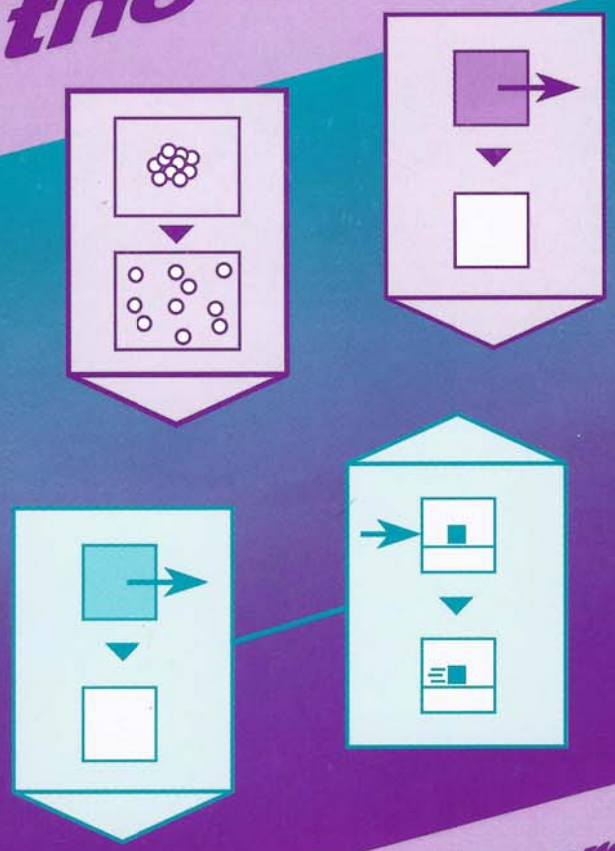
ENERGY AND CHANGE

Activities for the Classroom

Richard Boohan

Jon Ogborn



The key ideas behind the materials:

- Differences drive change
- Pictures help understanding

The Association for Science Education

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Preface

About the approach

Increasing emphasis in science education has been placed on making fundamental and everyday issues accessible to a wider range of pupils. The National Curriculum contains many such examples. Essentially, pupils are expected to make sense of *processes of change*. 'Energy and change' is a set of three booklets outlining a new approach to ways of talking about thermodynamic ideas starting from commonsense ways of explaining. In developing these materials we have had three important criteria in mind, namely, that the approach should be intelligible to pupils, useful to teachers and scientifically consistent.

Our central idea is that change is caused by *differences*, for example, differences in temperature or in concentration. To make these ideas intelligible to pupils we have developed a range of *abstract pictures*, examples of which can be found throughout this booklet. Some of these pictures may appear somewhat daunting at first, but we have found that pupils are quickly able to become familiar with them, and are stimulated into a good level of discussion.

About this booklet

This booklet is for those who want to pick out some activities to use in the classroom, and to find out how the ideas can fit into the existing curriculum.

Other booklets

Introducing a new approach - This booklet is for those who want to find out more about the general approach, the abstract pictures used and the scientific ideas behind the approach.

Background stories for teachers - This booklet is for those who want to read about some scientific topics and to see how they can be looked at in a new light.

Acknowledgements

We should like to thank the many teachers who have helped during the project and offered very valuable advice and insights. Particular thanks should go to Charlotte René for her support during the school trials, to Fani Stylianidou for carrying out a major part of the evaluation, and to Janet Maxwell for the illustrations used in the activities. We are grateful to all of those who have trialled the materials and given helpful feedback, including Karen Burrows, Deidre Canavan, Hester Greenstock, Jo Lang, Louise McCullogh, Mac McKenzie, Angela Mngaza, Cath Mitchinson, Gary Phillips, Inder Sharma, Keith Strachan, Keith Wiseman and to the pupils of South Camden Community School, Christ Church Secondary School, Lancaster Girls' Grammar School, Maria Fidelis Convent School, North London Collegiate School, Parliament Hill School, St Richard of Chichester School and William Ellis School.

Contents

Introduction

While working in classrooms developing this approach to teaching about energy and change, we produced over a hundred activities for pupils. This booklet includes a selection of these activities which can be tried out in the classroom. But it is intended to be more than just a collection of sample activities. The activities have been chosen to illustrate particularly important points in the story about 'energy and change', and the commentary which links the activities together draws out these points and indicates how the activities can be linked into the wider development of the ideas. Thus two questions are addressed in this commentary - 'what is the point now?' and 'what is the pay-off later?'.

Energy plays an important part of this story. But the approach is not relevant just to those topics which have previously been thought of as relating to energy. Since these ideas are about why changes happen they apply across a whole range of topics. So, the activities do not make up a complete teaching pack for a topic, but are designed to be easily 'slotted into' existing schemes of work. The activities all relate to topics which are already covered in the existing curriculum, such as separation of substances, pollution, insulation; they do encourage, however, different ideas to be emphasised in such topics, such as identifying differences in concentration or temperature. They are intended to be used with pupils in Key Stages 3 and 4. However, the nature of the early activities will suggest the kinds of approaches and work which would be useful in the primary school. Similarly, the later activities approach can be extended to deal with more advanced ideas post-16.

Many activities make use of an abstract 'picture language', which emerged during work in classrooms as a successful way of engaging pupils in thinking about and discussing the nature of changes. Typically, these activities involve matching changes to abstract pictures. When more than one match is made to the same picture, pupils can begin to generalise about what the changes have in common. The purpose of this is to start by encouraging pupils to pay attention to important features of phenomena, then later to begin to draw similarities between features of different phenomena, eventually leading to being able to see the few underlying principles involved. Though it takes a little time we would strongly recommend that the lists of changes are *cut up* and matched against pictures by *moving them around* which has a very positive effect on encouraging discussion. While most of the activities emphasise group activity and discussion, they could also be used for individual work.

The abstract pictures used tend to become more abstract as children progress through the activities. Initially, the abstract pictures show more specific aspects of the changes represented; later, the pictures used are more generalised and each relates to a wider range of changes. For example, in early use of pictures representing the particulate nature of matter, attention is paid to showing whether the substances involved in changes are solids, liquids or gases. In later pictures, the distinction may not always be made, so that dissolving and gaseous diffusion are both seen as similar since both involve 'spreading out' of matter.

It is important that the story should be convincing for pupils, but also that it should be scientifically correct. A plausible, but scientifically inaccurate, account will sooner or later run into difficulties. So, the development of the ideas through the classroom activities in this booklet is also presented in a parallel form in the booklet 'Introducing a new approach' emphasising the scientific ideas. It may be helpful to see how the activities fit into a broader story.

Ideas and activities

A good way to make a start on using this approach to 'energy and change' is to pick out some activities and try them out with pupils. Most of the following do not require previous experience with other activities in order for them to be used successfully. These activities have been selected from the booklets of support materials (see page 57). Linking the activities is a commentary which draws out important ideas being developed and indicates how they can fit into a wider scheme.

1 Backwards and forwards

Everything tends to go downhill.

Many changes happen rather easily in one direction but are more difficult to reverse. It is easy to break a window, but hardly possible to assemble the fragments to re-create the original. This is why a sheet of glass is more valuable than a pile of shattered fragments. Similarly, pure water is more useful to us than polluted water, and the price of an antique table is considerably reduced if it catches fire and is reduced to ashes. A film or video played backwards causes amusement because of the impossibility of the changes it shows. It is worthwhile to explore such ideas with children, thinking of changes which would look odd if played backwards; in fact, the problem is thinking of changes which could look sensible both forwards and backwards.

In Year 7, pupils are usually introduced to ideas about mixing and separating, and carry out practical activities such as investigating the factors affecting how quickly something dissolves and how solutions can be separated. The next activity is concerned with changes in which substances become mixed or separated. The essential point is that mixing tends to happen more easily than 'unmixing'. There are many familiar examples from everyday life of this.

Sample activity A - Backwards and forwards in the kitchen

The activity is about dissolving. Changes in which things are mixed (e.g. dissolving) happen more easily than changes in which they are 'unmixed'.

Sheet 1 contains information about the task, and may be used as an OHP. The idea of changes which happen more easily in one direction is introduced by thinking about a video of such changes being shown 'forwards' or 'backwards'.

Sheet 2 is for pupils. Each change on this sheet appears twice - once forwards and once backwards. The reason for this is to encourage pupils to think about each change in both directions and to familiarise them with the 'before' and 'after' conventions used in these materials.

Answers:
'Going forwards' - B, D, E, F, I, J 'Going backwards' - A, C, G, H, K, L

In writing up their reasons, pupils should be encouraged to use the terms 'mixing' and 'unmixing'.

[Reference to support materials: Activity A1]

Sample activity A

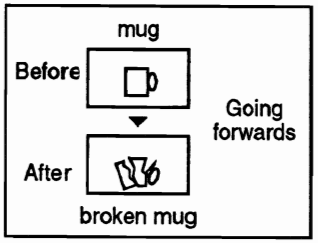
Backwards and forwards in the kitchen

Sheet 1

Some changes happen more easily than others.

Breaking a mug

These pictures show a mug breaking.



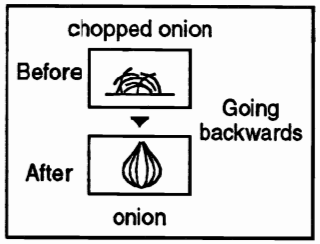
If you saw a video of this happening, you would guess that it was being played *forwards* not *backwards.*

It is easier to break a mug than to get the mug back.

This change happens more easily forwards than backwards.

'Unchopping' an onion

These pictures show an onion being 'unchopped' to make a whole onion.



If you saw a video of this happening, you would guess that it was being played *backwards* not *forwards.*

It is easier to chop up an onion than to get the onion back.

This change happens more easily backwards than forwards.

Backwards and forwards in the kitchen

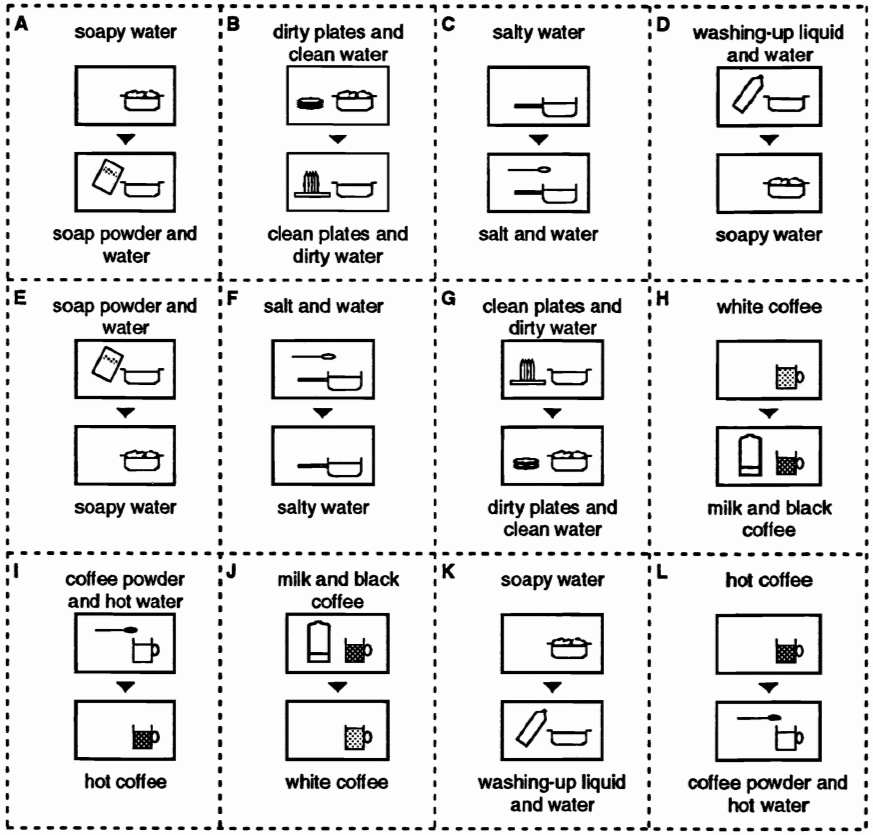
Sheet 2

1 Cut out the pictures below.

2 Sort them into two groups 'Going forwards' and 'Going backwards'.

3 Stick the pictures in the group 'Going forwards' in your books.

4 Why do you think these changes go forwards more easily than backwards?



Thinking about the direction of change sets the scene for all of the subsequent activities. As the story evolves, the relationship between what happens to matter and energy and the direction of spontaneous change is developed. In activities intended for Y7, pupils, they will be encouraged to pay attention to what is happening to the substances involved in changes such as mixing and 'unmixing', evaporation and condensation - are they 'spreading out' or 'bunching together'? In later years, they will look at a wider range of changes - chemical reactions (in which substances change into other substances) and changes involving energy.

2 Spreading and mixing of matter

Matter tends to go from where there's a lot to where there's not.

Matter tends to spread out, and differences in concentration and pressure tend to disappear. For example, salt spreads out when it dissolves in water, pollution spreads out in the air, and air spreads out when it escapes from a balloon. In such changes, substances may also be mixing together. All of these are changes which 'just happen' by themselves. In contrast, it is rather more difficult to 'unmix' or separate substances - matter tends not to 'bunch together'. (This is not to say that matter *never* 'bunches together'. But it can only happen if something else is changing - for example, a hot solution crystallises as it *cools*.).

Almost all of the activities in these materials use abstract pictures to represent changes. The following activity uses pictures to represent changes involving mixing. Since this is one of the first activities, intended for pupils in Y7, matter is here represented as being 'continuous' - later activities use 'particulate' representations. If desired, the early activities could be adapted to represent particles.

Sample activity B - Pictures of mixing

The activity is about matching changes to abstract pictures involving mixing. It also encourages pupils to think about mixing as a process in which substances 'spread out'.

Sheet 1 introduces the conventions of the abstract pictures with matched examples, and may be used as an OHP. The conventions are:

a liquid | a solid | two different substances | two different substances mixed together

When discussing these pictures with the class, pupils should be encouraged to use the list of words shown on sheet 1. It is also useful to identify not just the substance that is spreading out, but what it is spreading out into. For example:

- Coffee powder is a *solid*, hot water is a *liquid*. The coffee is *soluble* in water. They *mix* to make a *liquid*. The coffee *dissolves* in the water. The coffee *spreads out* into the water.
- Milk and black coffee are both *liquids*. When they are *mixed*, the milk *spreads out* into the coffee.

Sample activity B

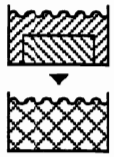
Pictures of mixing

Sheet 1

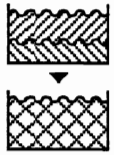
Here are some pictures showing different kinds of mixing.

Some useful words for talking about these changes are:

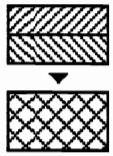
mixing, solvent, spreading out, solute, solid, solution, liquid, soluble, dissolving, insoluble



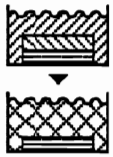
adding coffee powder to hot water to make coffee



adding milk to black coffee to make white coffee



stirring salt and pepper together



using soapy water to clean dirty plates

Pictures of mixing

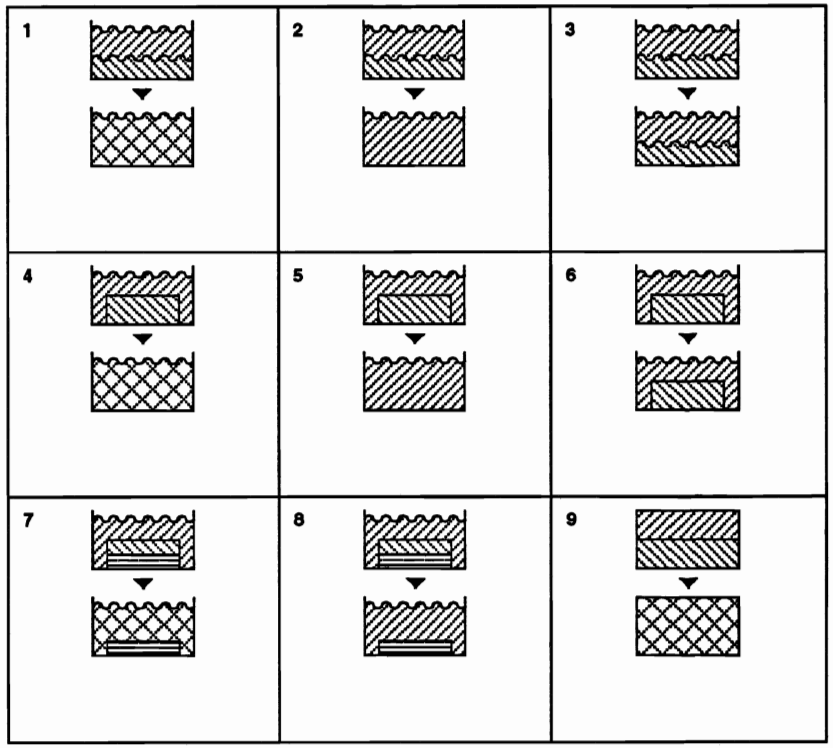
Sheet 2

1 Cut out the boxes at the bottom showing different changes.

2 Match them to pictures below.

3 Write about each change. Here are some words which might help you:

mixing, solvent, spreading out, solute, solid, solution, liquid, soluble, dissolving, insoluble



A dissolving sugar in a cup of tea	E adding water to orange squash
B adding sand to water	F adding oil to water
C washing a dirty T-shirt	G stirring flour and sugar together
D adding instant coffee to hot water	H making a cup of tea using a tea bag

- Salt and pepper are both *solids*. When they are stirred together, they *mix*. They *spread out* into each other.
- The dirt is *soluble* in soapy water, but the plates are *insoluble*. The dirt *spreads out* into the soapy water.

Sheet 2 is for pupils. They need to match the changes to the pictures. Note that there are no matches for pictures 2, 5 and 8 - these all show impossible changes in which something literally 'disappears' with the solvent remaining unchanged. Some pupils may have difficulties with these. For weaker pupils, the activity could be made less demanding by omitting pictures 6, 7 and 8, and examples C, G and H.

Answers:

1 E	2	3 F
4 A D	5	6 B
7 C H	8	9 G

In writing about the changes, pupils should be encouraged to pay attention to whether the substances are 'spreading out', and what they are 'spreading out' into.

[Reference to support materials: Activity A2]

The previous activity is concerned with the nature of the changes to substances when they are mixed. In subsequent work, this can be extended into thinking about changes involving 'mixing and 'unmixing' and whether each change can 'just happen by itself' (is it like 'falling downhill' or 'being pushed uphill'). An amusing way to illustrate these ideas is to set up an 'unfair competition' in which the teacher has to mix two beakers with balls of different colours and a pupil has to 'unmix' a beaker with the balls mixed together. (See support materials Theme A 'Mixing and unmixing'.)

Changes in which matter spreads out are not limited to solids and liquids, and many such changes often involve gases. Changes involving gases are more difficult for pupils to think about than those with solids and liquids, so activities with Y7 pupils need to focus on the nature of gases and changes involving gases, such as the idea that gases can be manipulated (e.g. squashed and poured), and on the concept of pressure. This can then lead into the idea that gases too tend to spread out and mix (for example, smells and pollution) and that concentration and pressure differences tend to disappear. Evaporation is another process in which matter tends to 'spread out' (and condensation is a process in which matter becomes more 'bunched together'). (See support materials Theme C 'Gases, liquids, solids'.)

Sample activity C - Evaporation and condensation

In this activity, pupils explore in more detail the nature of evaporation and condensation.

Sheet 1 is an activity which discusses in more detail the nature of evaporation, and its reverse process, condensation. Note that condensation, being a rather more difficult idea than evaporation, is not pursued further at this stage. This OHP is intended to encourage class discussion about the nature of evaporation and condensation (e.g. where is it coming from or going to, is it spreading out, etc.).

Sample activity C

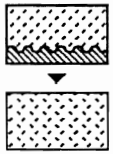
Evaporation and condensation

Sheet 1

Evaporation If you spill some water on the floor, it will eventually dry up. It **evaporates.**

What do you think is happening to the water?

Is it disappearing?
Is it pushing the air away?
Is it mixing with the air?
Is it spreading out?
Is it getting squashed together?
Is it bunching together?

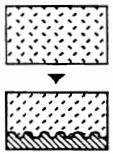


What do you think this picture is showing?

Condensation If you take a cold can of drink from a fridge, water forms on the outside. The water vapour in the air **condenses.**

What do you think is happening to the water?

Is it appearing from nowhere?
Is it coming from the can?
Is it separating from the air?
Is it spreading out?
Is it getting squashed together?
Is it bunching together?

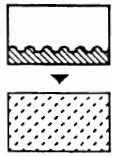


What do you think this picture is showing?

Evaporation

Sheet 2

Something **evaporates** when it changes from a liquid into a **vapour** (or gas).



1 Cut out the boxes at the bottom showing different changes.

2 Sort them into two groups:

Group 1: something evaporates Group 2: nothing evaporates

3 Choose an example from the first group. Explain why you put it in that group.

4 Choose an example from the second group. Explain why you put it in that group.

5 Do the same thing for some more examples.

A
dissolving sugar in water

B
a puddle drying in the Sun

C
a bottle of Tipp-ex left without the lid on it

D
using a sponge to soak up some spilt water

E
a candle burning

F
some sandwiches left on a plate and drying up

G
leaving some salt solution until crystals appear

H
breathing out

I
boiling some water in a kettle

J
a light bulb shining

K
a car rusting

L
clothes on a washing line

Sheet 2 is the pupil activity. They are asked to identify changes which involve evaporation, and then to give reasons why they chose to include and exclude some of the examples. They should be encouraged to write about these changes using the ideas from the OHP (it could be left on so that they can see the questions they discussed).

Pupils should first make their own grouping of the situations and write about as many as they can. Then there can be a class discussion of the correct answers.

Answers:
Something evaporates: B, C, F, G, I, L
Nothing evaporates: A, D, E, H, J, K

[Reference to support materials: Activity C7]

Ideas about 'spreading' and 'bunching' are of great importance in biology. In order to grow, organisms need to make substances in the environment 'bunch together' while waste substances 'spread out', and to stay alive the organism needs to be maintained in a 'steady state' with concentration differences between the organism and the environment. These ideas can be started early with young children, thinking about how water is obtained by plants and animals and how it is lost, leading to the concept of homeostasis with older pupils. (See support materials Theme D 'Life'.)

The emphasis in this section has been on the *direction* of changes in which matter becomes more 'spread out' or more 'bunched together'. However, it is also worth paying attention to the *rate* of change - the rate at which something dissolves or evaporates will be increased by any factor which makes the substance spread out more quickly.

3 Energy flows and temperature differences

Energy tends to go from where it's hot to where it's not.

We have already met the idea that concentration differences and pressure differences tend to disappear; this can help us make sense of changes in which matter flows from one place to another (for example, dissolving or evaporation). Similarly, an understanding of temperature differences is fundamental to thinking about the flow of energy. It is important to give children plenty of opportunities to explore things that are hot and things that are cold in order for them to get a feeling about the relative sizes of temperatures. (See support materials Theme B 'Hot and cold'.) These experiences provide a basis from which to develop the idea that temperature differences tend to level out or become equal. As in the previous section about matter spreading out, much useful work about temperature differences can be started in Year 7.

Sample activity D - Measuring temperature

This is a practical activity in which pupils gain experiences in looking at situations in which temperatures are becoming equal.

The first of these tasks is a pupil activity. The remaining tasks (2-6) are intended to be set up as a circus. Note that different thermometers may give readings one or two degrees apart when they are at the same temperature. So, for each task it is important to select thermometers that agree with each other if pupils are to be convinced that the temperatures really are the same!

Apparatus

1 Each pupil will need: beaker, test-tube, thermometer, access to hot water (one thermometer is better than two to ensure that when the temperatures are equal, pupils get the same reading!).
2 Two beakers containing different amounts of water at room temperature, two thermometers and clamps.
3 Wood block with hole, metal block with hole, three thermometers and clamps (one thermometer to measure temperature of room).
4 Beaker with hot water, metal block with hole, two thermometers and clamps.
5 Vacuum flask and hot water, beaker and hot water, two thermometers and clamps.
6 Two beakers with water at room temperature, insulation, two thermometers and clamps.

Answers

1 B 2 A 3 A 4 B 5 B 6 B

The lack of a temperature difference in the insulated and insulated beakers (6) may be the most surprising result. This is taken up in later activities about insulation.

[Reference to support materials: Activity B2]

As well as paying attention to the idea that temperature differences tend to disappear, pupils should also explore what temperature differences can do and how they can arise. Temperature differences do not spontaneously appear by themselves, though they can be created as a result of other changes, such as objects rubbing together, burning a fuel, using electricity, or from another temperature difference. Temperature differences are useful to us because they can be used to *do* things, such as cooking a meal or making an engine run. It is interesting to consider the history of inventions and the ways in which different changes have been harnessed for useful purposes. For example, rubbing sticks together to create a fire (using moving objects to make a temperature difference) came long before the steam engine (using a temperature difference to make objects move). (See support materials Theme B 'Hot and cold'.)

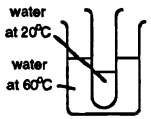
In all of this work on temperature differences, we have not yet introduced the concept of *energy*. A useful way of thinking about temperature is that it is a measure of the 'concentration' of energy. Thus, a hot object has energy more concentrated in it than when it is cold. Just as differences in the concentration of matter tend to disappear, so too do differences in concentration of energy because energy flows from hot to cold (high to low concentration).

Sample activity D

Measuring temperature

Sheet 1

1 Three pupils are talking about what will happen here:



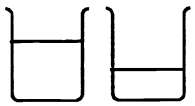
A "If you leave it, the water in the test tube will get a bit warmer. But it won't get as warm as the water in the beaker."

B "I think that they will both end up at the same temperature."

C "No, surely the water in the test tube will be hotter than the water in the beaker."

Which one do you think is right? Do an experiment to check.
Write about what you did in your book. Were you right? Explain why this happens.

2 Two beakers of water are left for an hour:

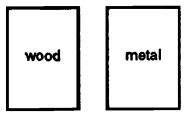


A "The water will be the same temperature in each beaker."

B "No, I think the first beaker will have a higher temperature - because there's more water."

Which one do you think is right? Check on the display '2'.
Write about this in your book. Were you right? Explain why this happens.

3 A metal block and a wooden block are left for an hour:

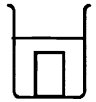


A "Both blocks will be the same temperature as the air in the room"

B "No, I think the metal will have a lower temperature."

Which one do you think is right? Check on the display '3'.
Write about this in your book. Were you right? Explain why this happens.

4 A lump of metal is put in some hot water:

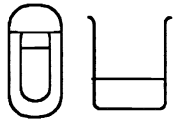


A "The metal will end up hotter than the water."

B "No, I think they will both have the same temperature."

Which one do you think is right? Check on the display '4'.
Write about this in your book. Were you right? Explain why this happens.

5 Some hot water is put in a vacuum flask and some in a beaker:

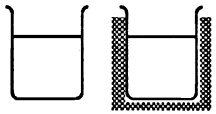


A "I think that they will both cool down the same."

B "I think that the water in the beaker will cool quicker."

Which one do you think is right? Check on the display '5'.
Write about this in your book. Were you right? Explain why this happens.

6 Here are two beakers with water. One beaker is surrounded with loft insulation.



A "I think that the one with loft insulation will get warmer."

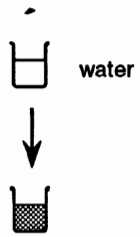
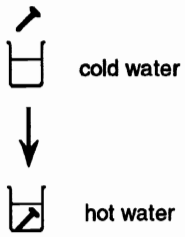
B "I think that they will both be at the same temperature - the temperature of the room"

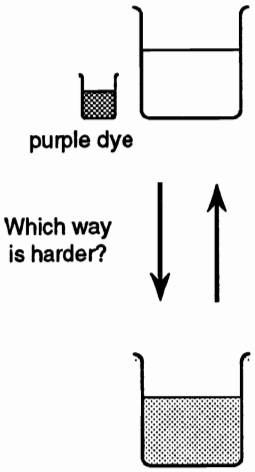
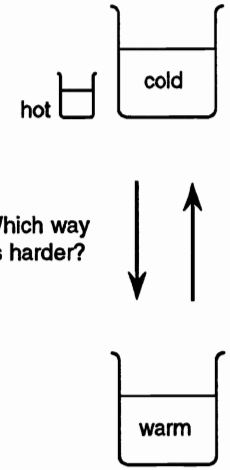
Which one do you think is right? Check on the display '6'.
Write about this in your book. Were you right? Explain why this happens.

Sample activity E

Concentrated energy

Sheet 1

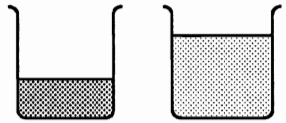
A crystal of purple dye	A red-hot nail
	
Is the purple dye 'spreading out' or 'bunching together'?	Is the energy 'spreading out' or 'bunching together'?

Substances spreading out	Energy spreading out
What is happenning to the concentration of the purple dye?	What is happenning to the concentration of the energy?
	
Which way is harder?	Which way is harder?

Concentrated energy

Sheet 2

1 Start with a beaker half-full with the purple dye. Fill the beaker up with water and stir. Can you still see the purple colour?



2 Pour half of the liquid away. Repeat what you have just done.

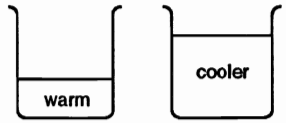
3 How many times can you dilute the dye before you can no longer see it?

Questions

a) If you put a small amount of dye in a large lake, eventually you could not see it. Has it disappeared or is it still there?

b) Would it be easy or difficult to get the purple dye back? Explain.

1 Start with a beaker half-full with hot water. Measure the temperature. Fill the beaker up with cold water and stir. Measure the temperature again. What has happened?



2 Pour half of the liquid away. Repeat what you have just done.

3 How many times can you 'dilute' the energy before you no longer notice the temperature changing?

Questions

a) If you put a small amount of hot water in a large lake, you would not notice that the lake had got any warmer. Has the energy disappeared or is it still there?

b) Would it be easy or difficult to get the energy back? Explain.

Sample activity E - Concentrated energy

The aim of this activity is to introduce the notion that we can think of a 'concentration' of energy in the same way as a concentration of a substance.

The first sheet is an OHP which can be used alongside a simple demonstration to introduce the idea of a 'concentration' of energy. In the crystal, the purple dye is highly concentrated; in the red-hot nail, the energy is highly concentrated. When they are put into a small beaker of water, the purple dye and the energy spread out and become less concentrated. Similarly if the small beaker of water is poured into a bigger beaker, the concentration decreases again. This 'spreading out' process happens more easily that the reverse - it is harder to get the purple dye or the energy to become more concentrated.

Apparatus:
2 small beakers, 2 large beakers, very small crystal of potassium permanganate, nail, tongs, Bunsen, thermometer.

The second sheet is a pupil activity based on the ideas introduced in the OHP. It makes the point that while matter and energy spread out they do not disappear, even though they may have spread out so much that they are undetectable.

Apparatus for each group:
Beaker, stirring rod, thermometer, access to dilute potassium permanganate solution, access to hot water.

[Reference to support materials: Activity E1]

There are many kinds of situations in which energy is transferred. In the following two activities in this section, we are concerned only with energy transfers due to *temperature differences.* Other kinds of energy transfer are taken up in later sections. However, looking at energy flow from hot to cold is of central importance, since it is a feature of so many changes, and can be started with pupils in Year 8. In addition, it is important in learning about energy, because in these activities we are attempting to provide pupils with ways of talking about energy which they will build on in further work. Energy flow from hot to cold is the simplest way of introducing the idea that energy *spreads out* from places where it is *concentrated.* Considering what happens to objects colder than the surroundings is also very important. Thus, an ice cube cools a drink but the energy flows from the drink to the ice cube - energy is not the cause that makes things happen, and what we might think of as a 'causal link' is not always in the same direction as energy flow.

Sample activity F - Energy on the move

This introduces the abstract pictures showing temperatures and energy flows which are used throughout this theme. The activity is a class discussion based on OHPs.

There are a set of OHPs which introduce the conventions used in the abstract pictures. Each section on the OHPs has a question for the class to discuss and answer. In each section, there is a reminder of the important points to bring out in the discussion. Discussion is helped by having equipment to demonstrate the situations (needed are a beaker of hot water, an ice cube and a metal block).

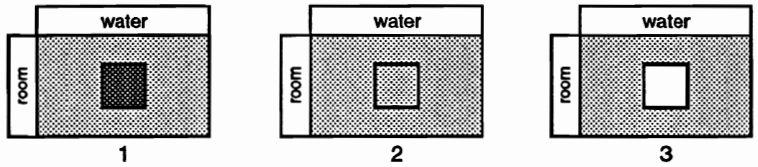
Sample activity F

Energy on the move

Sheet 1

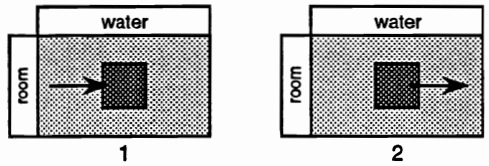
A beaker of hot water cools down

A Which shows a beaker of hot water best?



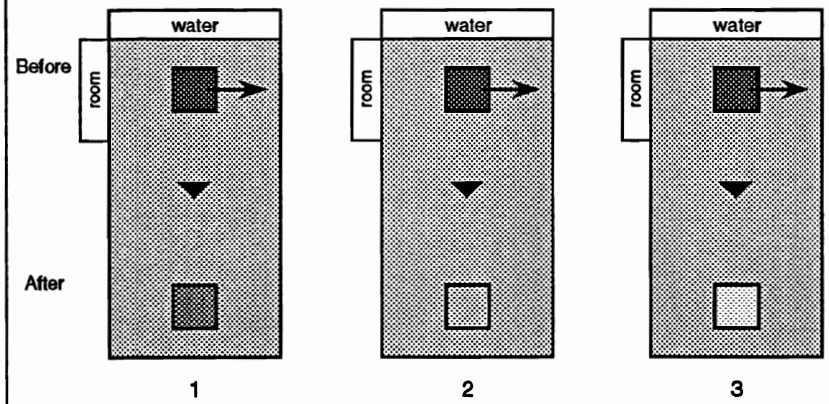
hot = high temperature = high concentration of energy = dark shading

B Which shows the energy transfer best?



energy goes from hotter to colder

C Which shows what happens best?



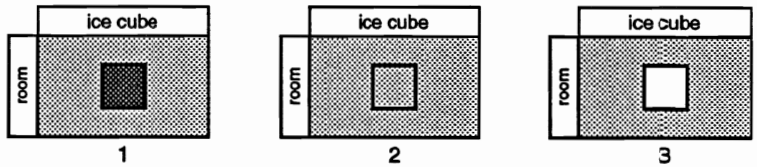
energy spreads out - concentration of energy becomes even - temperatures become equal

Energy on the move

Sheet 2

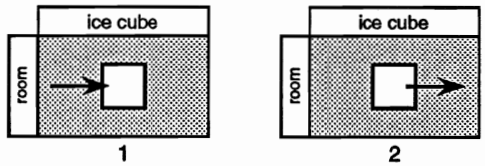
An ice cube melts in the room

A Which shows an ice cube best?



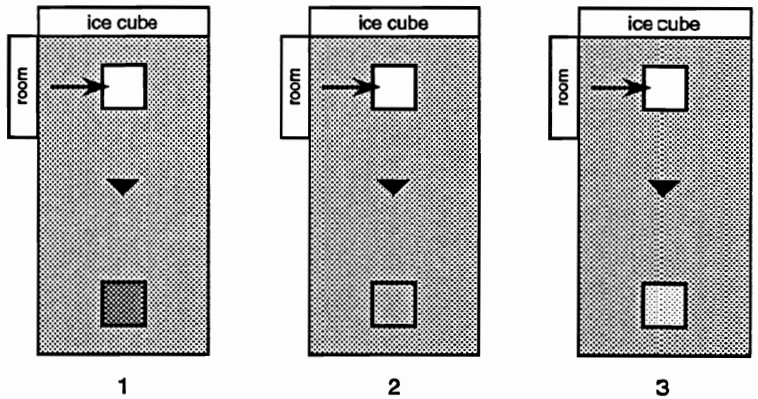
cold = low temperature = low concentration of energy = light shading

B Which shows the energy transfer best?



energy goes from hotter to colder

C Which shows what happens best?



energy spreads out - concentration of energy becomes even - temperatures become equal

Each picture shows an object and a background - the background represents the temperature of the room. The shading in these pictures shows how concentrated the energy is.

Sheet 1 - A beaker of hot water cools down

A Which shows a beaker of hot water best? Picture 1 shows something which contains concentrated energy (i.e. something hot). The energy in the background is less concentrated (i.e. the room is cooler).
B Which shows the energy transfer best? Picture 2 shows energy flowing from where it concentrated to where it is less concentrated (i.e. from hot to cold).
C Which shows what happens best? Picture 2 shows that the water has cooled down so that it is now at the same temperature as the background.

Sheet 2 - An ice cube melts in the room

A Which shows an ice cube best? Picture 3 shows something which contains less concentrated energy than the background (i.e. something cold).
B Which shows the energy transfer best? Picture 1 shows energy flowing from the background to the ice cube. (Some children may think that it is 'cold' that flows from the ice cube to the background.)
C Which shows what happens best? Picture 2 shows that after melting the water will end up at the same temperature as the background.

[Reference to support materials: Activity E2]

These OHPs serve only as an introduction to these ideas; pupils need to be given a lot of experience in using these pictures and matching them against a range of different situations. One example, about insulation, follows. Some pupils have a tendency to see insulation as *active*, in the sense that it *makes things warmer*. This activity emphasises the way that insulation acts as a barrier to energy flow between two temperature differences. This activity can be preceded by a practical activity in which pupils investigate the way in which insulation helps to keep hot things hot (a common activity in science courses) and *helps to keep cold things cold* (less commonly done). (See support materials Theme E 'Energy from hot to cold'.)

Sample activity G - Examples of insulation

The activity builds on the previous practical activity, by relating the ideas of energy flow and insulation to more familiar everyday examples.

In this activity pupils match situations involving insulation with abstract pictures of energy flow. It could be done as a poster activity, with each group writing reasons for their matches on the poster. They should cut up the sheets showing the abstract pictures and lay them out on the poster in the arrangement shown below, leaving spaces to match the situations against them.

Answers

1 A E H	2	3
4	5 D F	6
7	8	9 B C G

Having made their choices and written their reasons, the posters can form the basis for a class discussion.

Sample activity G

Examples of insulation

Sheet 1

1 On sheets 1 and 2 are 8 pairs of situations. In each pair the first is without insulation, and the second is with insulation.

2 On sheet 3 are some pictures pictures representing these changes. Cut them out and lay them out on a table.

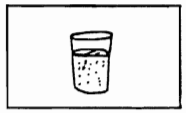
3 Cut out each of these situations and match it against the picture you think is best.

A Hot chocolate left in a room

hot chocolate in a cup

hot chocolate in a vacuum flask

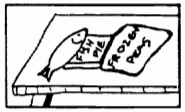
B Cold lemonade in a warm room



cold lemonade in a glass

cold lemonade in a vacuum flask

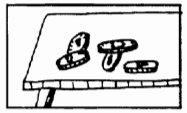
C Frozen food



frozen food left on a table

frozen food wrapped in newspaper

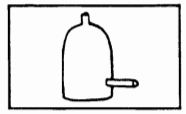
D Coins at room temperature



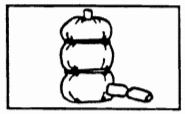
coins at room temperature left on a table

coins at room temperature wrapped in a woollen bag

E Hot water tank



hot water tank without insulation



hot water tank with insulation

F Snowman on a freezing day

snowman on a freezing day

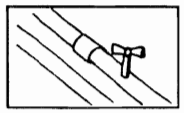
snowman wrapped in a coat on a freezing day

G Sun shining on a house

sun shining on a poorly insulated house

sun shining on a well insulated house

H Water pipes on a cold day in winter

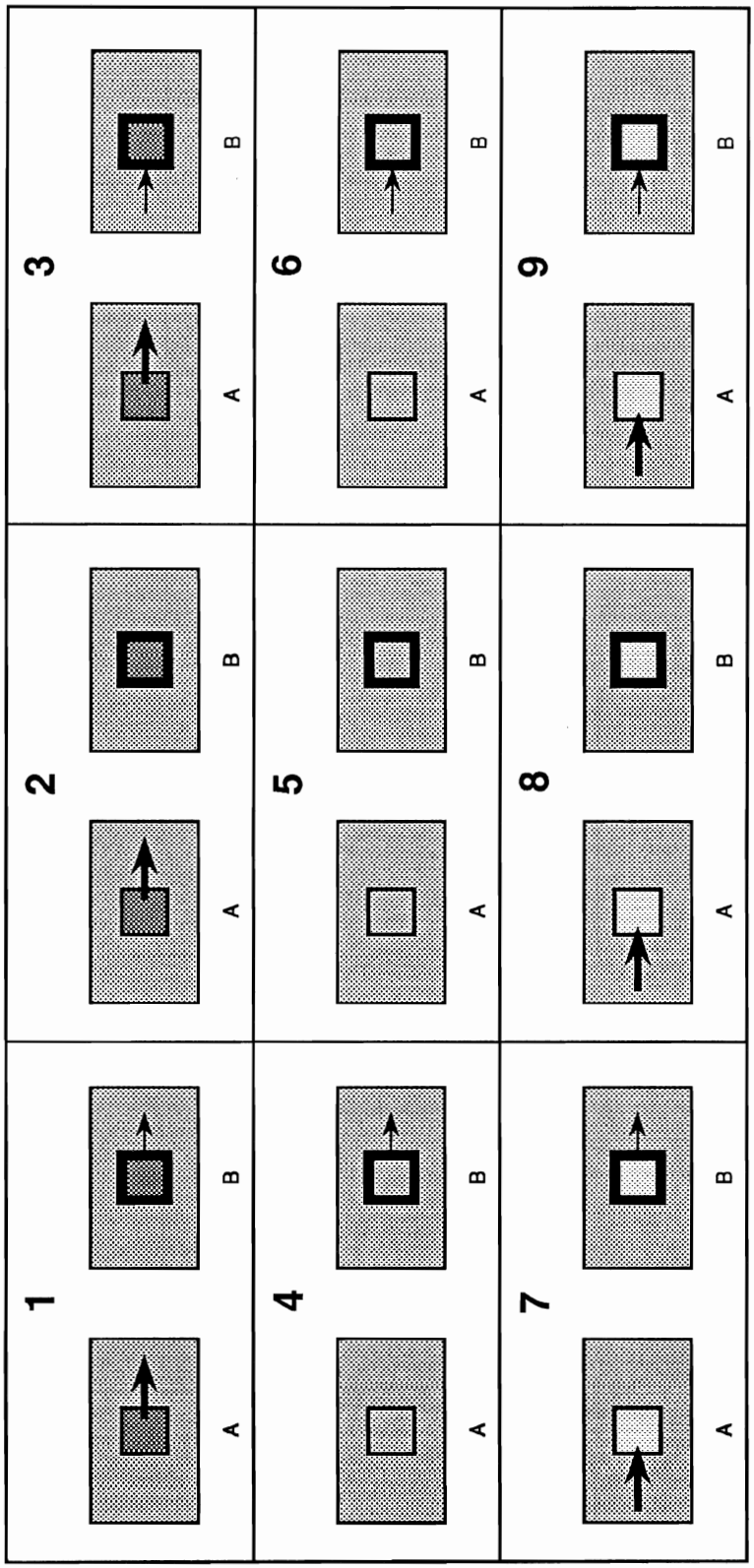


water pipes on a cold day

insulated water pipes on a cold day

Examples of insulation (continued)

Sheet 3



Note that the situations have been selected to cover a range of cases, in which the insulated object is cooler, warmer or at the same temperature as the background, and in which the background may be cooler, warmer or the same as room temperature. Also note that of the abstract pictures only 1, 5 and 9 show possible changes (2 and 8 are possible if you allow the existence of a perfect insulator).

[Reference to support materials: Activity E6]

In later sections we will be extending this way of talking about energy to other kinds of changes, for example, mechanical systems and chemical reactions. The approach will not be talking about different 'forms of energy' (heat energy, kinetic energy, chemical energy, etc.), which is the way in which many school textbooks treat energy. Instead we shall be concerned with questions about where the energy is located at the beginning and end of changes, how does it flow, what makes it flow, is it concentrated or spread out? This approach, unlike the 'forms of energy' approach, is consistent with the way in which the National Curriculum talks about energy transfers.

4 Differences can create differences

Some changes will just happen and others won't.
Those that do just happen can drive those that don't.

If you put some sugar in a cup of tea it will dissolve. You can, if you like, make it happen a bit faster by stirring it, but you do not need to - it is a change which 'just happens by itself'. While the reverse change does not 'just happen by itself', this does not mean that it cannot happen at all. We can accept that it might be possible to find a way to get the sugar back from the tea, even if we are not sure how this could be done. Activities for Y7 pupils have looked at the nature of changes in which differences (in concentration, pressure or temperature) appear or disappear. Pupils may also have been introduced to the idea that a change in which a difference *disappears* tends to 'just happen by itself'. Though they have met changes in which differences *appear*, we have not yet suggested how a change which does not 'just happen by itself' can be made to happen. We need now to look at how changes are coupled together, so that a change which 'just happens' drives a change which does not 'just happen'. (See also support materials Theme H 'Fuels and food'.)

Differences tend to disappear. However, differences can create other differences. For example, when water is left to evaporate, the remaining water may become cooler than the surrounding air - the spreading out of the water vapour (a concentration difference tending to disappear) drives the creation of a temperature difference. Similarly, copper sulphate crystals form when a hot saturated solution cools - the spreading out of the energy as the solution cools (a concentration difference tending to disappear) drives the creation of a concentration difference (matter becomes more 'bunched together'). In both of these cases, a change which 'just happens' drives a change which does not 'just happen'.

But these changes are rather subtle, involving two different kinds of changes taking place in the same system. The idea of using one change to drive another can be introduced more clearly to pupils using examples where one system acts on another - for example, burning petrol (first system) can drive the movement of a car (second system). So, this section does not include any activities about the idea of using one change to drive another - these are postponed until the following section in which we shall

look at mechanical systems. Pupils in Year 9, or even in Year 8, are able to grasp these ideas about coupling and using changes which 'just happen' to drive those that do not. In a later section, the idea will be extended to include changes involving chemical reactions.

It is common for children (and adults) to think of human action as being the means by which 'natural' changes are reversed. Thus, a ball rolls downhill; to get it back up the hill someone could kick it or throw it. But humans, like everything else, are bound by the laws of thermodynamics - if we kick or throw a ball up a hill, we too are using a change that 'just happens' (the oxidation of glucose in our bodies) to drive a change that does not 'just happen' (a ball going uphill).

Describing a change as 'just happening by itself' is a way of talking that has been rather carefully chosen to evoke the right kind of idea - that of *spontaneous* change. Though the language sounds informal it is also intended to be rather precise. Thus, the phrases 'just happens by itself' or 'happens naturally' seem to convey much the same idea and it is very easy to slide between the two. If fact, 'happens naturally' suggests something rather broader. Thus, it seems a good description not only for spontaneous changes such as dissolving, but also for many non-spontaneous changes such as a plant growing. In contrast, it sounds more reasonable to say that a plant growing is a change which does not 'just happen by itself', and encourages us to think further about what it is that might drive this change.

5 Moving things and springy things

Energy can be stored in hot things, moving things and pulled-out springs.

Energy is stored in a hot cup of tea; as the tea cools down, the energy escapes and warms the surroundings a little. Energy is also stored in a ball rolling along the ground; in a frictionless world no energy would escape, but in the real world the ball slows down as the energy escapes and warms the surroundings a little. Temperature differences disappearing and objects slowing down are changes which 'just happen by themselves'. The reverse processes do not 'just happen by themselves', but can be driven by processes which do 'just happen'.

Sample activity H - Things that 'just happen' and things that don't

The activity introduces the idea of spontaneous and non-spontaneous changes. Spontaneous changes are those that 'just happen' by themselves and are able to drive other changes which do not 'just happen' by themselves.

Pupils seem to take quite easily to the phrases 'changes that just happen by themselves' and 'changes that do not just happen by themselves', so we have used these terms throughout the activities in this booklet. The essential idea which is built on later is that changes which 'just happen' can drive those which do not. We are often concerned with energy in these changes, but the focus is on spontaneity rather than on the incorrect explanation that 'energy drives changes'.

Sheet 1 is intended to be used as an OHP to introduce the ideas. Sheet 2 is a matching activity for pupils - the changes are about things warming and cooling, and starting to move and stopping. This would be a useful opportunity to give pupils practical experiences of moving things getting warmer,

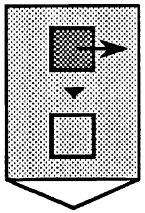
Sample activity H

Things that 'just happen' and things that don't

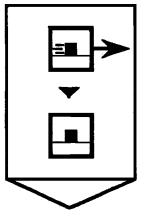
Sheet 1

Some changes 'just happen' by themselves:

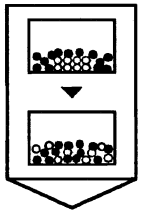
a beaker of hot water cools down



a moving ball slows down and stops



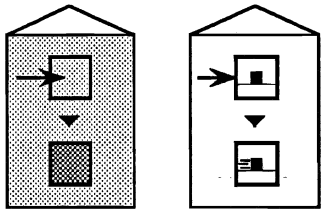
salt dissolves in water



These pictures have been drawn with a box around them pointing down - this is to show that the changes 'just happen'.

Some changes do not 'just happen':

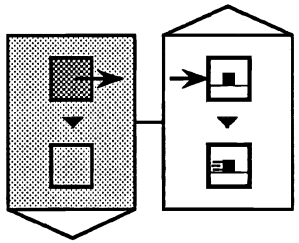
For example, things do not suddenly get hot or start moving for no reason:



Each of these pictures has a box around it pointing up - this is to show that the change does not 'just happen'.

However, we can use a change that 'just happens' to drive a change that does not.

For example, a steam engine - the engine moves because the hot steam cools.

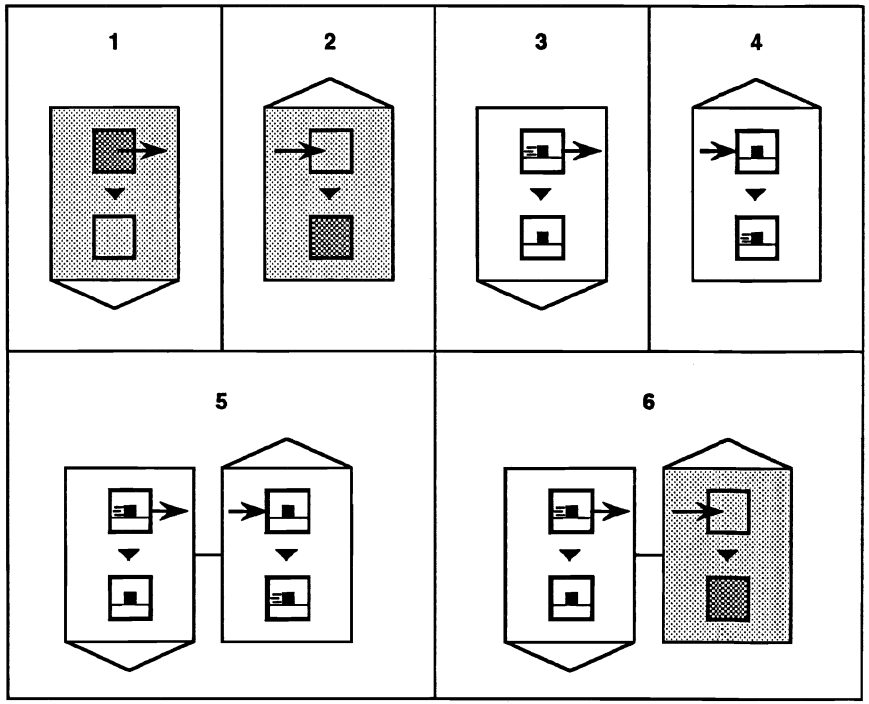


Things that 'just happen' and things that don't

Sheet 2

1 Below are some different changes. Match each one to the picture you think best represents the change. (There is one change for each of the six pictures.)

A If you stop pedalling a bicycle it will slow down and stop.	**B** A ball does not start moving just by itself.
C A hot cup of tea cools down.	**D** A tennis racquet hits a ball - the racquet slows down and the ball speeds up.
E When you use the brakes on a car, they get hot as the car slows down.	**F** A saucepan of water does not suddenly become hot for no reason.



and to discuss what is happening to the energy when moving things slow down. The energy is 'spreading out' and the surroundings warm up.

Answers:

1 C	2 F	3 A	4 B
5 D	6 E		

[Reference to support materials: Activity H1]

We have seen that energy is stored in moving things - both at the macroscopic level (a rolling ball) and at the microscopic level (the moving particles in a hot cup of tea). In a similar way, energy is stored when various kinds of 'spring' are pulled apart, both at the macroscopic level (for example, mechanical potential energy and gravitational potential energy) and at the microscopic level (for example, chemical potential energy). In the following activity, we shall look at the way in which energy is stored in and escapes from macroscopic mechanical systems.

Sample activity I - Springs and things

This activity introduces what happens when springs are pulled and released, and draws the similarity between this and lifting something away from the Earth. It is important in developing the idea of fuels later, since we shall be drawing similarities between fuels and springs.

Sheets 1 and 2 are intended to be used as OHPs to introduce the ideas. Sheet 1 draws the similarity between pulling a spring and lifting something away from the Earth, so the same picture can be used to represent these changes. Other examples of similar changes could be given, e.g. squashing a spring, pulling and releasing a luggage cord or a rubber band, a rocket being fired into space, a falling meteorite. Sheet 2 develops the idea that 'pulling apart' changes do not 'just happen' but that the opposite change does. However, when we say that these changes 'just happen' we need to add 'once they have been started' because there may be something preventing the change from happening. This is an important idea to be clear about since it causes confusion for pupils when they are thinking about changes to fuels, which often have to be set alight before they burn.

Sheet 3 is a matching activity for pupils - note that in this activity there is room for interpretation in the matches which could be made.

Answers:

1 F	2 E	3 B
4 A C H	5 D G	

[Reference to support materials: Activity H2]

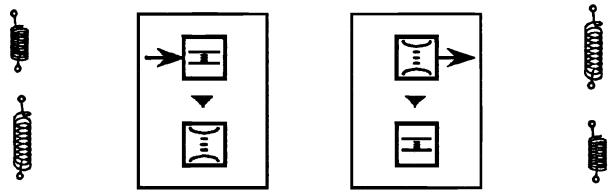
Before turning our attention to *energy* changes in chemical reactions, and the way it is stored in and escapes from 'chemical springs', we shall look in the next section at the nature of the changes to *matter* during chemical reactions.

Sample activity I

Springs and things

Sheet 1

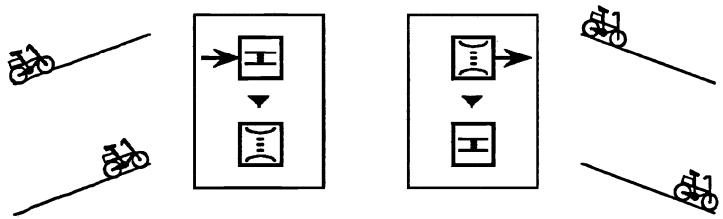
A Pulling a spring



When you pull the two ends of a spring apart, energy is stored.

When you 'let go' of the spring, the energy escapes and spreads out. The spring and the air around it warm up a little.

B Pulling something away from the Earth



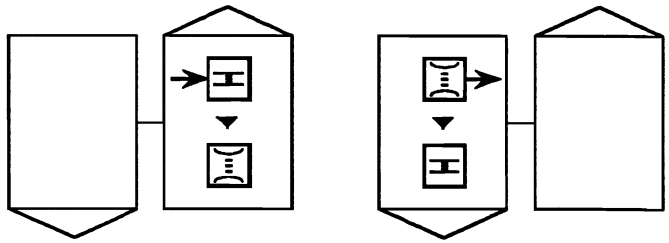
When you push a bicycle up a hill, it is a bit like pulling the two ends of a spring apart - you are 'pulling the bicycle and the Earth apart'.

When the bicycle runs down the hill, the energy escapes and spreads out. The bicycle and the air around it warm up a little.

C Things that 'just happen'

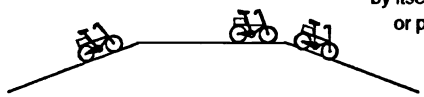
These kinds of changes do not 'just happen' by themselves. They need to be driven by other changes.

These kinds of changes 'just happen' by themselves (... once they have been started). They can drive other changes.



E.g. a bicycle does not go uphill by itself.

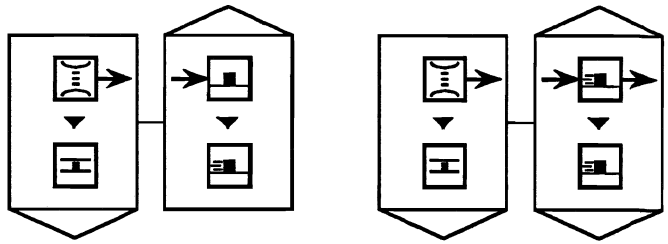
E.g. a bicycle goes downhill 'by itself' (... once you let go or push it over the edge).



D Getting something moving and keeping it moving

A change which 'just happens' can be used to *get* something moving.

A change which 'just happens' can be used to *keep* something moving.



E.g. the spring in a clockwork toy starts to move it along the floor.

E.g. the spring in a clockwork toy keeps it moving along the floor.

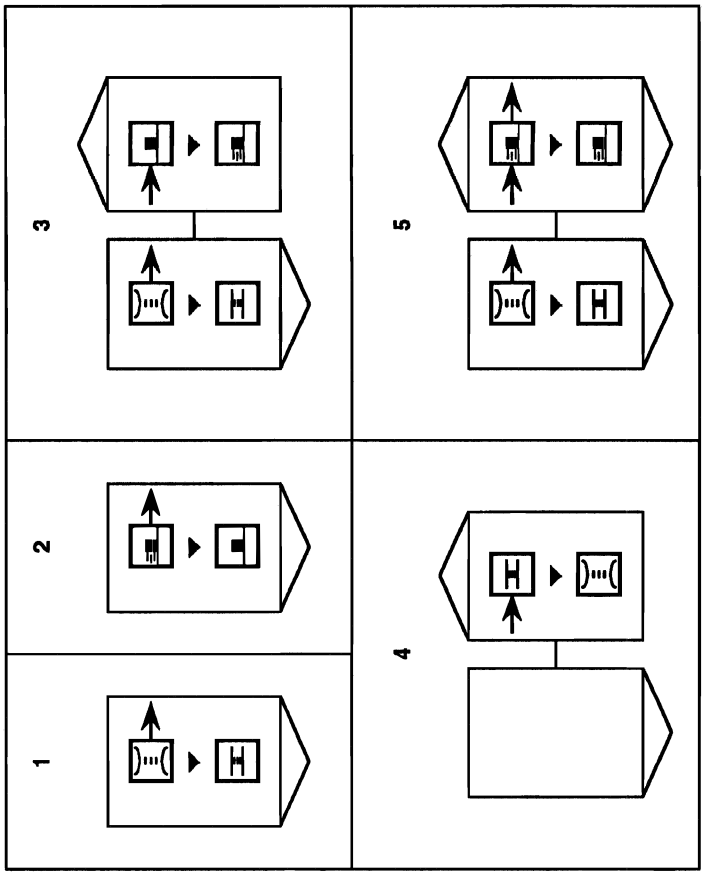
Sample activity I (continued)

Springs and things

Sheet 3

Below are some different changes. Match each one to the picture you think best represents the change. (You can match more than one change to a picture.)

A A clockwork toy is wound up.	**B** A stretched bow is released, firing an arrow.
C Water is pumped to the top of a hill.	**D** A clockwork toy is running along the floor.
E A ball is rolling along the ground and stops.	**F** An old building falls down.
G Water flowing down a river keeps a waterwheel turning.	**H** Someone lifts a bucket to the top of a building.



6 Particles - joining and splitting, building and breaking

Particles may spread or bunch - and stay unchanged.
Particles may split or join - and get re-arranged.

An understanding of particles is central to the understanding of the nature of change. We need to distinguish two different kinds of change:

- those in which the particles themselves do not change (e.g. squashing a piece of plasticene, chocolate melting, sugar dissolving in a cup of tea
- those in which particles form new particles - by splitting, joining, re-combining (e.g. hydrogen and oxygen reacting to form water, starch being broken down to glucose)

Changes tend to go in the direction in which particles become more disordered in some way (for example, more spread out or more mixed together). Not all changes do this because energy is also an important part of the story too - especially in changes in which new particles are being made by splitting and forming chemical bonds. In this section, however, we shall be concerned only with the nature of the changes to matter, leaving what is happening to energy in such changes until the next section.

An understanding of chemical change rests on an understanding of the nature of a *substance* - it is important for pupils to think about what changes and what stays the same during different kinds of changes (e.g. cutting a candle in half, melting it, burning it). Pupils in Years 7, 8 and 9 can be given many opportunities for using particle pictures to represent different states of matter, different kinds of physical changes, how particles may become more spread out or mixed together, and so on. (See support materials Theme F 'Particles and change'.) In the following activity, both physical changes and chemical changes, in which new substances are formed, are represented. The convention used initially in such activities is that different substances are represented by particles of different shading. For some pupils, such pictures may provoke them into thinking about the 'puzzle' of what exactly happens to the particles when new substances are formed. The idea that chemical change involves splitting and forming bonds will be dealt with in later activities.

Sample activity J - Everyday changes

Seeing what is essentially similar in superficially different changes is important in understanding the nature of change. Pupils are encouraged to do this in this activity with the support of particle pictures.

This could be done as a poster activity. As before, pupils match changes (on sheet 2) to pictures (sheet 3) - making these up as posters allows them to be used to promote class discussion amongst groups. It may help pupils to 'navigate' the set of pictures if they are told that pictures 1-5 all start with a single substance and pictures 6-10 all start with two substances.

Sheet 1 (not shown) asks pupils to compare selected changes in order to identify similarities and differences between them. For example, in 'bending a metal spoon' and 'a glass bottle breaking', a similarity is that the substances they are made of do not change. Seeing similarities between what appear to be superficially very different situations is essential to understanding the nature of changes. By focusing on the particle pictures, pupils may be helped to make these abstractions and pay less attention to superficial features of the changes.

An additional activity would be for pupils to try to put the changes into groups, with similar changes together (they could make up a second poster by cutting up another copy of sheet 2). They should be told that they can have 2, 3, 4 or as many groups as they want, and that they should give a reason for each group. Again they are being encouraged to pay attention to broad similarities between changes. (They could also be asked to think about this before matching them the particle pictures - do the particle pictures help them to see features that they had not seen before?)

This activity (along with the previous activities using particle pictures) can be used to introduce to pupils to standard scientific terminology such as physical change and chemical change, effervescence, corrosion, and so on.

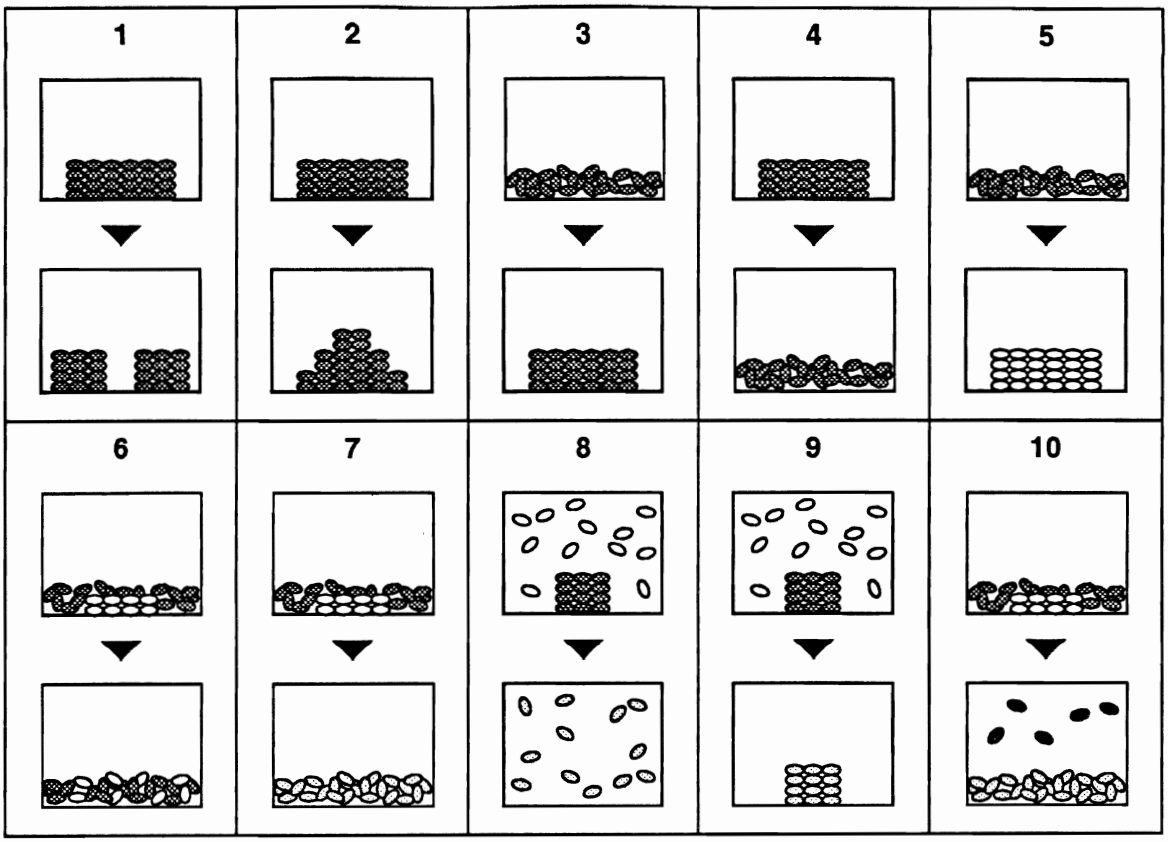
[Reference to support materials: Activity F5]

After pupils have had experience in using this kind of particle picture, they can be introduced to the idea that in a chemical reaction, particles do not appear or disappear but *join together in new ways.* This helps to solve the 'puzzle' of what exactly happens to particles when new substances are formed. 'Joining' needs to be distinguished from 'mixing' - for example, when sugar dissolves in water the particles *mix* together, but when copper is heated together in oxygen, the particles *join* together to form a new substance. Using children's building bricks of different colours may be a helpful analogy by

Sample activity J

Everyday changes (continued)

Sheet 3

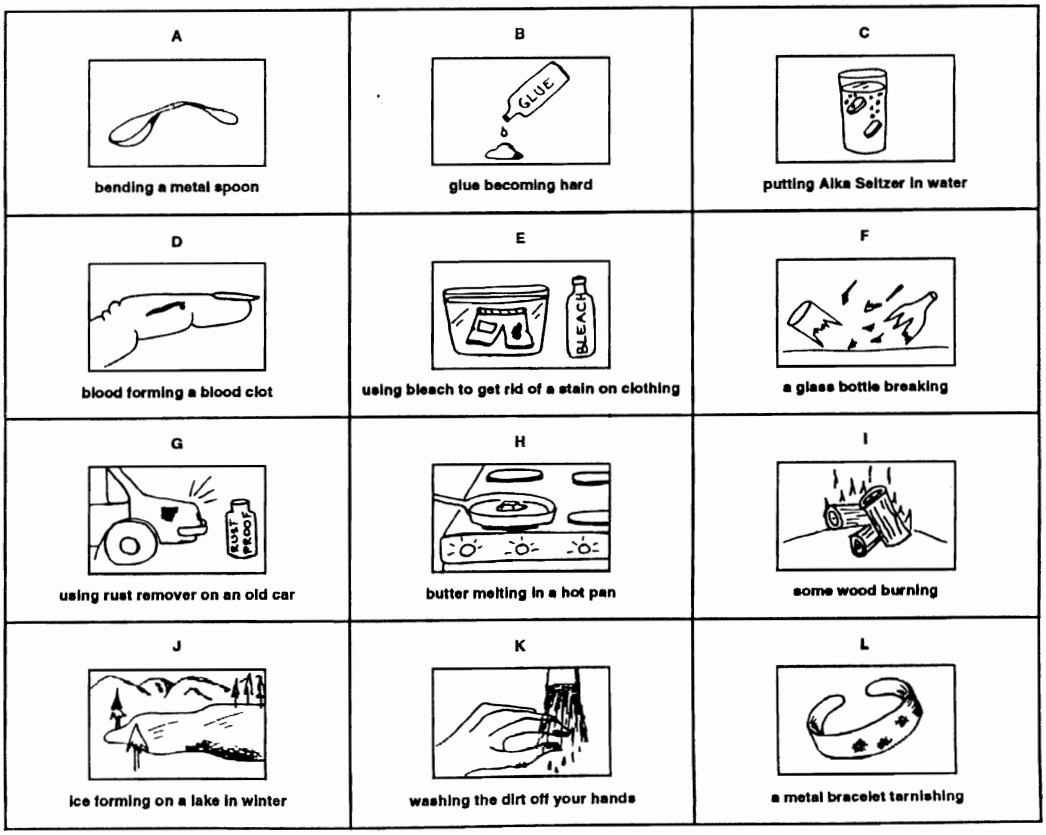


Energy and change

Sheet F5/3

Everyday changes (continued)

Sheet 2



Energy and change

Sheet F5/2

drawing the distinction between 'mixing them up' and 'joining them together in a new way'. (See support materials Theme G 'Up and down in complexity'.)

In the next activity, a new convention is used, in which chemical change is represented as a re-arrangement of particles. Using these pictures is a big step, but if pupils are given sufficient experience to explore these ideas, these representations can help them to achieve a deeper understanding of the nature of chemical change. In this approach, we have taken a rather broad view of the different kinds of change, and deliberately have not paid attention to details of the reactions in terms of atoms and molecules. Such material is readily available in existing text books, and may appropriately be used alongside these activities.

Sample activity K - Joining and splitting, mixing and 'unmixing'

This activity reinforces the idea that in a chemical reaction, particles may join together in new ways. It builds on this, introducing the idea that in some reactions particles may split to form new particles.

The first sheet can be used as an OHP, as well as for the pupil activity. This makes the distinction between two substances mixing (where no new substance is formed - the particles simply mix together) and joining (when a new substance is formed - the particles join together in a new way). It also shows pictures which represent the reverse changes - 'unmixing' and 'splitting'. It would be useful to use this sheet after pupils had been given some practical experience of a few examples of such changes (see the second sheet). Note that these pictures are rather more schematic than the earlier ones - there is no intention to represent the distinction between solid, liquid and gas.

The second sheet can be used by pupils, matching the changes to the pictures on the first sheet. Some of these examples they may have come across already, others they may not. Accompanying the changes is some information about the changes to help pupils to find an appropriate match.

Answers:

1 A D F I	2 C J L
3 B H	4 E G K

[Reference to support materials: Activities G5 and G6]

The point has been made earlier that changes tend to go in the direction in which *differences in concentration disappear* - i.e. particles become more spread out or more mixed together. Changes also tend to go in the direction in which *complexity disappears* - i.e. large particles break down to a greater number of smaller ones. So it is helpful to establish 'scales of complexity' and identify changes which go up or down a scale of complexity. (See support materials Theme G 'Up and down in complexity'.) The following activity illustrates how an 'atlas of molecules' (not shown here, but included with the support materials) can be used to categorise changes as 'building up' or 'breaking down'. Though 'breaking down' changes tend to happen more readily than 'building up' changes, energy changes will also help to determine the direction of change as with any chemical reaction.

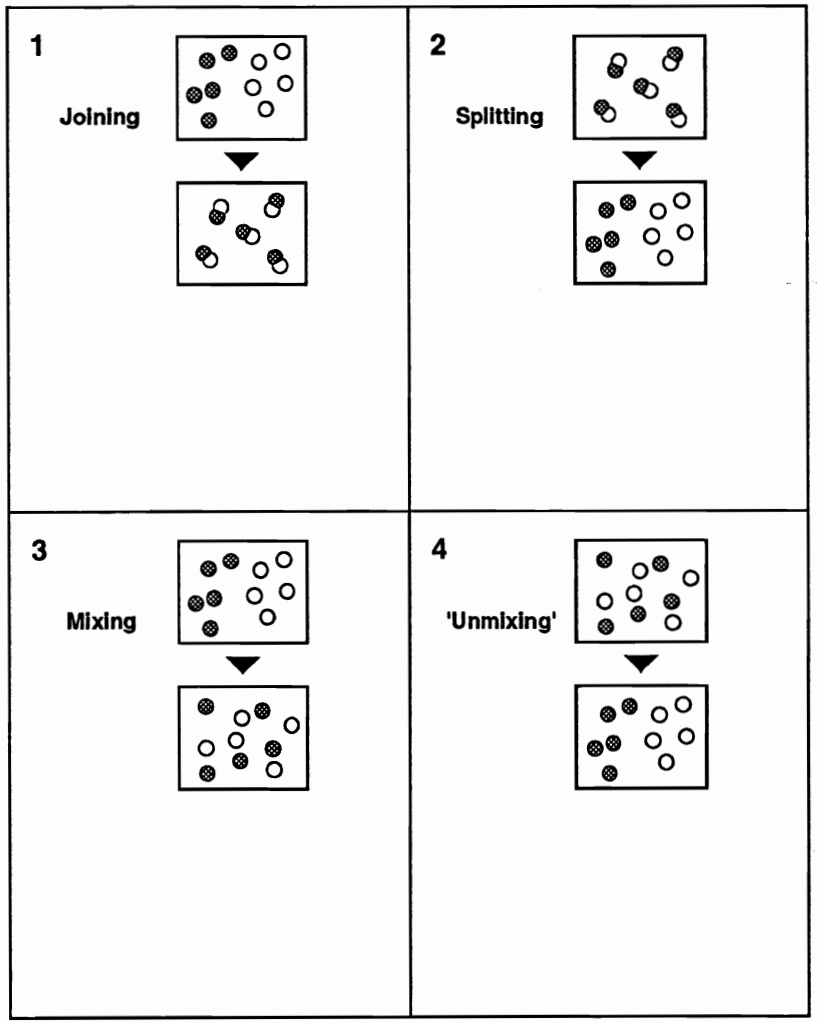
Sample activity K

Joining and splitting, mixing and 'unmixing'

Sheet 1

Changes to two substances:

- mixing - no new substance is formed - the particles simply mix together
- joining - a new substance is formed - the particles join together in a new way



Joining, splitting, mixing, 'unmixing' - some examples

Sheet 1

1 Cut out the changes below.

2 Match them to the pictures that you think show the changes best.

3 Write about the reasons you made the matches.

A Rusting When iron rusts, it reacts with oxygen in the air to form iron oxide (rust).	**B Dissolving sugar** If you add sugar to water, it will dissolve forming sugar solution.
C Electrolysis of water You can electrolyse water (with a little acid added). At one electrode you get hydrogen gas, and at the other electrode you get oxygen gas.	**D Heating copper** If you heat a piece of copper foil it turns black. The copper reacts with oxygen in the air to form copper oxide (which is black).
E Purifying rock salt Rock salt contains salt and impurities. You can make pure salt by dissolving the rock salt in water, filtering and evaporating.	**F Hydrogen and oxygen** If you mix together hydrogen and oxygen gases, and light it, you get an explosion. Water is formed.
G Getting iron from a mixture You have a mixture of iron and copper. You can get the iron out by using a magnet, leaving the copper behind.	**H Iron and sulphur** If you stir together some iron filings (dark gey) and sulphur powder (yellow), you get a dirty yelow mixture.
I Heating iron and sulphur If you heat together some iron filings (dark gey) and sulphur powder (yellow), you get a black compound called iron sulphide.	**J Making iron** Iron is made from iron ore in a blast furnace. Iron ore contains a compound of iron and oxygen (iron oxide). Carbon is used to remove the oxygen from the ore.
K Purifying water In some countries, there is not much fresh water for growing crops. However, sea water can be used if it is purified by removing the salt from it, eg by distillation.	**L Making copper** Copper is made from copper ore, which contains copper oxide. After reacting it with acid, it is electrolysed. Copper forms at one electrode (and oxygen at the other).

Sample activity L - Building up and breaking down

Many important chemical changes involve small molecules joining to form large ones, or large molecules splitting to form small ones.

Sheet 1 shows picture representations of two kinds of change - 'building up' and 'breaking down'. There are similarities which should be drawn here to the pictures introduced previously of 'joining' and 'splitting'. Pupils need to match examples from a range of chemical reactions - mainly biological but some non-biological - to the pictures of 'building up' and 'breaking down'. They need to use the information about the sizes of molecules from the atlas (included in the support materials, but the information could be found in many textbooks), and one example should be discussed with the class to show pupils how to do this.

One of the questions on the sheet asks pupils to consider whether it is easier to 'build up' or 'break down' molecules. The direction in which such changes tend to go is dealt with explicitly in later activities (included in the support materials), but there could be a discussion of this here. The analogy of breaking a bottle and mending a broken bottle could be used to explain why reactions tend to result in molecules breaking down rather than building up.

Answers:
Building up: A B D E (G) (K) M P
Breaking down: (C) F H I J L (N) O
(The letters in brackets are non-biological changes.)

[Reference to support materials: Activity G8]

Throughout the work on changes to matter, an increasing emphasis has been put on an understanding of particles. Thus, in the earlier activities, pupils are able to choose appropriate particle pictures to represent chemical reactions based only on knowing about the *surface* features; in the later activities, they need to have some knowledge of what is happening at the *particle* level. We now turn to look at how *energy* is involved in chemical reactions.

7 Storing differences in 'chemical springs'

A fuel is half a 'chemical spring' which has been pulled apart.
Energy spreads when the spring's released - with a push to make it start.

A commonly held (and commonsense) view is that 'fuels contain energy and energy makes things happen'. However this explanation is unhelpful because it fails to take account of the essential role of oxygen, and because it does not address the reason of *why* things happen.

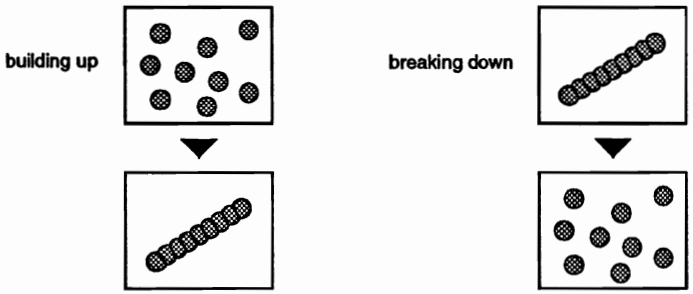
Fuels are of no use by themselves. We cannot burn them without oxygen, but we tend to take oxygen for granted because it is all around us and comes 'free'. If we lived on a planet with a methane atmosphere, we would have oxygen piped to our homes to burn in our cookers. What plants do when they make food (and ultimately fossil fuels) is essentially to 'pull apart' hydrogen from oxygen in water (a change which does not just happen), and store the hydrogen as fuel in carbohydrates. This is similar to stretching a spring.

Sample activity L

Building up and breaking down molecules

Sheet 1

1 In some reactions, large molecules are *built up* from lots of smaller molecules. In other reactions, large molecules are *broken down* into lots of smaller molecules:



2 Cut up the boxes below showing different kinds of changes. Sort them into two groups - 'building up' and 'breaking down'. (You need to use the ladder of molecules to find out the sizes of the molecules involved in the changes - these are shown in *italics.)*

Questions

1 Most of the changes are *biological.* Can you find two examples of 'building up' changes that are *non-biological?*

2 Can you find two examples of 'breaking down' changes that are non-biological?

3 Do you think it is easier to build up molecules or break down molecules? Why?

A Making proteins
Many of the parts of our bodies are made from proteins - muscles, skin, *hair* and nails. *Enzymes* are also proteins. We make proteins from *amino acids* which we get from our food.

B Photosynthesis
Plants use sunlight to make *glucose* (a sugar). They make this using *carbon dioxide* (which they get from their leaves) and *water* (which they get from their roots). During photosynthesis, plants also produce *oxygen.*

C Burning fuels
When fuels burn, they react with oxygen. For example, a car engine burns petrol which contains *octane.* When this reacts with *oxygen* it produces *carbon dioxide* and *water.*

D Plants storing food
Making *starch* is a good way for a plant to store food, because it is insoluble. A plant makes *starch* from *glucose* (a sugar which is soluble).

E Plants making cellulose
Cellulose is the 'building material' of plants. It is what gives strength and shape to the stems, roots and leaves of green plants. The structure of a cellulose molecule is very similar to a *starch* molecule. Plants make cellulose from *glucose.*

F Digesting starch
Many foods contain starch, but we are not able to use this starch until we digest it. Starch is insoluble. In a human's small intestine, *starch* is changed into *glucose.* Glucose is soluble and passes into the bloodstream.

G Making polythene
Polythene is a synthetic material - it is not found in nature. It is a long chain molecule made by joining together ethene molecules. (Ethene is not on the display - it has 6 atoms).

H Respiration in animals
We use *glucose* in our bodies to provide us with energy. To make our muscles move, glucose reacts with the *oxygen* in our blood and forms *carbon dioxide* and *water.*

I Respiration in plants
At night, when there is no sunlight, plants also respire - reacting *glucose* with *oxygen* to form *carbon dioxide* and *water.*

J Respiration in bacteria
Many bacteria can respire in the same way as humans - by reacting *glucose* with *oxygen* to form *carbon dioxide* and *water.*

K Making nylon
Nylon is a synthetic material - it is not found in nature. It is a long chain molecule made up by joining smaller molecules together. These smaller molecules (not on the display) are similar in size to the *amino acids.*

L Digesting protein
Many foods contain protein. In order to use this protein, we need to digest it. This is done in the stomach. Proteins are broken down into *amino acids.* (An example of a protein is *hair* - though we could not in fact digest this protein.)

M Storing food as fat
Many animals store food in the form of *fat.* When we do not eat enough then we use up our fat reserves. If we eat too much, then we make more fat. Our bodies can make fat from *sugars.*

N Making soap
Soap is made by boiling a *fat* with an alkali.

O Making 'biogas'
Some bacteria can live without oxygen, changing dead plant material (which contains a lot of cellulose - similar to *starch*) into *methane* and *water,* as well as other substances. These bacteria are used in 'biogas' fermenters, which provide gas for cooking and heating.

P Growth of bacteria
Like humans, bacteria need to make *proteins* in order to grow. They make the proteins from *amino acids.*

The reverse processes (burning fuels and releasing springs) do 'just happen' and can be used to drive other changes. To be more precise, we should say that they 'just happen once they have started'. Thus, a ball may roll down a hill 'just by itself' once it has been given a push to get it started, and wood burns in oxygen 'just by itself' once it has been made hot to get it started.

Sample activity M - Storing and releasing energy

This activity introduces a way of thinking about burning fuels as the coming together of fuel and oxygen that have been 'kept apart'. This is compared to releasing a spring or dropping an object.

An important idea to stress here is that energy is released when a fuel reacts with oxygen. A fuel on its own is not a store of energy - a candle would be useless in outer space and a car would not work on the Moon because there is no oxygen. They would be useful as fuels if there was a supply of oxygen as well. Fuel burning in oxygen releases energy - this is similar to a spring being released (and in the next activity a picture of a fuel burning will be introduced which looks similar to the equivalent picture for a spring).

Another important idea is that a fuel burning is a change that 'just happens'. Children may object to this idea, saying that you need to light it first. They are absolutely right - what we really mean when we say that fuel burning 'just happens' is that it 'just happens once it has been started'.

Answers:
All of the changes which 'just happen' are those in which energy is released (it 'spreads out' and becomes 'less concentrated'. All of the changes which 'do not just happen' are those in which energy is stored.

[Reference to support materials: Activity H3]

Why do we need fuels? We need fuels to make things happen that would not just happen by themselves. For example, things do not get hot or start moving on their own for no reason. But burning gas in a cooker can make a saucepan of water hot and burning petrol in an engine can make a car move. The essential point is that a change which just happens (e.g. a fuel burning) can drive a change which does not. Thus fuels (with oxygen) can be used to create *differences*, and we can think of them as *stored differences*.

The following activity looks at two ways in which water may be used as an energy store - we can make it hot or we can split it into hydrogen and oxygen. In some respects, these two processes are rather similar; in other respects, they are very different. The new picture representations introduced in this activity are intended to bring out these similarities and differences.

Sample activity N - Ways of storing energy

This activity looks in detail at one 'case-study' - using water to store energy. Some new 'pictures of changes' are introduced showing energy being stored and released during chemical change.

The pictures introduced here are probably the most difficult so far, since they are not just representing familiar changes in a new way (e.g. a hot object cooling or a moving object slowing down). The

Sample activity M

Storing and releasing energy

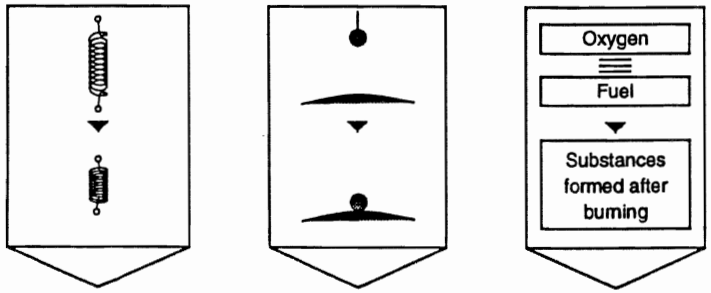
Sheet 1

Energy stores

a stretched spring - the two ends are being kept apart

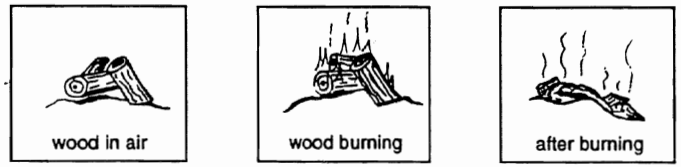
a ball above the ground - the ball and the Earth are being kept apart

a fuel in air - the fuel and the oxygen are being 'kept apart'

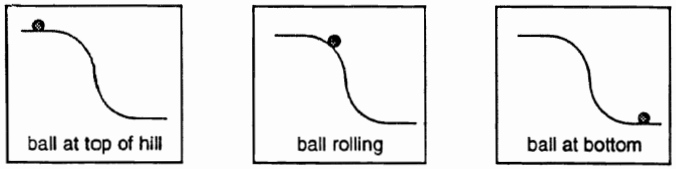


Could you light a candle in outer space? Could you run a car on the Moon? Could you light a match under water?

Fuel burning in air 'just happens' by itself ... once it has been started



wood burns in air 'just by itself' - though you may need to 'give it a push' (by making it hot) to get it started



a ball rolls down a hill 'just by itself' - though you may need to 'let it go' or 'give it a push' to get it started

Storing and releasing energy

Sheet 2

Here are some changes. Tick the boxes you think describe what happens in each change.	Is energy being stored? Or is energy being released? stored	released	Is the change something that 'just happens' (once started)? Or is it something that 'does not just happen' by itself? 'just happens'	'does not just happen'
A A clockwork toy is running along the floor.	☐	☐	☐	☐
B A candle burns with the oxygen in the air.	☐	☐	☐	☐
C A stretched bow is released, firing an arrow.	☐	☐	☐	☐
D Coal is burnt in a power station.	☐	☐	☐	☐
E Petrol is mixed with air in a car engine and burnt.	☐	☐	☐	☐
F A clockwork toy is wound up.	☐	☐	☐	☐
G A battery is recharged.	☐	☐	☐	☐
H Water is pumped up a hill.	☐	☐	☐	☐

1 Which are the changes which 'just happen' - energy being stored or released?

2 Which are the changes which 'do not just happen' - energy being stored or released?

3 Could you light a candle in outer space? Could you run a car on the Moon? Could you light a match under water?

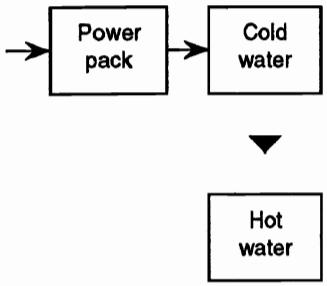
Sample activity N

Ways of storing energy

Sheet 1

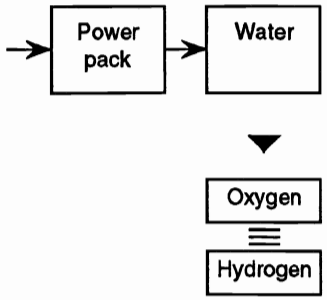
A Storing energy 1

Water is heated with an immersion heater.



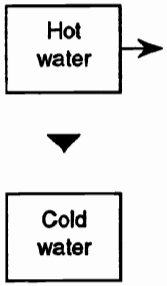
B Storing energy 2

Water is electrolysed to give hydrogen and oxygen.



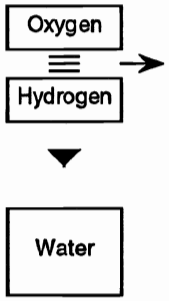
C Energy escaping 1

Hot water is left to cool.



D Energy escaping 2

Hydrogen and oxygen react to form water.

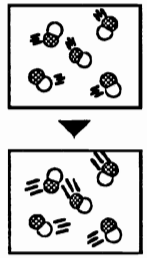


Ways of storing energy (continued)

Sheet 2

A Storing energy 1

- by making something hotter

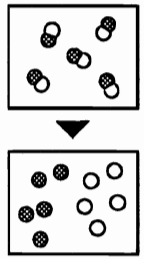


particles move faster

(e.g. water is heated with an immersion heater)

B Storing energy 2

- by splitting particles

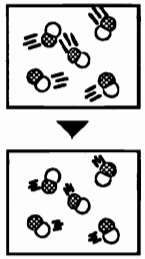


pulling particles apart

(e.g. water is electrolysed to give hydrogen and oxygen)

C Energy escaping 1

- by cooling down

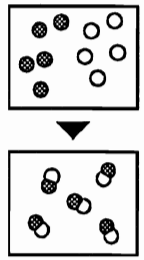


particles move slower

(e.g. hot water is left to cool)

D Energy escaping 2

- by particles joining

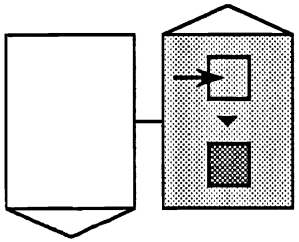


particles forming again

(e.g. hydrogen and oxygen react to form water)

A Storing energy 1

- by making something hotter

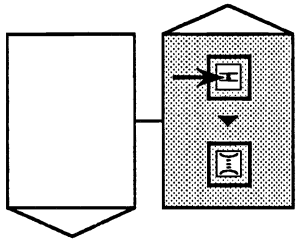


does not 'just happen'
needs to be driven

(e.g. water is heated with an immersion heater)

B Storing energy 2

- by 'hiding it away'

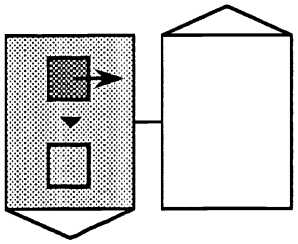


does not 'just happen'
needs to be driven

(e.g. water is electrolysed to give hydrogen and oxygen)

C Energy escaping 1

- by cooling down

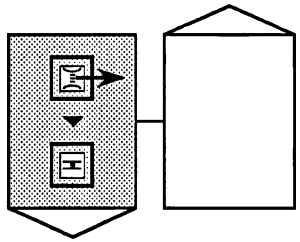


'just happens'
can drive another change

(e.g. hot water is left to cool)

D Energy escaping 2

- by releasing energy that was 'hidden away'



'just happens'
can drive another change

(e.g. hydrogen and oxygen react to form water)

Ways of storing energy

The pictures below show some ways of storing and releasing energy. Two ways of storing energy are shown:

- by making something hotter (the particles move faster)
- by 'hiding it away' (the particles are pulled apart).

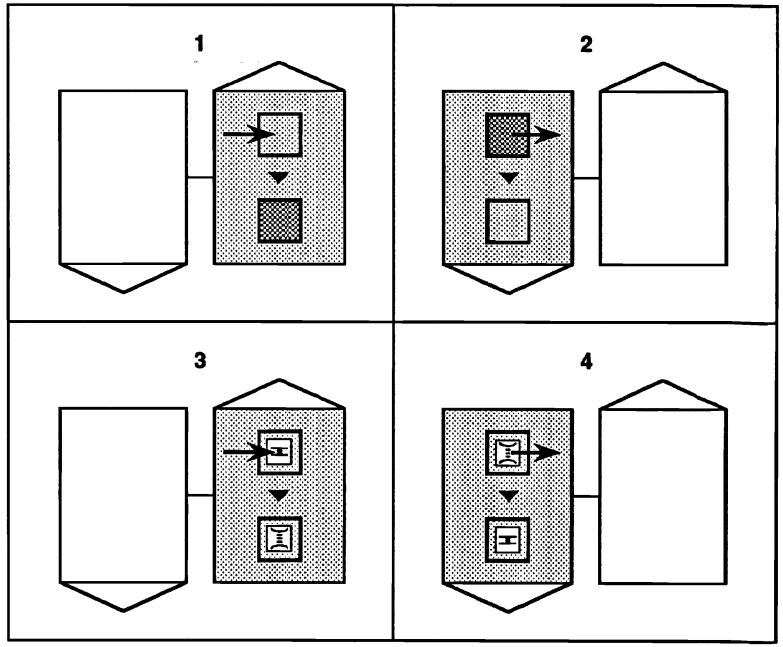
Match each of these changes to the the picture you think is best.

A Water is heated with an immersion heater
B Water is electrolysed to give hydrogen and oxygen
C Hot water is left to cool
D Hydrogen and oxygen react to form water

Questions

For each of the above changes, answer these questions:

1 What happens to the energy?
2 What happens to the particles?
3 Does the change 'just happen' by itself or does it need to be 'driven' by another change?



require pupils to look at a change in a completely new way. The essential idea is that energy can be stored by *making molecules move faster* or *by splitting molecules apart*. The particular example chosen is water, and the changes discussed are as follows:

A Storing energy by making something hotter We can store energy in water by making it hotter (making the particles move faster). This does not happen 'by itself' - it needs something to drive the change (e.g. a power pack).

B Storing energy by 'hiding it away' Heating water is not the only way can use it to store energy - we can also use store energy by *pulling* the molecules of water apart (the atoms in the molecules are attracted to each other). This is like storing energy in a *spring* by pulling it apart - the energy does not make the water hotter, the energy is 'hidden away' like in a stretched spring. Pulling apart water molecules gives hydrogen and oxygen. Again, this does not happen 'by itself' - it needs something to drive the change (e.g. a power pack).

C Energy escaping (cooling down) Energy escapes when the water cools down (the particles slow down). This 'just happens by itself', and we can use it to drive other changes, for example, making something else hot or making something move.

D Energy escaping (releasing energy that was 'hidden away') Energy escapes when the hydrogen atoms and oxygen atoms rejoin to form water - like a *spring* being released. The energy 'hidden away' in the hydrogen and oxygen now spreads out. Again, this 'just happens by itself', and we can use it to drive other changes, for example, making something hot or generating electricity.

Sheets 1, 2 and 3 are OHPs which introduce the ideas. Sheet 1 summarises the changes. Sheet 2 looked at what is happening in terms of particles, and Sheet 3 looks at what is happening in terms of energy. The changes may be illustrated by a practical demonstration (details are in the support materials). Sheet 4 is a pupil activity - they are asked to write about the changes and the explanations for them that are discussed on the OHPs. It would also be worth discussing with pupils in what ways changes A and B are similar and in what way they are different.

Answers:

A 1 B 3 C 2 D 4

[Reference to support materials: Activity H4]

This particular example - using water to store energy - has been looked at in some detail. The reason is that the 'splitting' and 'joining' of water are chemically rather simple changes, and are a good basis for introducing the essential nature of many more chemical reactions, such as combustion, photosynthesis, respiration, corrosion and the extraction of metals. The next activity uses the ideas and representations introduced in the previous activity, and extends them to a wider range of changes.

Sample activity O - Fuels and food

This activity develops from the way of thinking about fuels introduced in the previous activity, and extends the range of examples.

Sheet 1 gives a set of changes in which energy is being stored or released. Sheet 2 has a set of pictures to which pupils should match the changes. The pictures are things warming and cooling, starting to move and stopping, and energy being stored or released during chemical change.

Sample activity O

Fuels and food

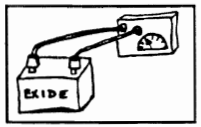
Sheet 1

Below are some different changes. Match each one to the picture you think best represents the change. (You can match more than one change to a picture.)

A

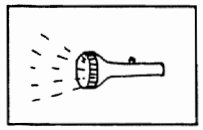
wood burning

B



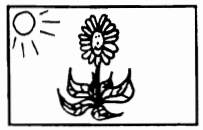
recharging a battery

C



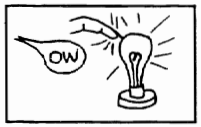
a torch battery runs down

D



a plant makes starch by photosynthesis

E

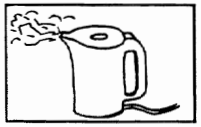


an electric light bulb gets hot

F

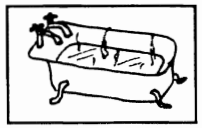
a person uses up food running a race

G



using a kettle to boil some water

H



a bath of hot water cools down

I

petrol is used in a car engine

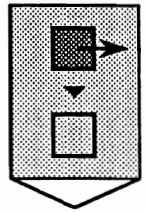
J

winds blow because energy goes from hot regions of the Earth to cold

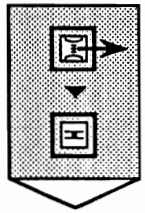
Fuels and food (continued)

Sheet 2

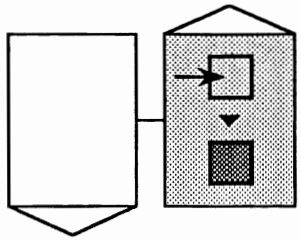
1



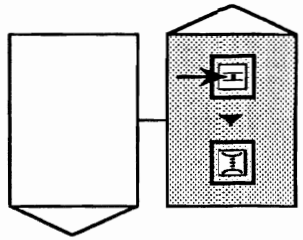
2



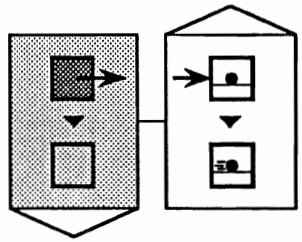
3



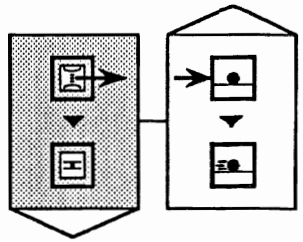
4



5



6



Answers:

1 H	2 A C
3 E G	4 B D
5 J	6 F I

[Reference to support materials: Activity H5]

We can extend this approach to look at the nature of the changes in chemical reactions in more detail. For example, we can think of photosynthesis as essentially a process in which a plant splits water into hydrogen and oxygen ('stretching a chemical spring'). Since there is oxygen in the atmosphere, the plant can throw this away, but the hydrogen needs to be stored. It is joined with carbon dioxide to make starch. Storing energy and building up complex organic molecules are both changes that do not 'just happen', and ultimately are driven by the spreading out of the energy from the Sun. (See support materials Theme H 'Fuels and food'.)

The energy changes taking place in all chemical reactions can be thought about as the stretching and releasing of 'chemical springs'. Usually, but not always, it is the spreading out of energy as 'chemical springs are released' which drives the direction of chemical change. Thus, most reactions are exothermic. However, in *all* chemical reactions, matter or energy or both must spread out.

8 Steady states - maintaining a difference

You can stay where you are by standing still,
But you need to keep running if you're sliding downhill.

What thoughts and feelings does the phrase 'Spaceship Earth' conjure up in you? The term was coined to encapsulate and encourage a certain attitude to the planet, based on the idea that the Earth is essentially a closed system - no matter gets in and none gets out. Nothing can be 'used up' in the sense that it disappears completely - matter flows around the planet, sometimes 'spread out', sometimes concentrated in one place, but always conserved. These changes to matter do not happen 'just by themselves'. They need to be driven - with nothing to drive them, flows of matter would stop and the chemicals on Earth would reach an equilibrium. What drives these changes?

The Earth is warmer than the space which surrounds it, so energy flows from the Earth into space. The Earth does not cool down, though, because energy is spreading out from the hot Sun into space, and some of this is intercepted by the Earth. The Earth stays at a constant average temperature because the energy falling on it is balanced by the energy escaping. Thus, while matter does not enter or leave 'Spaceship Earth', energy flows continually through it, from the hot Sun to warm Earth and into cold space. It is this 'spreading' out of energy from hot to cold which drives the changes which happen on Earth.

The Earth, then, is maintained in a 'steady state' - for example, winds constantly blow, rain continues to fall, and the Earth is kept at a constant average temperature. This is a very different sense of 'staying the same' than a planet which did not change at all - no winds, no rain and with the temperature the same as the space surrounding it. The next activity explores the idea of a 'steady state' in which

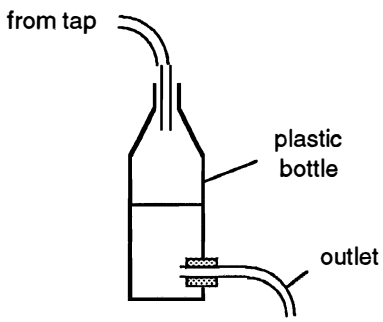
something needs to 'keep going to stay the same'. It focuses particularly on maintaining something at a temperature which is warmer than the surroundings, examples of which are a centrally-heated room, a human being, and the Earth itself.

Sample activity P - Going up and coming down

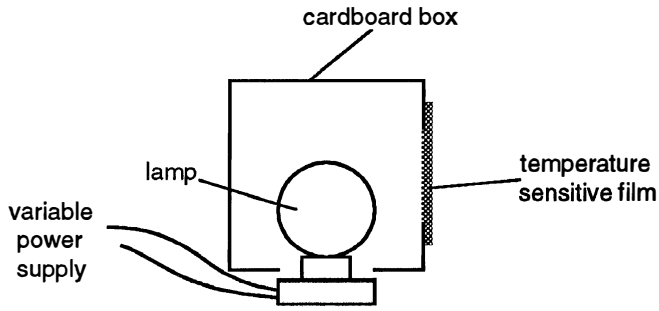
This activity looks at how a steady state system changes when the input in increased or decreased.

There are two demonstrations - the first showing a system with a flow of matter and the second showing a flow of energy. Both are about how the rate at which matter or energy affects the amount in the system, and how this in turn affects the rate at which matter or energy leaves the system.

Sheet 1 is an OHP which relates to the 'steady state bottle' as shown in figure (a) The emphasis is on paying attention to how the height is affected by changes to the rate of water flowing in. It would be useful to experiment with the bottle and encourage pupils to make suggestions and answer questions before looking at the OHP. For example, starting with an empty bottle, pupils could be asked to predict what will happen if the tap is turned on a little (the water level rises, the output of water increases, and eventually it reaches a steady state with a low level of water at which the input balances the output).



(a) A 'steady state bottle'



(b) A 'steady state box'

Sheet 2 is an OHP with similar ideas about energy flow. These can be illustrated using the 'steady state box', as shown in figure (b). This consists of a small cardboard box with two holes. Into one hole is inserted a lamp (12V 24W would be suitable) connected to a variable power pack, and the other hole is covered with temperature sensitive film. (The most useful kind is film which changes colour over the temperature range 25°C to 30°C. This can be obtained on small cards from the Science Museum Shop in London or in larger quantities from George Eliott, Stone Cottage, Tickerage Lane, Blackboys, East Sussex, TN22 5LX.)

As before it would be best to experiment with this before looking at the ideas on the OHP. Before looking at the box, another piece of temperature sensitive film should be used to demonstrate how the temperature sensitive film behaves. They could then be asked to predict what will happen when the lamp is turned on - will the temperature keep rising and if not, why not? What will happen if the lamp is on a higher setting?

The box can be discussed as a model of a central heating system (the lamp representing the radiator) or of the human body (the lamp representing the body's metabolism and the film showing surface temperature of body). In all these cases an object is being kept at a different temperature to that of the

Sample activity P

Going up and coming down

Sheet 1

1 Coming down

Water does not stay in leaky containers - it escapes and the water level drops.

Water escapes more slowly when the water level is lower.

Eventually, the level falls to the bottom. It now stays the same.

2 Going up

If you start putting water in, the level rises. Some of the water escapes.

As the level gets higher, more water escapes.

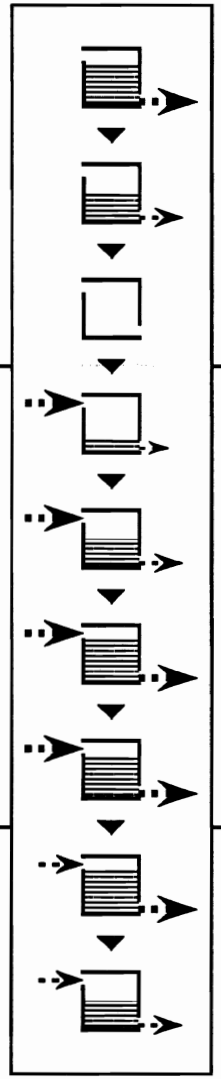
Eventually, the water escaping balances the water going in.

The level now stays the same. This is like 'keeping moving to stay where you are'.

3 Coming down again

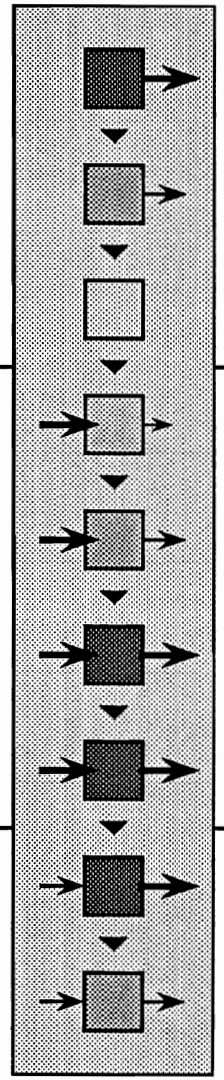
If you lower the water input, water still escapes.

The level drops until it reaches a new steady state.



Going up and coming down (continued)

Sheet 2



1 Coming down

Hot things don't stay hot - energy escapes and they cool down.

Energy escapes more slowly when it is nearer to room temperature.

Eventually, it becomes the same as room temperature. The temperature now stays the same.

2 Going up

If you start to heat something, energy flows in and makes it hotter. Some of the energy escapes.

As it gets hotter, more energy escapes.

Eventually, the energy escaping balances the energy going in.

The temperature now stays the same. This is like 'keeping moving to stay where you are'.

3 Coming down again

If you lower the energy input, energy still escapes.

It cools down until it reaches a new steady state.

surroundings by a constant flow of energy. In both the central heating system and in the human body there is also a constant flow of matter.

[Reference to support materials: Activity J2]

The previous activity illustrates how the Earth is maintained at a temperature higher than that of its surroundings. But, as well as a temperature difference between the Earth and space, there are also temperature differences between different regions of the Earth. Regions where it is day are warmer than those where it is night, the equator is warmer than the poles, and so on. These temperature differences can drive other changes - they are responsible for convection currents in the atmosphere. Winds keep blowing because these temperature differences are constantly maintained. The next activity looks at the way in which temperature differences drive convection currents.

Sample activity Q - Convection currents

Temperature differences can drive other changes. Energy moving from hot to cold can make something move.

Sheets 1 and 2 are OHPs which introduce the idea of a convection current as being driven by an energy flow from hot to cold. The example used is that of a beaker of water being warmed - if a small crystal of potassium permanganate is dropped down by the side into a beaker of water, and this part is then warmed by a low Bunsen flame, the convection currents can easily be seen as the purple dye dissolves. Another way of making the currents visible is to project a shadow onto a screen using a point source of light (for example, a car headlight), warming the beaker in the middle with an electrical heater. The emphasis of the OHPs is on the idea that a change which 'just happens' can drive a change which does not 'just happen'.

What happens in a warmed beaker of water is very similar to the way in which convection currents arise in a centrally-heated room. Sheets 3 and 4 are for the pupil activity, in which they are asked to match situations concerned with a radiator being switched on and off (on sheet 2) with the pictures shown on sheet 4.

Answers

A 1	B 4	C 9	D 8
E 5	F 2	G 3	H 6

[Reference to support materials: Activity J5]

In this section, the activities have been concerned with steady states and flows of *energy*. But there are many other important systems which are also maintained in a steady state by flows of *matter* - a flame, a tree, an ecosystem, the nitrogen cycle, 'Spaceship Earth'. All of these examples are 'steady states', and changes which 'just happen' are needed to maintain them. (See support materials Theme J 'Flows of matter and energy'.)

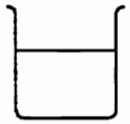
Sample activity Q

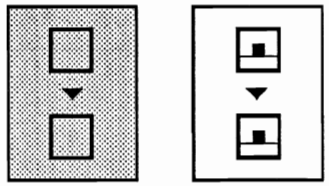
Convection currents

Sheet 1

A A beaker of water

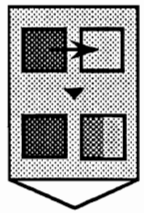
The beaker is at the same temperature as the air in the room. The water is not moving.





B Making it hot

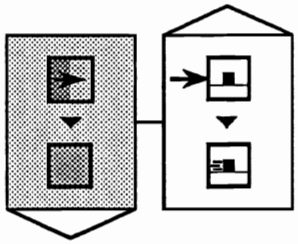
You start warming the water with a Bunsen flame. The flame is hot - energy goes from the flame to the beaker. More energy goes to some parts of the beaker than others, so some parts get hotter.



C Convection currents

Different parts of the beaker are at different temperatures. Energy flows from hot to cold parts, and this makes the water move. The temperature of the water in different parts of the beaker tends to become the same.

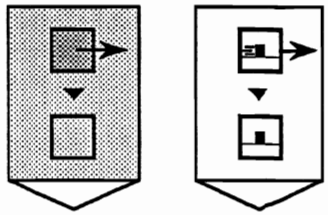
A change which 'just happens' drives one that does not.



D Letting the beaker cool down

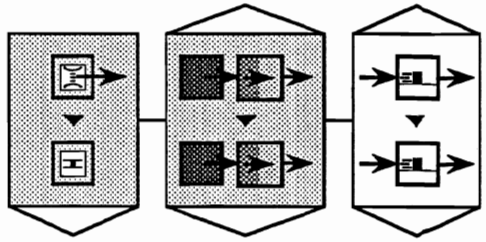
If you take the flame away, energy escapes from the warm water until it is at the same temperature as the air in the room.

With no temperature differences, the water stops moving.

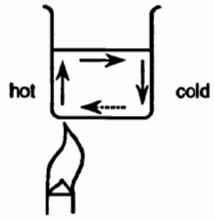


E Keeping it going

If you keep warming the water with the flame, then the water will keep moving. It is kept moving because the temperature difference is kept going. The temperature difference is kept going by burning fuel.



F Convection currents in a beaker of water



The flame keeps one part of the beaker hotter than another.

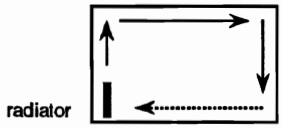
Energy is carried by the water from where it is hot to where it is not.

The hot water is less dense that the cold water. The cold water sinks and pushes the hot water up.

Convection currents

Sheet 3

In a centrally-heated room, convection currents are started because of the temperature difference created. Energy flows from hot regions of the room to cold and is carried by moving currents of air.



The situations below explain what happens when a radiator is switched on in a cold room. Match each situation to the picture on sheet 4 which you think is best.

A When the radiator is off, the air in the room stays the same temperature as the air outside.

B The air in the room does not move when the radiator is off (since there are no temperature differences to drive this change).

C When the radiator is switched on, a temperature difference is created - some of the air becomes warmer than the rest of the air in the room.

D Because of this temperature difference, air starts moving. Energy moving from hot to cold drives this convection current.

E When the radiator is switched off, the convection currents slow down and eventually the air stops moving.

F The temperature of the room drops until it is the same temperature as the air outside.

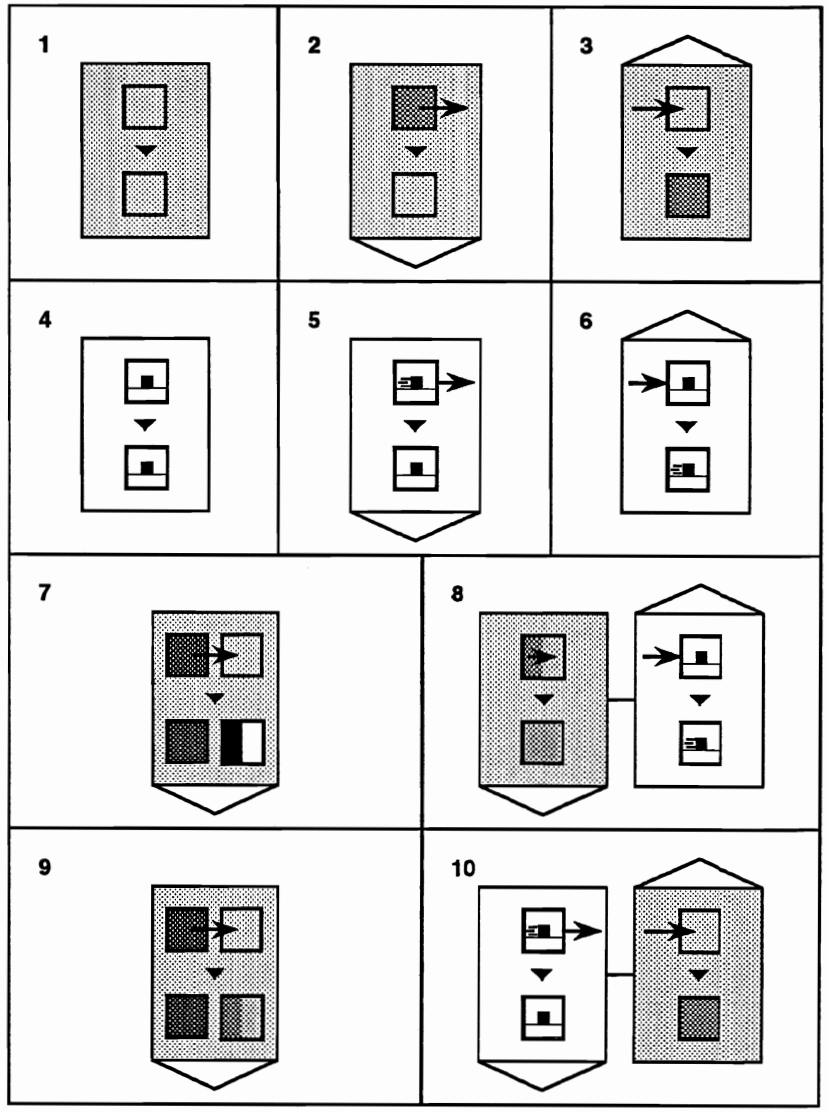
G Now that the radiator is off, the room cannot get warmer 'just by itself'.

H With the radiator off, the air cannot start moving 'just by itself'.

Convection currents (continued)

Sheet 4

Match these pictures to the changes on sheet 3.



9 Making measurements

All the previous sections have been concerned with the *direction* of change. Here, we shall be concerned with *how big* the changes are. Here are two questions:

> Can you bring a saucepan of cold water to the boil using an ice cube?
> Can you bring a saucepan of cold water to the boil using a burning match?

The answer to both of these questions is 'no', but for different reasons. In the first case it is because energy flows, but in the wrong direction. In the second case, energy flows in the right direction but not enough to do the job.

Energy transfers can be measured. So, we can talk about *how much* energy is transferred when we boil a saucepan of cold water, or *how much* escapes when we burn a match. Knowing these values, we can say whether the change could possibly happen. Energy does not determine whether a change will happen in a particular direction, but it does put constraints on what is possible.

There are many kinds of activities which can help pupils get a 'feel' for the amounts of energy, and rates of energy flow involved in various changes. Although we have left a discussion of quantitative work until last, it is important that this should be started with young pupils alongside a qualitative approach. One simple activity would be to look at the amounts of energy which escape when different amounts of fuel burn and the amounts used when different things becomes hot. Comparing values allows pupils to predict how much fuel is needed for different jobs. The following activity, suitable for Y8 upwards, compares amount of energy involved in a wider range of changes.

Sample activity R - Comparing energy values

This activity looks at different kinds of changes which can be compared quantitatively.

The kinds of changes involve fuels, food, moving things, electricity, light and making things hot. There are 4 sheets in this activity though only 2 are included here. The changes to be put in order are shown on Sheet 2 - pupils can write their guesses in the boxes on the sheet or could cut out the boxes and re-arrange in order. Whereas in previous activities (not included) pupils do not find it too difficult to put the changes in an approximate order, here thinking about the order is more challenging. It is intended to stimulate discussion about why the changes are in the order they are. For example, why is 'using an electric fire for 3 hours' higher up the ladder than 'using a TV for 5 hours'? Many pupils may initially pay attention only to the time involved. This activity therefore makes us think about rates and amounts.

On Sheet 4, there are questions about making comparisons across the 'rungs' of the ladder. Some may seem surprising and are worth discussing - e.g. relating a car travelling to amount of fuel, or walking to amount of food.

Sample activity R

	Fuels	Food	Releasing things pulled apart	Moving things	Using electricity	The Sun	Making things hot
	A a candle	A a biscuit	A a 'fist-sized' meteorite falling from outer space	A a car travelling 200 yards	A using an electric fire for 3 hours	A sunlight shining on a person for 20 seconds	A evaporating one drop of water
	B a wooden pencil	B a loaf of bread	B releasing 1000 stretched elastic luggage cords	B walking 5 miles	B using a light bulb for half an hour	B sunlight shining on a small plant for 20 minutes	B hot water for a bath
	C a bottle of meths	C a spoon of milk	C a tonne of water flowing down a 100 metre high hill	C walking 100 yards	C using a TV for 5 hours	C sunlight shining on a house for 2 minutes	C making one cup of tea
	D some petrol in a dropper	D a packet of crisps	D a car falling from the height of a house	D a car travelling 10 miles	D using an electric fire for 10 seconds	D sunlight shining on a person for half an hour	D heating a large saucepan of water till it boils

Questions

When you have constructed an energy ladder, you can use it to compare energy values.

1. Pick the things which have the same energy value, for example:

   'The energy value of a biscuit is the same as that of sunlight shining on a small plant for 20 minutes (100 kJ).'

Now do the following:

a) The energy needed to make a car move 10 miles is the same as ...
(use the column 'Making things hot').

b) The energy value of a loaf of bread is the same as ...
(use the column 'The Sun').

c) The energy value of a candle is the same as ...
('Making things hot').

d) The energy to walk 100 yards is the same as ...
('Food')

e) The energy needed to make one cup of tea is the same as ...
('Moving things')

f) The energy flowing through an electric fire in 3 hours is the same as ...
('Fuels').

g) The energy value of a bottle of meths is the same as ...
('Using electricity').

h) The energy released when 1 tonne of water flows down 100 metres is the same as ...
('Fuels').

i) The energy of sunlight shining on a person for 20 seconds is the same as ...
('Moving things').

j) The energy needed to make the hot water for a bath is the same as ...
('Food').

k) The energy flowing through a TV in 5 hours is the same as ...
('The Sun').

l) The energy released from a falling 'fist-sized' meteorite is the same as ...
('Making things hot').

2. Did any of these surprise you? If so, explain why.

3. Try making up some more of your own.

Answers:

	Fuels	Food	Releasing things pulled apart	Moving things	Using electricity	The Sun	Making things hot
10 000 kJ	C	B	A	D	A	C	B
1 000 kJ	A	D	C	B	C	D	D
100 kJ	B	A	D	A	B	B	C
10 kJ	D	C	B	C	D	A	A

[Reference to support materials: Activity I2]

Using 'ladders of energy' makes the point that energy can be quantified and gives pupils a 'feel' for different values of energy. Our perceptions of amounts of energy are rather unreliable. It may appear to us that, for changes involving the same amount of energy, rather large effects are produced when things are made to move or are lifted up in comparison to the more modest effects when things get warmer.

In early work, such as the previous activity, it is best to focus on ladders which cover a range of values related to events which happen at the 'individual human scale' - walking a short distance or making a cup of tea. Later, the ladders can be extended to look at larger values of energy, such as those involved in a country's energy budget, or even further to the total amounts of energy involved in global processes such as solar radiation, winds and photosynthesis. It is important to think not just about *amounts* of energy but the *rate* at which energy flows, so 'ladders of power' are also useful. (See support materials Theme I 'How much energy?'.)

Ladders of energy or power are effective for comparing the values involved in *given* situations, but what if we want to explore what happens if we change the variables of these situations - such as looking at the effect on petrol consumed when a car's speed varies, or how much fuel could be saved if the insulation of a house is improved. The calculations involved are rather time-consuming, and in any case, most pupils would find them too demanding. However, estimates can be quickly and easily made using charts (known as 'nomograms') from which derived values can be read off. An example of the use of such a chart is given in the next activity.

Sample activity S - Keeping your home warm

This activity is about working out the cost of keeping a house or a flat at a higher temperature than the air outside. It is concerned with the rate at which energy escapes, which depends on the level of insulation and the temperature difference.

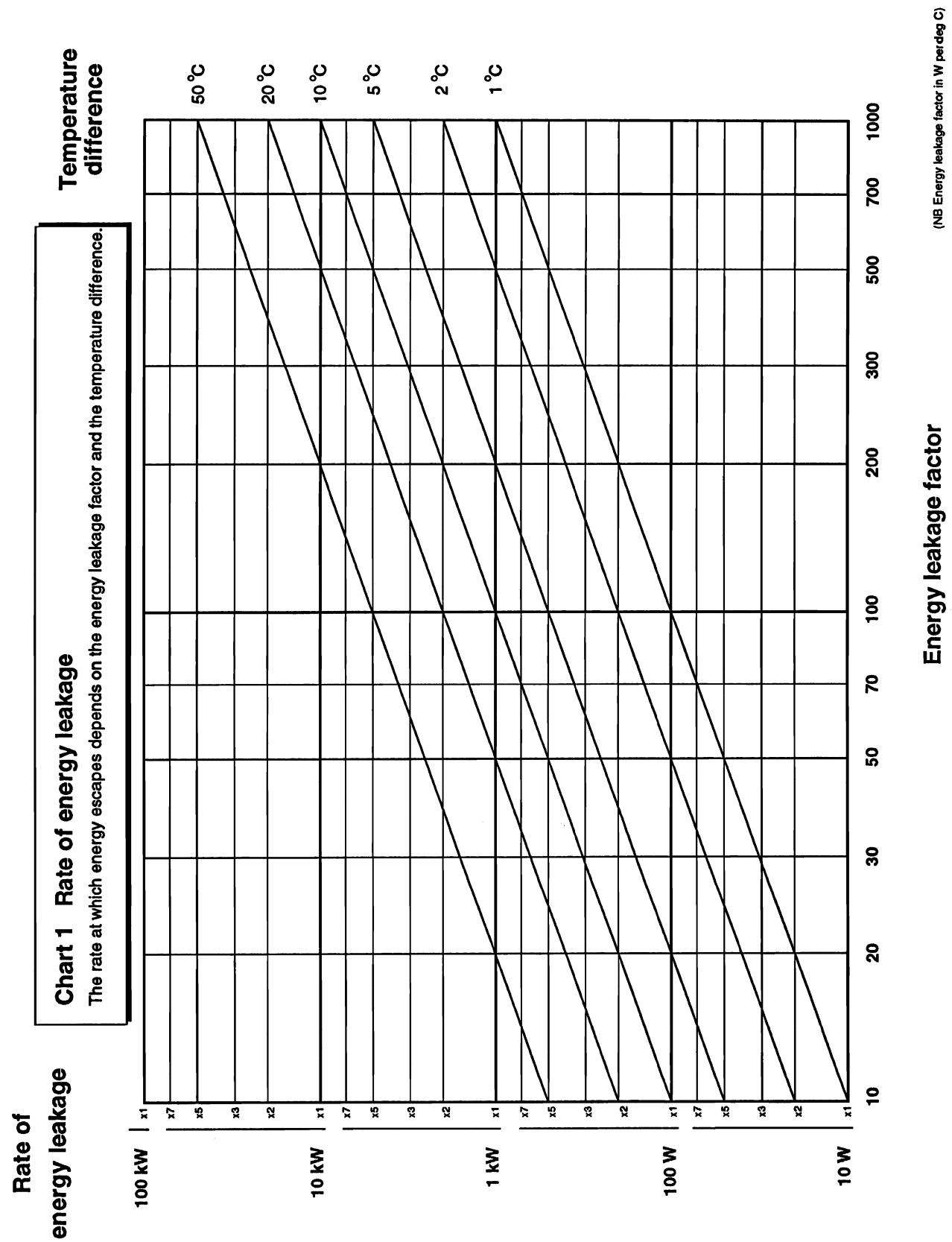
Only one of the charts used in this activity is given as an example here. The full set of tables and charts, and the instructions for using them to make estimates, are included in the support materials.

Keeping your home warm (continued)

Sheet 5

Chart 1 Rate of energy leakage

The rate at which energy escapes depends on the energy leakage factor and the temperature difference.



In working out the cost of the fuel required to maintain a building at a desired temperature, the first step is to work out the 'energy leakage factors' (The materials needed to do this are not included here, but some example values are shown below.). These are commonly called U values, and more detailed values can be found in many DIY books and books on home central heating. U values are the rate at which energy passes through a material with unit area through a temperature difference of $1^{o}C$. They are measured in units of $W/^{o}C/m^{2}$. In planning a central heating system, it is necessary to know the rate at which energy escapes from all of the rooms in the home, in order to install a radiator with the appropriate output to balance the energy escaping. The term 'energy leakage factor' has been coined here to emphasise what it is that is being measured. Note too, that the activity talks about energy 'leakage' rather than energy 'loss' - 'loss' may imply that the energy 'disappears'. Some typical 'energy leakage factors' are shown below:

	energy leakage factor $W/^{o}C$
A small ground-floor flat with good insulation	50
A small top-floor flat with poor insulation	130
An average-sized terrace house with poor insulation	210
A large detached house with average insulation	480

The chart included in this booklet (sheet 5) relates the rate at which energy leaks out to the level of insulation of the home (energy leakage factor) and the temperature difference between the inside and outside. It is calculated by multiplying the energy leakage factor by the temperature difference. Knowing the rate at which energy leaks out, it is possible to use other charts (not included) to estimate the amount of energy which leaks out (for different periods of time), and hence the cost of the fuel needed (for different fuels).

[Reference to support materials: Activity I6]

The previous activity looked at one aspect of fuel use in the home - keeping rooms warm (or 'space heating'). Other things in the home also need to be made hotter, and deserve attention. While rooms are kept at around 22°C, hot water is at a higher temperature (about 60°C), and cooking needs an even higher temperature (a typical oven is at around 350°C). Though cooking needs a high temperature it costs relatively little. There is not very much to make hot. Rooms need to be warmed only to quite a low temperature, but, being large, account for the biggest part of the fuel bill. Other activities (included in the support materials Theme I 'How much energy?') look at the cost of using electrical appliances and of running a car.

This section started by making the distinction between questions about the *direction* of a change and questions about the *size* of a change. All of the quantitative work in these activities has been concerned with the *sizes* of changes. At a more advanced level, we are also concerned with a quantitative treatment to determine the direction of changes, and this is discussed in the booklet 'Introducing a new approach'.

Teachers' reactions and pupils' responses

The activities in this booklet are all based on an approach which emphasises the way in which differences drive change, and which uses a novel set of abstract pictures to introduce these ideas. How do teachers and pupils react to this approach? Below, we discuss some illustrative examples.

Teachers' reactions

We will give some impression of teachers' reactions from two sources. A group of teachers in one school, who had used the materials, were interviewed afterwards to see what they felt about the experience. The same questions were also put, but in questionnaire form, to 42 teachers who had attended one-day INSET sessions about the materials, to test immediate reactions.

Thinking about the scientific ideas

One obvious issue is whether teachers saw the materials as raising fundamental scientific issues of importance and leading them to re-think some of their own ideas. All the teachers who attended the INSET days agreed that the ideas are fundamental and can help link together many parts of science, up to GCSE and beyond. All but a very few agreed that the work gets teachers thinking again about ideas they may not have been too sure of, and helps them sort out these ideas a bit better, though on another question one third doubted whether there were really new ideas.

Amongst the teachers interviewed, the head of science, agreeing that the ideas are fundamental, said:

> *"They're fundamental because they're probably essential ideas to understand ... that's what I found very satisfying about it ... none of it has been a waste of time ... if they can retain and build on what they've got it could have a very interesting effect if we could follow those groups through to GCSE."*

Another of these teachers looked to basics:

> *" ... the ideas behind what I was teaching were certainly very fundamental ... the children can't progress onto understanding the way matter behaves or about chemical changes unless they understand about mixing and things like that."*

She agreed that the materials had made her think, and that she had seen how they fitted ideas together:

> *"I had to think very hard on a couple of things ... it's good. Also I found it makes me really understand the ideas behind a lot of the things you're meant to be teaching them anyway ... You tend to do lots of things in isolation - in bits and pieces - for example the energy topic. You don't really see a progression or a theme and you definitely do when you're using these materials."*

The head of science saw potential benefit for staff as a whole, and for herself:

> *"As far as helping staff understand what they're trying to teach, it's a fresh way, you know, and if you're not sure of an idea it gives you a chance to check it with somebody else. I found it very interesting, particularly the idea of one change driving another ... sorting out ideas for myself ... I've found it at times very challenging, but enjoyable and quite rewarding."*

About whether there are really new ideas here, one teacher perceptively remarked:

> *"It brings to the fore ideas which are usually too buried, like the idea of always looking at the change."*

Children's understanding of the ideas

If the work challenges teachers, can pupils cope with it? Almost all the INSET teachers thought that the materials would keep children active and busy, discussing and thinking, but two thirds were worried that the pictures would prove too abstract and have too many hard-to-remember conventions. Three quarters saw the work as an accessible way of introducing the particle nature of matter for Years 8 and 9. But they were about equally divided on whether there is too much special and non-scientific vocabulary and on whether the materials could work with low ability pupils and ones with language difficulties. Nearly all thought that the materials could help teachers find simple ways of talking with pupils about energy and physical and chemical changes. And nearly all thought that the activities offer a challenge to higher ability pupils to think hard.

The teachers interviewed were from an inner city comprehensive with at least its fair share of children of modest ability, and whose pupils had at least a dozen first languages between them. These teachers tended to be particularly positive about the use of pictures and simple non-technical language:

> *"If you teach them what the diagrams mean ... then I didn't have any problems at all. Most of the children were understanding what they were meant to be seeing. I find it easier using the diagrams for our students that have lower English abilities ... that makes the work accessible to them."*

> *"I think if anything using simple words like spreading out and bunching together has made the children understand it straight away, and once they've got that understanding then you can use the proper words."*

> *"I've been very surprised at the number of times some of the less able children have come up with the right answer ... I'm convinced they are able to follow those pictures and apply them to new situations."*

They broadly agreed about the value of the discussions amongst pupils:

> *"It gets the kids talking to one another, so as a tool ... to introduce them to talking science it's good ... there's very few good materials to do that."*

Of course there were doubts mixed with positive reactions:

> *" ... the children can't find a book where they use words like concentrating and spreading out ... if the children want to go home and learn it won't make any sense."*

> *"One can spend a lot of time teaching the pictures. But the pupils whose language is poor or who are bilingual probably in the end get a better understanding than they would ... without the pictures. The benefits outweigh the problems."*

Broadly the teachers who used the materials saw it as working for most pupils and as challenging for many:

> *"It's working really well and the pupils really seem to have a better understanding - they could apply it to the extension work they are now doing".*

> *"Every single kid in the class, no matter what their ability, can get something out of it, and they do have to think about it before they can do it ... They are busy all the time. And positively on task."*

> *"I think some of it challenged (one of my best pupils). It was good for him - he would have to think about it. When he was writing his own examples he'd have to sit and think about that."*

> *"They were quite proud of themselves at actually having to understand something quite difficult - they liked that."*

Relating to practical experiences

In the activities, pupil discussion obviously has to be based on a lot of first hand experience, whether in everyday life or in the laboratory. Because we have concentrated on developing pencil-and-paper activities, it would be easy - but wrong - to suppose that we do not care about associated practical experience. What is needed is however already either being done or is rather obvious, so we kept our attention on what to do with that experience. The teachers doing the INSET seemed largely to take this point: two thirds denied that practical experiences might be better than all the work comparing pictures, and all but one or two agreed that it is easy to see how the activities could build on practical work. And nearly three quarters denied that the ideas are too general, better replaced by particular things to think about. The teachers who used the materials were clear about the need for a mixture:

> *"We did practical work before we went onto those things - (you need) a sort of a mixture really."*
>
> *"Instead of giving pictures of what's happening it could be done in front of the class."*
>
> *"I think some practical experiences are very confusing - there is no point in doing a practical if there's not been a lot of talk about it beforehand."*

Incorporating the materials into the curriculum

The materials are not a complete course, but are intended to be incorporated flexibly in existing schemes of work. Is this possible? Eighty percent of the teachers doing the INSET thought it would be possible to find places for the activities in their schemes of work, and more than three quarters agreed that they could easily be used alongside existing schemes. Amongst the teachers interviewed, the head of science saw some virtues related to the style of work and problems arising from the skills required of pupils and the effort required of teachers:

> *"I can see how I can find good places to fit the activities in because there's a lot of talking and discussing - you can often be glad of that emphasis. The Year 7 stuff, that is definitely going into schemes of work."*
>
> *"At the moment I believe it will be an extra to the scheme, but I think staff will dip into it and that's what we're going to encourage them to do rather than to say that this has got to be used."*

She was realistically clear that some of the work would take time to get absorbed into staff thinking:

> *The energy stuff, though I think it can be well integrated, I have a feeling that (the idea of) one change driving another will not be taught by many of us ... it would need an INSET on what it means. You're asking them to learn something else ... and since they've done it successfully in their opinion another way they might just stick to their other way."*

Aims and outcomes

Finally, we asked the teachers who had tried the materials what they felt the overall point of the approach to be. Their focus was on understanding, progression and fitting ideas together:

> *"The good thing about it is that it attempts to get the children to understand what is sort of going on if you like behind the scenes. What is causing things to happen and why things happen ... And I really like quite a lot of the stuff because it leads on directly to the ideas at a higher level - a simple example of that is chemical bonding."*

One teacher was a bit cynical about whether understanding was what was going to be tested:

> *"Everything now is seen as a vehicle for achieving better examination results. Nobody is interested any more in pupils understanding what's going on. And I don't doubt that this work helps kids understand things better, but whether it helps them understand examination questions better (I don't know)."*

The head of science, however, had an ambitious perspective on what might be achieved:

> *"Raising students' achievement through encouraging them to think more abstractly about changes. And more accurately perhaps."*

Pupils' responses

The approach is intended for a wide range of pupils, being both accessible to lower-ability pupils while being sufficiently challenging for more able pupils. The materials have been trialled in a variety of kinds of schools, though the extracts from pupils' discussion show below are selected to be typical of children of modest ability. Pupils' performance on some of the sample activities in this booklet is discussed, before turning to look at more general issues.

Insulation (Sample activity G)

Children often tend to see insulation as something which actively keeps or makes things hot, and think of 'cold' as well as 'heat' as being something that flows from one place to another. The abstract pictures in this activity aim to encourage children to start thinking of insulation as a barrier to energy flow from a higher to a lower temperature. The activity has been used with a number of different Y8 groups. Nearly all pupils were able to use the abstract pictures to make matches which they could justify with a reasonable explanation. Even though some children do not differentiate the meanings of heat, energy and temperature, they still attempted to think in terms of *differences* and *flows*.

> *"The hot chocolate is hotter than the room temperature ... and when the hot chocolate is left in the room, 'cos the room is colder the energy goes out of it and the hot chocolate starts to get cold slowly."*

> *"Because the frozen food left on the table and the food is colder than the room and the room temperature melts the frozen food ... the energy is going into the food and makes it warmer."*

Explanations in which concepts are not differentiated can be useful starting points for teachers to discuss with pupils:

> *"The food is more colder so the room temperature will go into the food and the newspaper is not that powerful so the room temperature will slowly go into the newspaper wrapping the food."*

A number of pupils managed quite sophisticated explanations, referring explicitly to the pictures. Here, a pupil is explaining what happens to a hot chocolate drink in a cup and in a thermos flask:

> *"The hot chocolate is hotter than the room temperature so this* (the central region in the representation) *is darker* (i.e. hotter with energy more concentrated) *and when the hot chocolate is left in the room, because the room is colder the energy goes out of it* (the chocolate) *and the hot chocolate starts to get colder slowly. This one in here* (in the vacuum flask) *- the hot chocolate is still hotter than the room so it's darker but it stays the same, as it's in the vacuum flask so no heat will come out and no heat will come in."*

Supported by these abstract pictures, many pupils were able to give extended explanations like this. Differences in choices of representations can also provoke a fundamental discussion, here about whether heat and cold are two things or just aspects of one thing:

> One choice of picture:
> *"It's colder on the inside, and then the energy from the heat on the outside is going in making it warmer, and when it's in the vacuum flask the coldness just escapes making it warmer."*
> A different choice of picture:
> *"Mine's the same really but the cold doesn't escape - the insulation makes the lemonade warmer."*
> *"That's what I meant - the insulation makes it warmer."*
> *"No but that means if the insulation made it warmer the cold wouldn't go out but the heat would come in - so the heat goes in not comes out."*

Using the abstract pictures appeared to encourage pupils to pay attention in their explanations to important features of these situations, such as temperature differences and energy flows.

Everyday changes (Sample activity J)

This activity introduces pupils to the use of particle pictures to represent physical and chemical changes, and encourages them to think about the nature of these changes, such as whether particles are staying the same or new particles are forming and whether substances are changing state. As in the previous example, most pupils in Y8 and Y9 are able to make matches which they could justify with an explanation referring to relevant features of the abstract pictures Some typical reasons for making matches are:

> (Alka Seltzter in water)
> *"Because that is solid and this is liquid and they react as gas and they ... "*
> *" ... they mix together, and that dissolves into the liquid and releases gas."*
>
> (blood clotting)
> *"Blood's a liquid first, red colour, and then it forms a clot and it changes colour. It goes to black doesn't it? And it becomes a solid afterwards."*
>
> (using bleach on a stain)
> *"Because you see the solid part with the dirt and the bleach, you mix it, then the dirt disappears, the stain disappears."*

In many cases, the pictures prompted pupils to have extended discussions about the nature of a change or a substance. For example, they may consider whether air is involved in glue becoming hard, whether the nature of blood changes when it becomes a solid, whether the clothing is involved in the removal of stain by bleach, or, as shown below, what rust remover is like and the nature of an aerosol:

> *"Because it* (the abstract picture chosen by the pupil) *shows a gas mixing with a solid the solid changes colour ... the rust remover is the gas."*
> *"It might not be a gas - it might be in a bottle."*
> *"You don't see a spray can. It's rust remover ... it's a liquid."*
> *"As it sprays it's a gas and a liquid ..."*
> *"How is it a liquid?"*
> *"Because it is a liquid in a can and when you spray it is a gas."*
> *"Yeah, it's like shaving foam inside."* (They had recently discussed the nature of shaving foam.)

Using these kinds of abstract pictures can lead to two kinds of problems for pupils. The first is that it makes explicit children's problems in understanding the nature of a change. This is a very positive aspect of the approach. For example, since in these pictures different substances are represented by particles of different shading, pupils are prompted to talk about whether substances change or stay the same. Some pupils are better able than others to identify these correctly.

> *"It's still the same substance but it changes. It just bended."* (spoon bending)
>
> *"That changes substance and that changes shape."* (butter melting and spoon bending)
>
> *"Because it shows a liquid turning into a solid but it is the same substance."* (glue hardening)

The second, and less desirable, problem is the relatively few pupils who have difficulties in interpreting the conventions correctly. For example, some pupils interpreted the shading of the particles to represent substances of different *colours*, though most understood that it merely implied different *substances*, even when this was counter-intuitive.

> *"The clothes is the black one and the dirt is the white one."*

Sometimes the pictures raise fundamental issues, such as when, occasionally, a few pupils refer to fire or heat as being represented in the pictures:

> *"It's a solid (wood) but I don't know what the fire is - is it a solid, liquid or a gas?"*

Such points are particularly useful to be taken up by a teacher to discuss with pupils.

Things that 'just happen' and things that don't (Sample activity H)

This activity introduces pupils to the fundamental notion that spontaneous changes can drive non-spontaneous changes. The situations in the activity are chosen to be as straightforward as possible, in order for pupils to be able to focus on understanding the conventions. Groups of Y9 pupils, over a month after they had done this activity and other activities using similar conventions, were shown some examples of these pictures and asked to explain in their own words what they understood by them.

Pupils had no difficulty in interpreting the picture which shows a hot object spontaneously cooling as energy flows from it to the cooler surroundings.

> *"Something hot losing energy - getting cold."*
>
> *"This is a room and this is a block and it is giving heat to the room and becoming the same temperature as the room."*
>
> *"This happens usually, naturally."*
>
> *"It just happens normally."*

They also had no difficulty in interpreting the reverse change.

> *"It's showing taking energy in."*
>
> *"This is an example right. There is a glass of water and to make it hot just wouldn't happen."*
>
> *"It does happen, but it is difficult to make it happen."*

"It doesn't happen naturally but people ... You can make it happen."

On the whole, they were able to interpret the pictures which show objects slowing down and speeding up, though occasionally, a few pupils interpret the 'moving object' symbol as meaning that the object is moved by the action of an agent (the 'wind').

"Something that is going fast and then slows down."
"Something starts moving."
"Natural and.."
"One works - that one - and that one doesn't usually happen."
"Poltergeist!"

"Something that is moving and that is slowing down - stopping."
"Could be the wind that is pushing it or it just happens."

Finally, pupils seem to grasp the essential nature of coupled changes.

"This is the argument that it's possible, yeah? So you use something that is possible to make something that is impossible possible!"

"The 'down' one is something that happens and the 'up' one is - someone has to make it happen."

The idea that changes which 'just happen' can drive those which do not 'just happen' is unfamiliar in school science, and at first the pictures which represent them may seem rather abstract. In fact, pupils pick up the idea quite readily, as the few examples above suggest, and are able to remember them even after a period without using them.

Fuels and food (Sample activity O)

Perhaps the most difficult idea in all of the activities is the notion of a' chemical spring'. The extracts below are from discussions of Y8 and Y9 pupils doing an activity in which they need to distinguish energy released from hot objects and from 'chemical springs' as well as understanding the idea of changes which 'just happen' and those that do not. Ideally, the pupils would have had much more experience of building up their understanding about the approach over a long period of time. In fact all of the relevant work on using the abstract pictures had been done in the few weeks before the activity.

The pupils made correct matches in very many of the situations, and were able to give explanations using relevant features of the pictures. Some situations are rather easier than others to explain, since what is identified as the 'system' is less open to inerpretation. Here, pupils explain correct matches:

"Like something happens by itself ... so ... it's from stored to released.
"Because energy was inside and it went outside." (torch battery)

"Because it goes from hot to cold, and it's heat and energy is being released." (bath cooling)

"Because it's stored and then it's released which makes the car move." (petrol used in a car)

"Someone's driving that to get hot." (light bulb)

"Number 6 then, because that's like pulling chemicals and things (6), and this is just cooling down (5)." (person running)

However, some situations are more complex and are open to different interpretations depending on the features to which pupils pay attention. Wood burning and photosynthesis are examples of such situations. Like a torch battery, when wood burns energy is released from a 'chemical spring'. However, as it burns, the system makes itself hot, and energy also flows into the cooler surroundings, and pupils also pay attention to these features.

> *"It's the wrong picture (2). That's the release of stored energy. It is number 1 because it's like going from hot to cold."*

> *"That's between hot and cold (1)."*
> *"That's stored energy (2)."*
> *"Can be both but because heat is fire ... so it goes with number one."*

> *"Because the energy is stored up and then it's being released and it happens by itself, so I thought it was number two."*

> *"Something is making that burn, and like it's getting hotter and energy is being used (3)."*

Most pupils seem aware in their answers that a plant growing is not a change which 'just happens by itself' but is a change which needs to be driven. However, they may see a plant growing as essentially a change in which an object needs to be moved, rather than one in which a fuel is being made. So some pupils chose pictures which represented energy from Sun seen as driving change to make something move (5) or energy from food making something move (6).

Pupils were also asked whether there were any similarities between situations that they had matched to the same abstract picture.

> 'an electric light bulb gets hot' and 'using a kettle to boil some water'
> *"Energy is being stored up "*
> *"Something is driving the water, something has to drive the light bulb."*
> *"It doesn't just happen by itself."*

> 'petrol is used in a car engine' and 'a person uses up food running a race'
> *"You gotta put energy in and then take it out - use it, burn it up, in other words."*
> *"That is stored ... "*
> *"That is driving that."*
> *" ... but then it's released. It's stored then it's released, but then the person's running."*

Using the abstract pictures pupils were able to see more fundamental similarities between different changes than in an earlier activity, in which they had to identify similar changes but without the support of the abstract pictures.

General issues

The above discussion gives some impression of what pupils are able to achieve on a few of the activities, but also raises some more general issues. We discuss some of these issues in more detail now, including some further examples.

Can pupils use the pictures effectively?

At first sight the pictures may appear to be abstract and difficult for pupils to manage, but it is our experience that in general, pupils are able to understand the conventions. The focus of their discussion

is, as we would hope, about the *nature of the changes* and not about the *meaning of the conventions*. This Y8 pupil is explaining why 'wood burning' could be matched to the picture of a 'chemical spring':

> *"The wood is now burning so nothing needs to happen to make it burn more. OK, I know you have to light a fire to make the wood burn but now that it's already burning you don't need anything else to make it burn more. It's burning and it's burning and it's just happening by itself and the energy is going out and the thing is getting cold."*

This explanation is about the spontaneity of the change and what is happening to the energy. In contrast, these pupils are also considering the same match, but are discussing their confusion about what the pictures say. Such discussions about the meaning of conventions are rather rare.

> *"But that's not saying that you're having energy back, that's just saying energy is escaping same as that."*
> *"No you can ... it joins back doesn't it ... this shows like a spring stretching coming back together again."*

The pictures often prompt pupils to have extended discussions about the nature of changes, as in this Y8 group which is considering which picture is best at showing the way that energy is stored when a plant grows:

> *" ... because it does need energy to grow it gets energy from the sun and ... "*
> *"And it doesn't happen by itself."*
> *"Right, does it get warmer?"*
> *"It doesn't get warmer but that's a problem."*
> *"Yes I mean it needs energy to grow but a different kind of energy."*

After further discussion, they consider what is happening to the particles during the change.

> *"No it's not getting warmer but it's ... "*
> *"I think it might be one of those."*
> *"I think it might be the other one."*
> *"It could be, maybe by splitting the particles it's making it grow bigger ... "*
> *" ... we are storing energy in the plant by making it bigger but it doesn't get warm."*
> *" ... first the particles are together and then the energy goes in and splits the particles into parts and it's stored itself in the particles."*

We have designed the classroom activities with a view to encourage extended discussions between pupils.

Can pupils use the scientific ideas introduced in this approach?

The theme running throughout all the activities is that changes are driven by differences. In the secondary school, the development of this idea can be started by identifying differences in concentration and temperature, and thinking about changes as involving 'spreading out' or 'bunching together'. Some Y7 pupils are explaining why they matched various situations to abstract pictures:

> 'sweating to stay cool'
> *"It's because when you get rid off the water from you body it spreads out into the air. It evaporates."*

> 'crystals forming in copper sulphate solution as it cools'
> *"Before it was like solution right, it wasn't like a part and then it turns into copper sulphate crystals so it bunches together to make a crystal."*

'a cold drink left out in the sun'
"Because the sun is hot and the drink is cold and when the sun heats the drink up it becomes the same temperature."

In general, pupils are able to make sense of the scientific ideas that are introduced, and to use them in their discussions.

How can the approach help in the further development of pupils' ideas?

Pupils bring to the classroom their own ideas about energy and change, and merely using a pictorial language will not move their thinking towards a more scientific point of view. However, the pictures are a useful tool to stimulate discussions and explanations in which pupils make their ideas more explicit. Conflicts about ideas can help pupils to see things a different way, and it is particularly valuable for teachers to pick up on these ideas so that they can further develop pupils' scientific understanding.

In this example, pupils are discussing whether a plant growing should be seen as a case of 'spreading out' or 'bunching together'. In the sense in which these terms are used in the activities, substances from the environment become more concentrated or 'bunched together' in the plant, though commensense suggests that a plant 'spreads' as it grows.

" ... the plant needs food to eat and grow so it is bunching together. How is it spreading out?"
"It is spreading out because the leaves can't all stay together in one line and all the leaves are stuck on together and bunches."

We have already seen other examples in the activities described above, which teachers can use as a basis for discussion with pupils, such as the idea that plant growth can be thought of as a change in which an object is moving, the notion that fire is a substance or the belief that temperature differences can lead to flows of both 'heat' and of 'cold'.

What would count as progress?

There are two ways in which we might look for progress in pupils' performance. A particularly striking aspect in the use of these pictures, which we have already hinted at in a number of places above, is that they tend to stimulate pupils into more extended and fundamental discussion about the nature of changes.

In this example, a group of Y8 pupils are trying to put a number of different changes into similar groups and are discussing in what ways 'charging a car battery' is similar to 'pulling a catapult to get ready to fire a stone'.

"Yes because charging a car battery you're charging so that it can work ... and so the car can go and ... the other one is you're getting it ready to fire ... "
"It's only been used once ... so you're putting something else again to let it go, you're making that ready again."

After being given a set of abstract pictures to which they need to match all of the changes, their thinking moves on to consider more fundamental aspects of the changes:

"They both need energy."
"And they both need something to make it happen."
"They both need something to make it go or something to add to it to make it go."

So, in the short-term, we can expect to see progress in the level of pupils' discussion when they are introduced to activities using the pictures. The second sense of progress is in the development of pupils' ideas as a result of being taught about this approach to energy and change, for which evidence needs to be sought in what pupils do when they are engaged in activities which are not supported by the picture language.

In this activity, some Y8 pupils are putting changes into similar groups. They are considering the change 'a hot bath cools down' and trying to decide what it is most similar to - 'a cold drink left out in the Sun', 'hot lava from a volcano turns solid', 'ice forming on a pond', and so on.

"It could go with drinking water."
"Because the hot bath gets cool and the cold drink gets warmer ... "
"It could go with this because when the lava forms it gets cool."
"Or it could go with the ice because the ice is cold and the bath water gets cold."
"Yes, the ice gets cold."

Several months later, the same pupils are doing a similar activity. During this period they have had a number of lessons in which they used the abstract pictures, though they are not using the pictures in this activity. They identified 'a hot bath cools down' and 'ice forming on a pond' as similar changes more readily than they did in the first activity, and go on to give an explanation in terms of energy.

"Because the hot water is giving out all the energy and get cools down and the ice forming on a pond ... the pond was normal and it gave out all the energy it had and became ice."

It is always important to remember that the pictures are merely a device to promote pupils' discussion and their scientific understanding. Learning to use the picture language is *not* an end in itself, so progress must be seen in relation to pupils' conceptual development and not simply in their mastery of the pictures.

Support materials

The pupil activities shown in this booklet have been selected from the large number of activities which were developed during the work of the project. A set of booklets, with a comprehensive range of pupil activities covering all of the ideas in the approach, is available direct from the Institute of Education in London. Each booklet consists of a set of A4 photocopiable masters for about 8 pupil activities, with accompanying teaching notes. There is also a booklet of INSET materials to support the introduction of the approach to teachers.

A Mixing and 'unmixing'
Simple changes to substances, e.g. dissolving and mixing, purifying and separating mixtures.

B Hot and cold
Temperatures differences, warming and cooling, ways of making things hot, introducing energy.

C Solids, liquids, gases
More changes to substances, e.g. smells and air pollution, evaporation and other changes of state.

D Living things
Processes of life, e.g. how living things obtain and get rid of substances from their surroundings.

E Energy from hot to cold
Pictures of temperature differences and energy flow, e.g. Sun/Earth, human body, insulation, burning.

F Particles and change
Pictures of physical and chemical changes, e.g. melting, combustion, corrosion, metal extraction.

G Up and down in complexity
Building up and breaking down molecules, e.g. fermentation, photosynthesis, decay, polymerisation.

H Fuels and food
Storing, transferring, releasing energy, e.g. engines, fuels, electrical cells, photosynthesis, respiration.

I How much energy?
Quantitative activities on energy, e.g. simple 'ladders' of energy, efficiency, costs of domestic fuels.

J Flows of matter and energy
Keeping things in balance, e.g. weather, organisms, food chains, carbon cycle, ecosystems.

K INSET pack
Materials to support the introduction of the approach to teachers.

Energy and change - support materials

For further details about ordering these support materials, please return this form to BMBC Bookshop, University of London Institute of Education, 20 Bedford Way, London WC1H 0AL (or telephone 0171-612 6050).

Name _____

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