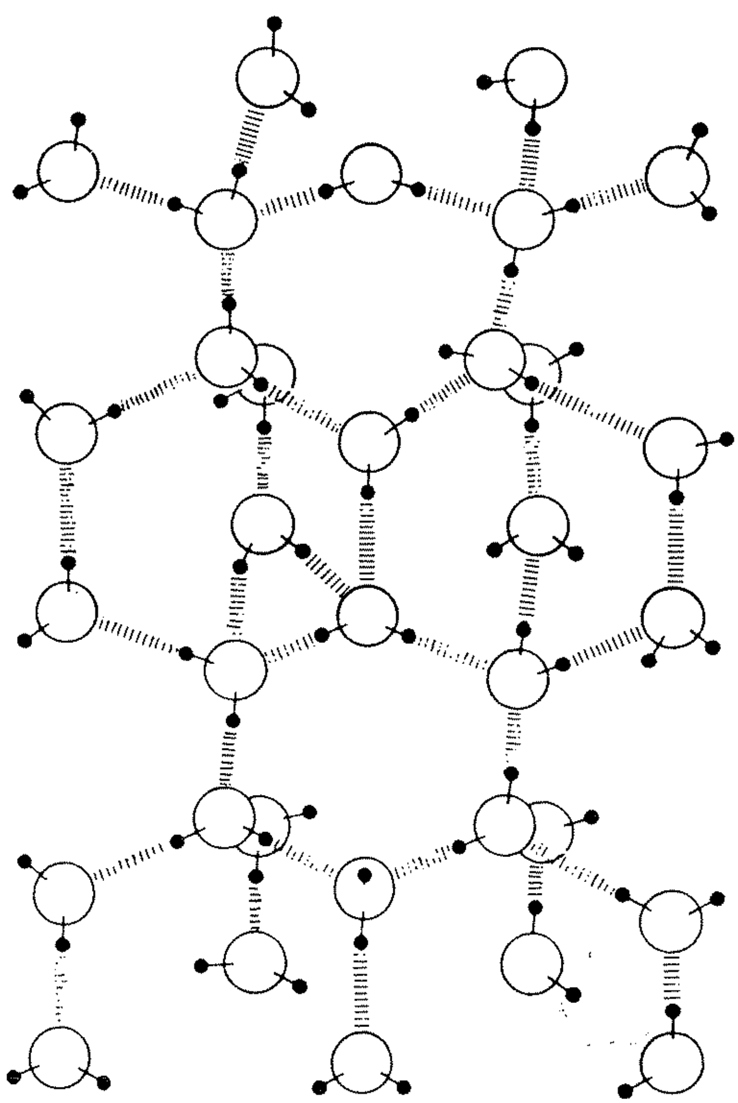


Figure 1: The arrangement of water molecules in ice creates a very open structure which is, in fact, less dense than water

As water cools between 4°C and 0°C, more of these bonds are formed and the water molecules take up a fully hydrogen-bonded, very open structure. As ice melts, some of these bonds break and the structure collapses in on itself, becoming more dense.

The hydrogen bonding in water also means that it has an unexpectedly high boiling point: water remains a liquid at much higher temperatures than would be expected for a liquid of its molecular size.

The separation of charges also helps water to act as a solvent especially for ionic solids.

SOLIDS, LIQUIDS AND GASES

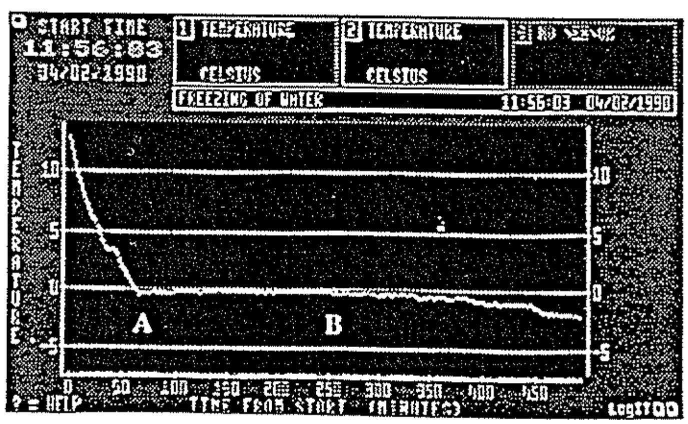
INVESTIGATING FREEZING AND MELTING USING A DATALOGGER

It has often been difficult to show pupils the temperature changes which take place when a substance melts of freezes. Teachers have had to rely on using unfamiliar substances such as stearic acid to demonstrate changes of state. Frequently the results showing no change in temperature when the change of state takes place are not convincing.

A datalogging device such as LogIT is ideal for investigating the process of melting and freezing. The resulting graph shown on the computer screen is a useful and accurate visual display of what happens. Electronic temperature sensors can be connected to the datalogger and placed in different foods or suitable containers filled with water. These can then be placed in the freezing compartment of a fridge or freezer. As the food or liquid cools over a period of several hours the sensors accurately record the temperature changes. This would not be possible with ordinary thermometers.

Once the food or liquid has frozen and reached below zero in the freezer it can then be removed and allowed to slowly thaw. The temperature sensors can again be used to monitor the temperature changes over a prolonged period of time. If sensors had been implanted at different depths into the food item before freezing the results from thawing would provide useful data to investigate questions about how long to leave food to defrost before cooking.

A range of investigations can be easily carried out. For example, it is also possible to look at the effect of adding substances to a pure liquid (for example, adding salt or sugar to water).



The display shows the results obtained when a temperature sensor was placed in a small container of water and placed inside a freezer. The results clearly show the temperature changes which take place on freezing. When the same container of water is allowed to thaw a similar graph (but in reverse) is obtained. The period (from A to B) over which the water was actually freezing is clearly visible and strongly reinforces the fact that during freezing (or melting) the actual temperature of the water/ice remains constant.