Contents

Preface

To the student

Science is the study of everything in the universe and scientists go about their studies in a very special way. They use the scientific method, which is about making a scientific enquiry or investigation. It helps scientists build up knowledge – scientific knowledge – about how things are and how things happen.

Science, then, has two parts. One part is about making a scientific enquiry and this process involves having ideas, making observations and carrying out investigations. The other part is the huge collection of scientific facts – from the colour of a butterfly on a tree or the shape of a galaxy in space to what happens when we breathe and how a volcano can suddenly blow its top! In this book, we are going to look at how you can make scientific enquiries too, and how *you* can also learn about the many facts that scientists have discovered.

Checkpoint Science covers the requirements of your examinations in a way that I hope will help you understand how observations, investigations and ideas have led to the scientific facts we use today. The questions are set to help you extract information from what you read and see, and to help you think more deeply about each chapter in the book. Some questions are set so you can discuss your ideas with others and sometimes develop a point of view on different scientific issues. This should help you in the future when new scientific issues, which are as yet unknown, affect your life.

The scientific activities of thinking up ideas to test and carrying out investigations are enjoyed so much by many people that they take up a career in science. Perhaps *Checkpoint Science 1* might help you to take the first step towards a career in science too.

To the teacher

Checkpoint Science 1 has been developed from *Checkpoint Biology*, *Checkpoint Chemistry* and *Checkpoint Physics* to cover the requirements of the University of Cambridge International Examinations Checkpoint tests and other equivalent junior secondary science courses. It also has three further aims:

- to help students become more scientifically literate by encouraging them to examine the information in the text and illustrations in order to answer questions about it in a variety of ways
- to encourage students to talk together about what they have read
- to present science as a human activity by considering the development of scientific ideas from the earliest times to the present day.

The Student's book begins with a chapter called *Introducing science* where the separate sciences of biology, chemistry and physics are presented in the context of the work of present day scientists. Items of general laboratory apparatus, including the Bunsen burner and spirit burner, are introduced before the requirements for scientific enquiry are set out for stage 7 of the Cambridge Secondary 1 Science Curriculum. This is followed by a feature on the history of the development of scientific enquiry, and then the students are set tasks that are involved in carrying out investigations. The chapter ends by looking at safety in the laboratory.

The chapters that follow are arranged in sections with Chapters 1–7 addressing the learning requirements for biology stage 7, Chapters 8–12 addressing the learning requirements for chemistry stage 7 and Chapters 13–17 addressing the learning requirements for physics stage 7 of the Cambridge Secondary 1 Science Curriculum.

The Student's book is supported by a Teacher's resource book that provides answers to all the questions in the Student's book – those in the body of the chapter and those that occur as end of chapter questions. Each chapter is supported by a chapter in the Teacher's resource book which features a summary, chapter notes providing additional information and suggestions, a curriculum framework reference table, practical activities (some of which can be used for assessing science enquiry skills), homework activities, a 'lesson ideas' section integrating the practical activities and homework activities, and an end of chapter test which has been prepared in the style of Checkpoint tests.

Peter D Riley
May 2011

BIOLOGY

1 The characteristics of living things

- Comparing living things with those that have never lived
- Signs of life and animals
- Signs of life and plants
- Eating and feeding
- Respiration
- Movement
- Irritability
- Growth and reproduction
- Excretion
- Testing for carbon dioxide

Biology is the study of living things. In this chapter, we are going to look at the features or characteristics that something must have for us to identify it as a living thing.

Living and never lived

You can make two groups of things – living things and things that have never lived. The klipspringers in Figure 1.1 are living things, but the rock they are standing on has never lived.

Figure 1.1 Klipspringers live in parts of the African savannah. They spend the hottest part of the day resting among rocks.

1 How is a living thing different from something that has never lived?

For discussion

If you grouped things into living things and things that have never lived, where would you place a block of wood?

Signs of life

If something is called a living thing, it must have seven special features. These are called the characteristics of life. The characteristics are:

- feeding
- **respiration**
- movement
- growth
- **excretion** (getting rid of waste)
- **reproduction**
- **irritability** (being sensitive to the surroundings).

These activities are also known as life processes.

2 Which characteristics of life are shown by the mice in the pictures A–D in Figure 1.2?

3 Does each of the following have any characteristics of life? Explain your answers.

a) an aeroplane
b) a computer
c) a brick

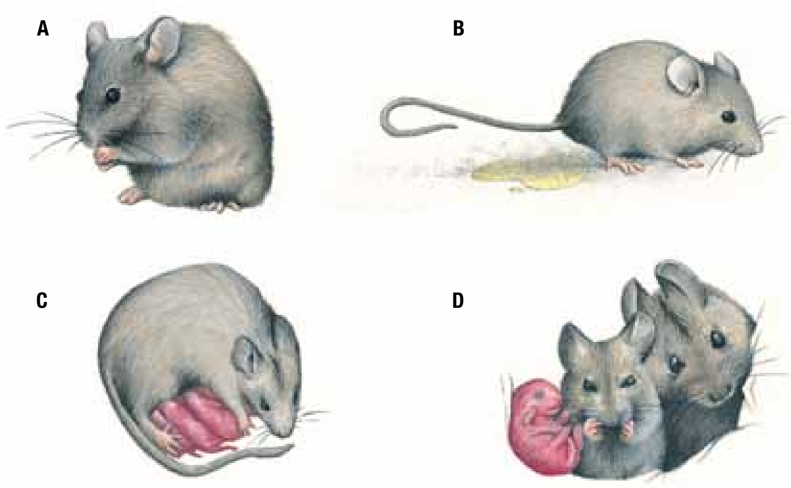

Figure 1.2 Four of the characteristics of life

Figure 1.3 This desert locust is shedding its last skeleton. Here the wings are rolled together, forming an arch on the locust's back.

Animal life

All animals have the same seven characteristics of life but they may show them in different ways. For example, all animals grow, but some have a skeleton on the outside of the body and can grow only when they shed the old skeleton and stretch a new soft skeleton beneath before it sets. Insects and spiders do this by taking in air. Crabs and lobsters stretch their new skeletons by taking in water. Animals with skeletons inside their bodies simply grow larger without having to shed their skeletons.

All living things respire, and most of them use oxygen for this. Many animals living on land have lungs, in which they take oxygen from the air. Many aquatic animals have gills, which take up oxygen dissolved in the water.

Figure 1.4 This axolotl lives in Lake Xochimilco in Mexico. Its gills are on the outside of its body behind its head.

Plant life

4 How is a green plant's way of feeding different from an animal's way of feeding?

Green plants also have the same seven features but they show them in different ways to animals. Plants make food from carbon dioxide in the air and water, by using energy from sunlight. Chemicals in the soil are also needed, but in very small amounts. All plant cells respire and gaseous exchange takes place through their leaves.

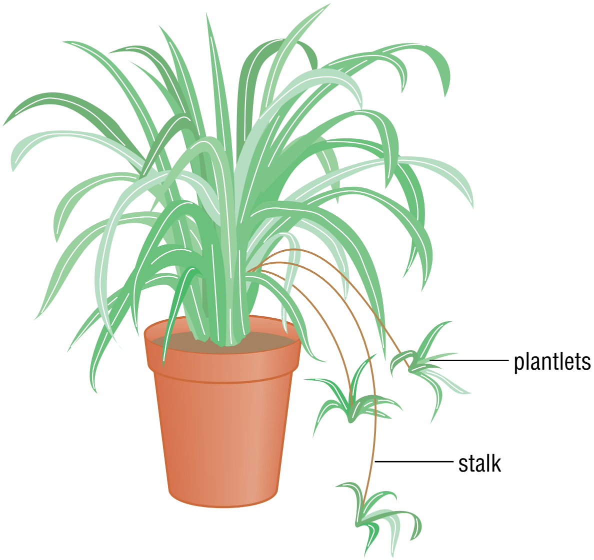

Figure 1.5 The spider plant grows in many moist woodlands in the warmer regions of the world. It amakes plantlets on stalks.

For discussion

A car may have five of the characteristics of life. What are they and how does the car show them?

If there are drought conditions, why might a plant produce seeds rather than grow new plantlets?

Plants move as they grow and can spread out over the ground. Wastes may also be stored in the leaves. Green plants are sensitive to light and grow towards it. Plants reproduce by making seeds or spores. Some plants can reproduce by making copies of themselves, called plantlets.

Looking at signs of life

Eating and feeding

All living things need food. Plants make their own food but animals must get it from other living things. Some animals, like ourselves, eat a wide range of foods, while others eat only a small range of foods.

In the rainforest ticks, lice, leeches and mosquitoes feed on just one food – blood. They have mouths that can break through skin and suck up their meal. Every animal has a mouth that is specially developed or adapted for the animal to feed in a particular way.

Figure 1.6 These leeches are being used to draw out blood as part of a medical operation.

5 How many different kinds of foods do you eat?

6 How is the mouth of a crocodile adapted for feeding?

Respiration

Respiration is the process in which energy is released from food. The released energy is used for life processes such as growth and movement. Respiration takes place in the bodies of both plants and animals. It is a chemical reaction. During respiration, a food called glucose reacts with oxygen to release energy, and carbon dioxide and water are produced. The word equation for this chemical reaction is:

$$\text{glucose} + \text{oxygen} \rightarrow \text{carbon dioxide} + \text{water}$$

Respiration should not be confused with breathing, which is the process of moving air in and out of the body (see page 39). Later, when you study how plants make food, you must remember that while the plants are making food in a process called **photosynthesis** they are also respiring to stay alive.

Movement

Let your right arm hang down by your chair. Stick the fingers of your left hand into the skin in the upper part of your right arm (above the forearm). Raise your right forearm and you should feel the flesh in the upper arm become harder. This is muscle, and it is working to move your forearm upwards. Muscles provide movement for all animals. Animals move to find food, avoid enemies and find shelter. Even when an animal is sitting or standing still, muscles are at work. On page 39 you can see that the diaphragm muscle helps you to breathe, and there are muscles between your ribs that move them up and down. Inside your body your heart muscle pumps blood around the body, and muscles in the wall of your stomach churn up your food to help it digest.

Irritability

Animals detect or sense changes in their surroundings by their sense organs. These are the skin, eyes, ears, tongue and nose. Some animals such as insects and centipedes have long antennae, which they use to touch the ground in front of them. The information their brains receive helps them decide if it is safe to move forwards.

Figure 1.7 This grass snake is collecting chemicals in the air with its forked tongue. Grass snakes live in Europe and Northwest Africa.

Like many animals, we use our eyes and ears to tell us a great deal about our surroundings. We use our tongue and nose to provide us with information about food. If it smells and tastes pleasant it may be suitable to eat, but if it smells and tastes bad it could contain poisons. The snake shown in Figure 1.7 appears to be tasting the air when it sticks out its tongue, but it is really collecting chemicals in the air, such as scents. It draws its tongue back into its mouth and pushes the tip into a pit in its nose where the chemicals are detected.

Growth and reproduction

Living things need food for energy to keep the body alive and for materials. They need the materials for growth and to repair parts of the body that have been damaged. Young animals, like the baby elephants in Figure 1.8, need food to grow healthily.

Figure 1.8 Elephants live in large family groups called herds, ruled by an elderly female called a matriarch. African elephants, like these, have large ears while the Asian or Asiatic elephant has smaller ears.

Once the elephants are fully grown, they need food to keep themselves in good health and to produce offspring. If the elephants did not produce offspring the herd would eventually disappear as the old elephants died. **Reproduction** is the process that keeps a plant or animal species in existence.

Excretion

When food and oxygen are used up in the body, waste products are made. These are poisonous, and if they build up inside the body they can kill it. To prevent this from happening, the body has a way of getting rid of its harmful wastes. It is called **excretion**. Wastes are released in urine, sweat and the air that we breathe out. The waste product we release in our breath is carbon dioxide.

Testing for carbon dioxide in exhaled breath

You can test your exhaled air for carbon dioxide by passing it through limewater (Figure 1.8). If carbon dioxide is present it reacts with the calcium hydroxide dissolved in the water to produce insoluble calcium carbonate. This makes the water turn white or milky.

For discussion

How could you adapt the apparatus shown in Figure 1.9 to find out:

a) if other animals produce carbon dioxide

b) if plants produce carbon dioxide?

7 What scientific enquiry skills are you using in answering the questions in the box above?

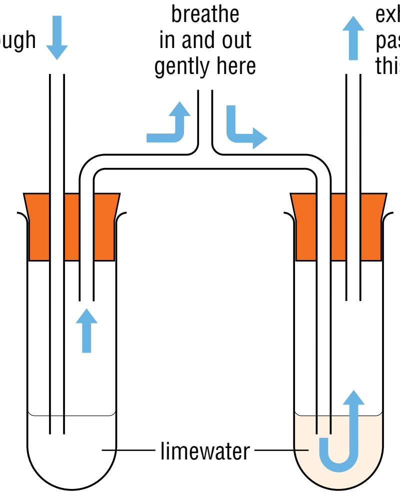

Figure 1.9 Testing inhaled and exhaled air for carbon dioxide

Testing for carbon dioxide in air around seeds

Carbon dioxide production can be used as an indication of respiration and a sign of life. Hydrogen carbonate indicator is a liquid that changes colour in the presence of carbon dioxide. It changes from an orange-red colour to yellow. The production of carbon dioxide by germinating pea seeds can be shown by setting up the apparatus in Figure 1.10.

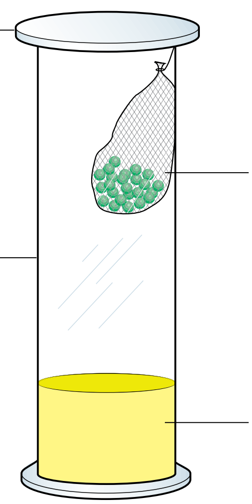

Figure 1.10 Investigating carbon dioxide production by germinating pea seeds

For discussion

The apparatus shown in Figure 1.10 could be used to show that maggots release carbon dioxide. Should animals be used in experiments to show signs of life such as respiration?

Looking for life beyond the Earth

Almost everyone has an opinion about alien life in space but how do scientists go about investigating it? In the 1970s, the Viking missions to Mars took place and this provided scientists with a chance to devise a scientific investigation to test for signs of life.

For discussion

What is your opinion about alien life? Explain your answer.

In the first stage of the investigation, scientists thought about the link between food and respiration. They reasoned that if living things were present in the soil they might be detected in the following way. Water containing food could be put into the soil. If living things were present in the soil, they would feed on the food and produce carbon dioxide in respiration. So if carbon dioxide was detected in the soil, living things were present. Apparatus was then designed to dig up the soil and put it in a container where food and water was added. As Mars is much colder than Earth, a heater was built around the container to warm up the soil and make the living things, if they were present, feed and respire faster.

Figure A A Viking lander on Mars with its digging tool ready to scoop up Martian soil for testing

When the spacecraft reached Mars, the soil was tested and carbon dioxide gas was detected. It seemed that the gas had been produced by living things, but when the evidence from other investigations taking place there was considered, the scientists concluded that there could be other explanations for the gas being produced. More missions to Mars are planned in the next few years to re-test the soils for living things.

Scientists are also planning to look for living things on a moon of Jupiter called Europa. In the first stage of their investigation, they are considering the following evidence to support their idea. **Space probes** indicate that there is a strong possibility of oceans of water on Europa, beneath a thick icy surface. We know that water is needed for life on Earth. Deep in the Earth's oceans, hot springs of black water have been found, called black smokers. The water contains large amounts of a substance called hydrogen sulphide. Some tiny forms of living things have been found which use this substance for food. Perhaps there are black smokers and tiny living things on Europa.

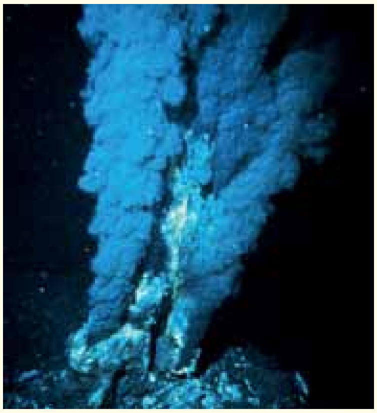

Figure B A black smoker on the ocean floor

1 The scientists used feeding and respiration as characteristics of life to investigate. How could irritability and movement be used to plan an investigation?

2 Did the investigations show that the gas definitely did *not* come from living things? Explain your answer.

3 What kind of equipment would need to be carried on a space probe to Europa to look for life on its ocean floor?

4 In planning the first stage of the investigation, what was the idea to be tested?

5 What pieces of evidence for life would help you decide how to plan an investigation to look for life on Europa?

◆ SUMMARY ◆

- There are seven characteristics of life – feeding, respiration, movement, growth, excretion, reproduction and irritability (*see page 21*).
- Green plants make food from carbon dioxide and water (*see page 22*).
- Animals must obtain food from other living things (*see page 23*).
- Energy for life processes is released in respiration (*see page 23*).
- Muscles provide movement for all animals (*see page 24*).
- Sense organs are used to detect changes in the environment (*see page 24*).
- Food is needed for growth (*see page 25*).
- Plant and animal species stay in existence through reproduction (*see page 25*).
- Excretion is the release of harmful waste products (*see page 25*).
- Limewater is used to test for carbon dioxide (*see page 25*).
- Hydrogen carbonate indicator is used to test for carbon dioxide (*see page 26*).

End of chapter questions

The apparatus shown in Figure 1.11 is set up to show that seeds use up oxygen when they respire. The soda lime absorbs any carbon dioxide in the tube.

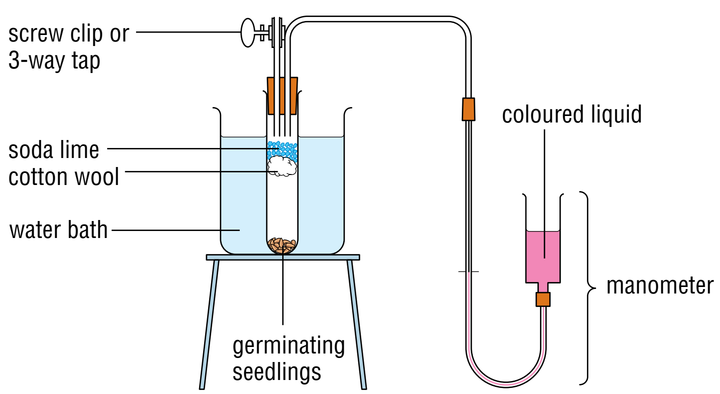

Figure 1.11

1 What happens to the coloured liquid in the tube as the seedlings respire?

2 Why does the volume of the gas around the seedlings change?

3 How would you use boiled seedlings to show that any change of gas was due to respiration?

10 Acids and alkalis

- The meanings of the terms ‘acid’ and ‘alkali’
- Acids produced by living things
- Organic and mineral acids
- Uses of alkalis in the home
- Detecting acids and alkalis using indicators
- The pH scale
- Neutralisation
- Using neutralisation reactions
- Acid rain and its prevention

In Chapter 9, we looked at different kinds of substances and examined their properties. In this chapter, we are going to look at two kinds of solutions that are widely used in science. They are called acids and alkalis.

Early acids and alkalis

People have known since the time of the Ancient Egyptians and Greeks that some substances taste sour and some feel slippery. Vinegar is probably the best example of a sour-tasting liquid that early peoples would have known about. Early examples of slippery substances included potash found in the ashes of burnt wood, soda made from the evaporation of some **solutions**, and lime made from the burning of seashells. Scientists developed the word acid from *acidus*, which is the Latin word for ‘sour’. The word alkali was developed from *al-qaliy*, which is an Arabic word meaning ‘the ashes’.

A great deal of early investigative work in chemistry was done in Muslim countries, starting about 1200 years ago. Probably the greatest of the Muslim chemists at this time was Jabir ibn Haiyan who was also known as Geber. He worked on many investigations, which resulted in him devising new apparatus and discovering different kinds of acids.

1 Look at the alembic in Figure 10.2 and the Liebig condenser in Figure 8 on page 6.
How are they:
a) similar
b) different?

2 Which piece of apparatus do you think condenses water faster and why?

Figure 10.1 This is a laboratory in Geber's time. It shows one of his inventions, the alembic. It has a long down-pointing spout for condensing steam and letting water escape from inside.

Acids

Most people think of **acids** as corrosive liquids that fizz when they come into contact with solids and burn when they touch the skin. This description is true for many acids, and when they are being transported the container holding them has the hazard symbol shown in **Figure 10.2**.

corrosive

Figure 10.2 The hazard symbol for a corrosive substance

Some acids are not corrosive, and are found in our food. They give some foods their sour taste. Many acids are found in living things. Table 10.1 shows some acids found in plants and animals.

3 Look at Table 10.1 and state the organ systems in your body where three of the acids are found.

Table 10.1 Acids found in plants and animals

Acids with plant origins	Acids with animal origins
• citric acid in orange and lemon juice • tartaric acid in grapes • ascorbic acid (vitamin C) in citrus fruits and blackcurrants • methanoic acid in nettle stings	• hydrochloric acid in mammalian stomach • lactic acid in muscles during vigorous exercise • uric acid in urine • methanoic acid in ant sting

Figure 10.3 Animals and plants that produce acid

The acid in vinegar

Ethanoic acid is found in vinegar and is produced as wine becomes sour. The wine contains ethanol and also has some oxygen dissolved in it from the air. Over a period of time, the oxygen reacts with the ethanol and converts it to ethanoic acid. This chemical reaction happens more quickly if the wine bottle is left uncorked.

4 Why does wine go sour faster if the cork is removed from the bottle?

Organic acids and mineral acids

The acids produced by plants and animals (with the exception of hydrochloric acid) are known as organic acids. Ethanoic acid is also an organic acid.

Mineral acids are not produced by living things and their discovery began with the work of chemists such as Geber. The first mineral acid to be discovered was nitric acid. It was used to separate silver and gold. When the acid was applied to a mixture of the two metals it dissolved the silver but not the gold. Later, sulfuric acid and then hydrochloric acid were discovered.

Figure 10.4 Bottles of dilute and concentrated acids

5 How do you think these terms came to be used?
a) organic acids
b) mineral acids

6 Acids in the laboratory are stored in labelled bottles, as shown in Figure 10.4.
a) Which acids are dilute and which are concentrated?
b) How is a dilute solution different from a concentrated one?

Alkalis

Sodium hydroxide solution and potassium hydroxide solution are examples of **alkalis** that are used in laboratories. Calcium hydroxide, also called slaked lime, is used in many industries to make products such as bleach and whitewash. A weak solution of calcium hydroxide is used in the laboratory, where it is known as limewater. It is used to test for carbon dioxide gas. If this gas passes through limewater, it turns the limewater milky.

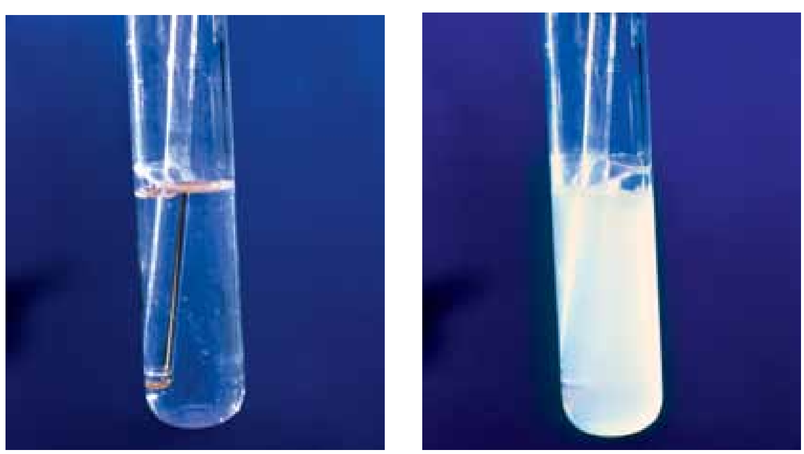

Figure 10.5 Limewater is clear but becomes cloudy when carbon dioxide is bubbled into it.

Figure 10.6 Alkalis used in the home

7 Why should alkalis be treated with care?

A concentrated solution of an alkali is corrosive and can burn the skin. The same hazard symbol as the one used for acids (Figure 10.2) is used on containers of alkalis when they are transported. Even dilute solutions of alkali, such as dilute sodium hydroxide solution, react with fat on the surface of the skin and change it into substances found in soap. Many household cleaners used on metal, floors and ovens contain alkalis and must be handled with great care.

Detecting acids and alkalis

8 What question do you think Boyle asked himself when he learnt about the work of the French dyers?

9 Which scientific skill did Boyle use in his tests on plant juices?

10 When Boyle tested a liquid with red cabbage juice, it turned the indicator from purple to red.
- **a)** What was the liquid?
- **b)** What colour would it turn Boyle's violet juice?

11 When Boyle tested a liquid with litmus solution, it went blue.
- **a)** What was the liquid?
- **b)** What colour would it turn violet juice?
- **c)** What colour would it turn red cabbage juice?

Robert Boyle was an Irish scientist who lived just over 300 years ago. He studied acids and alkalis and decided to try and find an easy way to identify them. He knew that in France workers who made silk clothes dyed them with the juices of plants, and he began testing plant juices to see if they would solve his problem.

When Boyle tested acids and alkalis with the juice from red cabbage, he found a way to identify them easily. When acid is added to red cabbage juice, it turns from purple to red. When alkali is added, the juice turns from purple to green. He also found that juices from violets turned purple with acid and greenish yellow with an alkali, but his discovery about the colour change in litmus, a juice from a **lichen**, went on to be used in chemistry laboratories around the world.

Litmus is used as a solution, or it is absorbed onto paper strips. Litmus solution is purple but it turns red when it comes into contact with an acid. Litmus paper for testing for acids is blue. The paper turns red when it is dipped in acid or a drop of acid is put on it. When an alkali comes into contact with purple litmus solution, the solution turns blue. Litmus paper used for testing for an alkali is red. When red litmus paper comes into contact with an alkali, it turns blue.

Figure 10.7 Robert Boyle and his assistant at work in his laboratory

12 Compare the laboratory of Geber (Figure 10.1) with that of Boyle (Figure 10.7).
- **a)** Which two pieces of apparatus in the different laboratories look similar?
- **b)** What differences do you notice?

There are over 20 indicators that scientists use. Here are two examples:

- methyl orange is pink in acid solutions and yellow in alkaline solutions
- phenolphthalein is colourless in acid solutions and pink in alkaline solutions.

There is even a plant that can be used as an indicator as it grows in the soil. It is the hydrangea. The colour of flowers can be affected by alkali in the soil. Hydrangeas have pink flowers when they are grown in a soil containing lime (calcium hydroxide, an alkali) and blue flowers when grown in a lime-free soil. The colour of the flowers can be used to assess the alkalinity of the soil.

Figure 10.8 Pink and blue hydrangeas

The pH scale

After indicators had been found to identify acids and alkalis, scientists wanted to know how to compare the strengths of acids and alkalis. In 1909, a Danish scientist called Søren Sørensen invented a scale called the **pH scale** to do just that. The letters p and H stand for the 'power of hydrogen' because this is an element that is found in acids, which takes an active part in their chemical reactions.

The pH scale runs from 0 to 14. On this scale, the strongest acid is 0 and the strongest alkali is 14. A strong acid has a pH of 0–2, a weak acid has a pH of 3–6, a weak alkali has a pH of 8–11 and a strong alkali has a pH of 12–14. A solution with a pH of 7 is **neutral**. It is neither an acid nor an alkali.

An electrical instrument called a pH meter is used to measure the pH of an acid or alkali accurately.

13 Look at Sørensen's laboratory in Figure 10.9. How is it different from the laboratories of Geber and Boyle?

14 Here are some measurements of solutions that were made using a pH meter:

solution A pH 0
solution B pH 11
solution C pH 6
solution D pH 3
solution E pH 13
solution F pH 8

a) Which of the solutions are:
i) acids
ii) alkalis?

b) If the solutions were tested with universal indicator paper, what colour would the indicator paper be with each one?

c) Fresh milk has a pH of 6. How do you think the pH would change as it became sour? Explain your answer.

15 Here are some results of solutions tested with universal indicator paper:

sulfuric acid – red
metal polish – dark blue
washing-up liquid – yellow
milk of magnesia – light blue
oven cleaner – purple
car battery acid – pink

Arrange the solutions in order of their pH, starting with the one with the lowest pH.

16 Identify the strong and weak acids and alkalis from the results shown in questions **14** and **15**.

17 Look at page 147 about acids and predict whether nitric acid is a strong or a weak acid. Explain your answer.

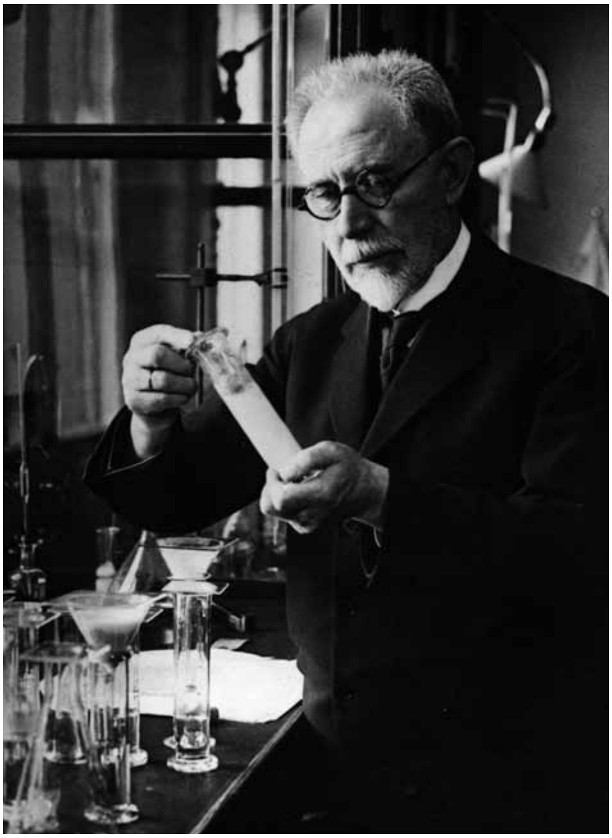

Figure 10.9 Søren Sørensen at work in his laboratory

For general laboratory use, the pH of an acid or an alkali is measured with universal indicator. This is made from a mixture of indicators. Each indicator changes colour over part of the range of the scale. By combining the indicators, a solution is made that gives different colours over the whole of the pH range (Figure 10.10).

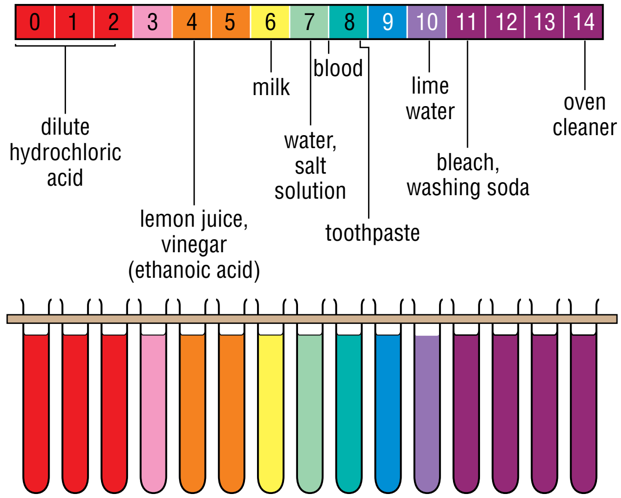

Figure 10.10 The pH scale (top) and universal indicator (bottom)

18 Write the word equation for the reaction between:
- **a)** hydrochloric acid and potassium hydroxide
- **b)** sulfuric acid and sodium hydroxide
- **c)** nitric acid and potassium hydroxide.

19 Write the word equation for the reaction between sodium hydrogen carbonate and sulfuric acid.

20 Why are alkalis sometimes described as the opposite of acids?

21 How are acids and alkalis similar?

Neutralisation

When an acid reacts with an alkali, a process called **neutralisation** occurs in which a salt and water are formed. This reaction can be written as a general word equation:

$$\text{acid} + \text{alkali} \rightarrow \text{salt} + \text{water}$$

Specific examples of neutralisation reactions are:

$$\text{hydrochloric acid} + \text{sodium hydroxide} \rightarrow \text{sodium chloride} + \text{water}$$

$$\text{sulfuric acid} + \text{potassium hydroxide} \rightarrow \text{potassium sulfate} + \text{water}$$

$$\text{nitric acid} + \text{sodium hydroxide} \rightarrow \text{sodium nitrate} + \text{water}$$

Sodium hydrogen carbonate is a white solid. It is not an alkali but dissolves in water to produce an alkaline solution. It also takes part in neutralisation reactions with acids but produces another substance as well as a salt and water. It produces carbon dioxide. The word equation for this reaction involving hydrochloric acid is:

$$\text{sodium hydrogen carbonate} + \text{hydrochloric acid} \rightarrow \text{sodium chloride} + \text{carbon dioxide} + \text{water}$$

Sodium hydrogen carbonate is also called sodium bicarbonate. It has several uses in neutralisation reactions. Some of these are described in the next section.

Using neutralisation reactions

Insect stings

A bee sting is acidic and may be neutralised by soap, which is an alkali. A wasp sting is alkaline and may be neutralised with vinegar, which is a weak acid.

Figure 10.11 The acid or alkali used in an insect sting is delivered by a sharp point at the insect's tail.

Curing indigestion

Sodium bicarbonate is used in some of the tablets that are made to cure indigestion. Indigestion is caused by the stomach making too much acid as it digests food. When a tablet of sodium bicarbonate is swallowed, the chemical dissolves to make an alkaline solution, which neutralises the acid in the stomach and cures the indigestion.

Baking a cake

Baking powder contains a mixture of a solid acid and sodium bicarbonate. When the baking powder is mixed with water and flour to make a cake, the acid and the sodium bicarbonate dissolve in the water and take part in a neutralisation reaction. The carbon dioxide gas forms bubbles in the mixture and makes it rise to give the cake a light texture.

A model volcano

In the past, you may have made a model volcano. To do this, you may have added a tablespoon of sodium bicarbonate, called baking soda, to an empty plastic drink bottle and then built a mound of sand around the bottle so that it looked like a conical volcano. Finally you may have added red dye to half a cup of vinegar, then poured the vinegar into the bottle. Moments later a red froth would have emerged from the top of the bottle and flowed down the cone of sand, like lava flowing down a volcano (Figure 10.12). The model looks impressive! It does not illustrate how lava is formed, but it does show the power of a neutralisation reaction – between the baking soda and the vinegar.

Figure 10.12 The ingredients (left) for making a model volcano (right)

Fighting a fire

The soda–acid fire extinguisher contains a bottle of sulfuric acid and a solution of sodium bicarbonate. When the plunger is struck or the extinguisher is turned upside down, the acid mixes with the sodium bicarbonate solution and a neutralisation reaction takes place. The pressure of the carbon dioxide produced in the reaction pushes the water out of the extinguisher and onto the fire.

Figure 10.13 Liming fields in England to improve crop production

Improving crop growth

Acidity in the soil affects the growth of crops. It makes them produce less food. Lime (calcium hydroxide) is used to neutralise acidity in soil. When it is applied to fields it makes them appear temporarily white, as Figure 10.13 shows.

Acid rain

Natural acid rain

Water vapour high in the air condenses on dust particles to form huge numbers of tiny water droplets. They reflect light in all directions and we see them as a cloud. Carbon dioxide present in the air dissolves in the water and forms a weak acid called carbonic acid.

When this weak acid rain falls onto the rocks in limestone country, a chemical reaction takes place. In this reaction a very small amount of limestone is dissolved and washed away. Over thousands of years the dissolving of the rocks can produce a range of features in the landscape.

When part of a limestone surface is dissolved, cracks called grikes form and the surface is called a limestone pavement. In some places where most of the limestone surface is dissolved away, pinnacles of rock are left behind. As the acid rainwater dissolves the rock, it sinks into it and makes passages for underground streams. In time, the water passing along these streams dissolves more of the rock and creates caves. Eventually, as the cave becomes larger and larger, its roof may weaken and collapse to make a gorge.

Figure 10.14 This limestone pavement is in the Pennine hills of England.

22 Describe how naturally acidic rainwater can affect a mountain of limestone.

23 A sample of acid rain turned universal indicator yellow. What would you expect its pH to be? Is it a strong or a weak acid?

Air pollution and acid rain

Fuels such as coal and oil contain sulfur. When the fuel is burnt, the sulfur takes part in a chemical reaction with oxygen in the air and sulfur dioxide is produced. This gas reacts with water vapour and oxygen in the air to form sulfuric acid. This may fall to the ground in raindrops and make acid rain that is much more harmful than usual.

Power stations that burn coal and oil produce sulfur dioxide in the gases they release from their chimneys. They also produce chemicals called oxides of nitrogen, which form nitric acid and this too makes rain acidic. Oxides of nitrogen are also produced in the exhaust gases of cars and trucks.

The effect of acid rain

When acid rain reaches the ground, it drains into the soil, dissolves some of the minerals there and carries them away. This process is called **leaching**. Some of the minerals are needed for the healthy growth of plants. Without the minerals the plants become stunted and may die.

The acid rain drains into rivers and lakes and lowers the pH of the water. Many forms of water life are sensitive to the pH of the water and cannot survive if it is too acidic. If the pH changes, they die and the animals that feed on them, such as fish, may also die. Acid rain leaches aluminium ions out of the soil. If they reach a high concentration in the water, the gills of fish are affected. It causes the fish to suffocate.

24 In the Arctic regions, snow lies on the ground all winter.
As spring approaches and the air warms up, some of the water in the snow evaporates. Later, all the snow melts.

a) How does the evaporation of the water in the snow affect the concentrations of acids in the snow?

b) The table opposite shows how the pH of a river in the Arctic may change during the spring.

i) Plot a graph of the data.
ii) Why do you think the pH changed in weeks 5–7?
iii) Why do you think the pH changed in weeks 8–10?
iv) How do you expect the pH to change in the next few weeks after week 10? Explain your answer.

Week	pH
1	7.1
2	7.0
3	6.9
4	6.8
5	5.5
6	5.0
7	4.7
8	5.1
9	5.5
10	5.9

Neutralisation and acid rain

Rivers and lakes that have become acidic due to acid rain can be treated with lime (calcium hydroxide). This reacts with the acid in the water and neutralises it. This method of restoring aquatic habitats has been used in Norway, Sweden and Wales. It is expensive and must be applied for as long as the source of the acid rain affects the rivers and lakes.

A better way is to remove the cause of the acid rain where it is being produced – at the power station. In the power station chimney a mixture of lime and water is sprayed into the smoke. Sulfur dioxide dissolves in the water and takes part in a neutralisation reaction with the lime. Calcium sulfate is produced. This substance is also known as gypsum. It is made into plaster of Paris, which is used to support broken limbs in hospitals and is also used in the making of cement and concrete in the building industry.

SUMMARY

- Some acids are made by living things (*see page 146*).
- The acid in vinegar is ethanoic acid (*see page 147*).
- The mineral acids are nitric acid, sulfuric acid and hydrochloric acid (*see page 147*).
- Sodium hydroxide and potassium hydroxide are examples of alkalis (*see page 148*).
- An acid turns blue litmus paper red (*see page 149*).
- An alkali turns red litmus paper blue (*see page 149*).
- The pH scale is used to measure the degree of acidity or alkalinity of a solution (*see page 150*).
- When an acid reacts with an alkali a neutralisation reaction takes place (*see page 151*).
- Neutralisation reactions have a wide range of uses (*see page 152*).
- Acid rain can form naturally (*see page 154*).
- Air pollution can cause acid rain (*see page 155*).
- Alkalis can be used to prevent acid rain (*see page 156*).

End of chapter questions

1 Write an account entitled 'The acids and alkalis in our lives'.

2 How can you tell when an acid has neutralised an alkali?

15 Energy

- What is energy?
- Forms of energy
- Energy changes
- Wasted energy
- Fuels

What is energy?

In everyday language, we use the word 'energy' in many different ways. Just look at the examples in Figure 15.1.

Figure 15.1 Different ways of using the word 'energy'

For discussion

Think about conversations where you might use the word 'energy'. What do you mean when you use the word?

The scientific way of thinking about energy is that it is the property of something that makes it able to exert a force and do work. To understand this, it is helpful to think about the ways that energy is stored and what happens when it is changed from one form to another.

Forms of energy

There are two kinds of energy – stored energy and movement energy. Stored energy is also called **potential energy** because it gives something the potential to use its stored energy, as we shall see in the examples.
Movement energy is also called **kinetic energy**. The word 'kinetic' comes from a Greek word meaning 'motion'.
There are several forms of each kind of energy.

Gravitational potential energy

The force of **gravity** between an object and the Earth pulls the object towards the centre of the planet. If an object is in a position above the surface of the Earth, it possesses stored energy called gravitational potential energy.

Examples of objects with this type of stored energy are plates on a table, books on a shelf, a child at the top of a slide and an apple growing on a branch. Each of these objects is supported by something but if the support is removed they will accelerate to the Earth's surface and their potential energy will be released and changed into other forms.

1 If you are holding this book, or if it is resting on a table or desk, why does it possess potential energy?

2 If you held a stone over the mouth of a well and then let it go, what would happen to the stone? Explain your answer.

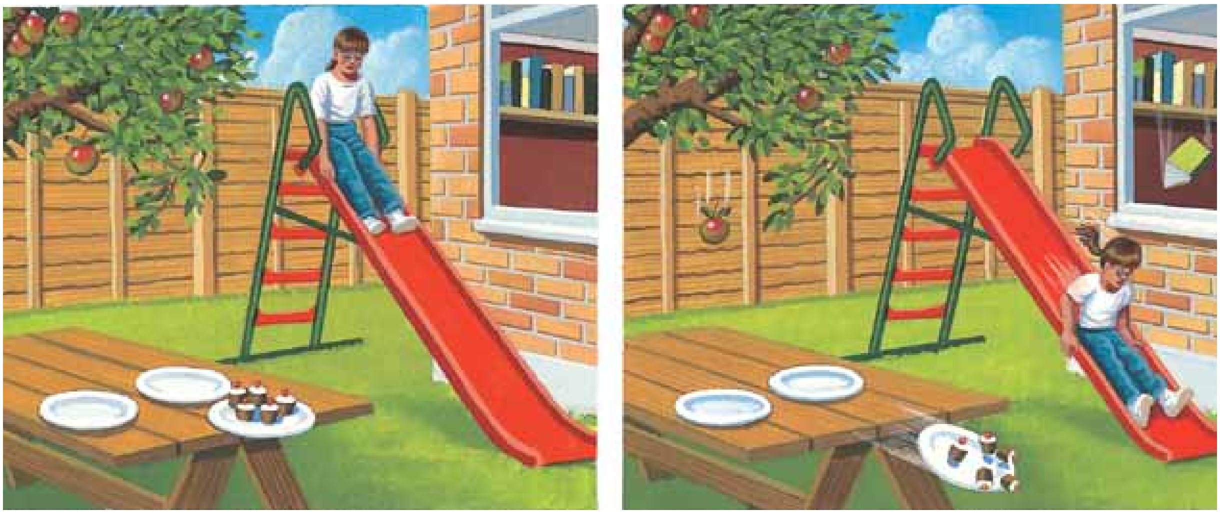

Figure 15.2 When the objects fall, their stored potential energy is released.

Strain energy

Strain energy is also called elastic potential energy. Some materials can be easily squashed, stretched or bent, but spring back into shape once the force acting on them is removed. They are called **elastic materials**. When their shape is changed by squashing, stretching or bending they store energy, which will allow them to return to their original shape.

A spring stores energy when it is stretched or squashed. Gases store strain energy in them when they are squashed. For example, when the gas used in an aerosol is squashed into a can it stores strain energy. Some of this is used up when the nozzle is pressed down and some of the gas is released in the spray.

3 Look at Figure 15.3. When is elastic potential energy stored and when is it released in:
a) a toy glider launcher
b) the elastic cords or springs beneath a sun-lounger
c) a diving board?

4 Does stretching an elastic band further store up more energy? Plan an investigation to answer this question.

Figure 15.3 Places where strain energy can be stored and released

Chemical energy

Energy can be stored in the chemicals from which a material is made. The chemicals are made from **atoms** that are linked together to make **molecules.** The chemical energy is stored in the links between the atoms. Food, fuel and the chemicals in an electrical cell (or battery) are examples containing stored chemical energy.

The energy is released when the links between some of the atoms are broken and the molecule in which the energy was stored is broken down into smaller molecules. For example, carbohydrates are a store of chemical energy in food. During **respiration**, carbohydrate is broken down into carbon dioxide and water. The energy that is released in this process is used by your body to keep you alive. The energy released by a fuel is used to heat homes, to heat water to produce steam for generating electricity in power stations, and for the production of new materials.

Figure 15.4 Energy is stored in all of these objects.

Figure 15.5 The kinetic energy of the demolition ball is transferred to the building and breaks up its structure.

5 Look out of a window and make a list of everything you can see that has kinetic energy.

Kinetic energy

Any moving object has kinetic energy. The object may be as large as a planet or as small as an atom and because of its motion it can do work. When an object with kinetic energy strikes another object, a force acts on them both that will distort the second object or set it moving. For example, if you move your foot and kick a stationary ball, the ball moves away.

Sound energy

Sound energy is produced by the vibration of an object such as the twang of a guitar string. The energy passes though the air by the movement of the atoms and molecules. They move backwards and forwards in an orderly way. This makes a wave that spreads out in all directions from the point of the vibration. Sound energy can also pass through solids, liquids and other gases. The atoms move in a similar way to the turns on a slinky spring when a ‘push–pull’ wave moves along it.

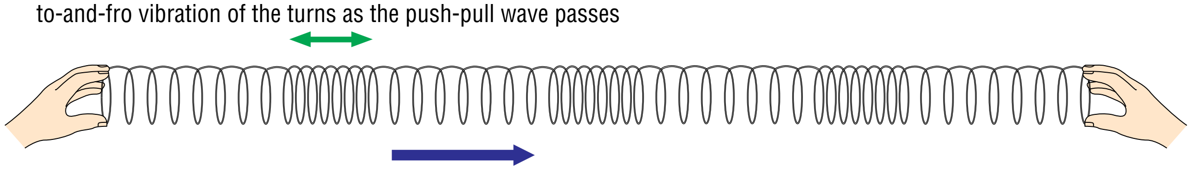

Figure 15.6 A slinky spring shows how sound waves move.

Electrical energy

Electric current is the movement of electric charges through a conductor such as copper or graphite.
The electric charges are given electrical energy by the battery and carry it to the working parts of a circuit. This may be a lamp, for example, where the energy is changed into light and heat.

6 In what ways is electrical energy put to work in your home?

Internal energy

Internal energy is also called thermal energy.
All substances are made up of particles. They possess a certain amount of energy, which allows them to move. When a substance is heated this movement increases. For example, the particles in a solid are moving backwards and forwards about a fixed position. The particles in a liquid move more quickly and can move past each other. The particles in a gas can move freely in all directions at high speeds. When a substance is heated, the particles receive more energy and move faster.

Electromagnetic energy

There is a form of energy that can travel through space at the speed of light. This kind of energy travels in waves that have some properties of electricity and some properties of magnetism. They are called **electromagnetic waves**. As these waves make up rays of light and heat, this form of energy is sometimes called radiation energy.

There is a huge range of possible wave sizes, or wavelengths. A wavelength is shown in Figure 15.7.

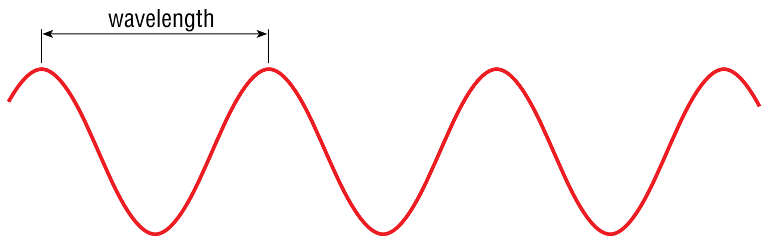

Figure 15.7 A wave showing wavelength

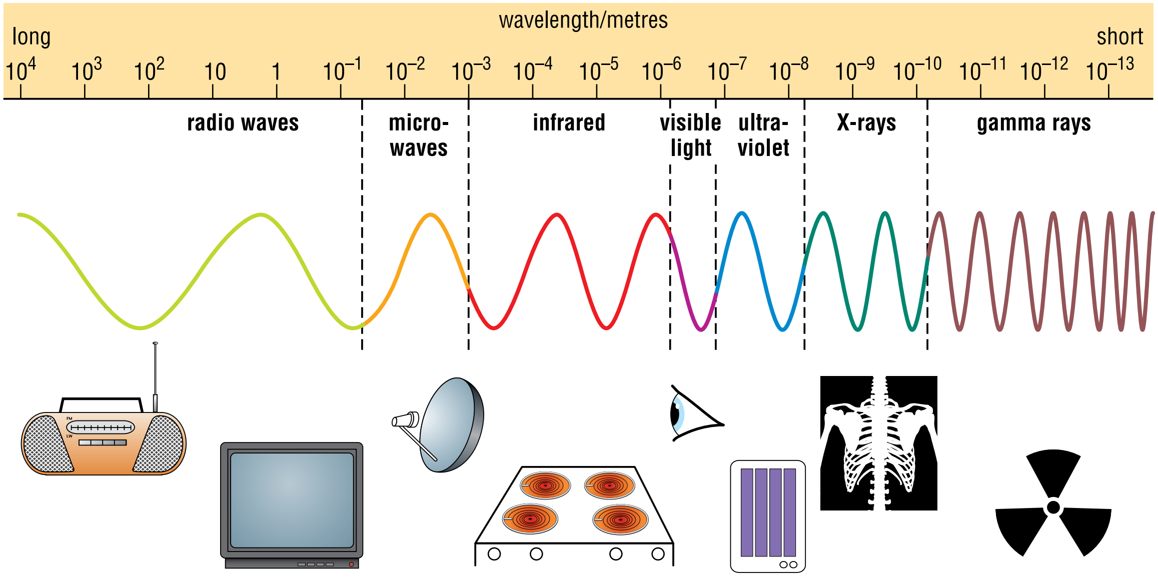

Figure 15.8 The electromagnetic spectrum

Electromagnetic waves are split into seven groups according to wavelength, as Figure 15.8 shows. The different groups have different properties and different uses. The two most familiar groups are light and radio waves.

Light energy

Light is the energy that we detect with our eyes. The light energy escaping from the Sun can be spread out by a prism or a shower of raindrops into light of different wavelengths. This forms the colours of the rainbow (Figure 13.1, page 192) because our eyes see different wavelengths of light as different colours.

7 Which radiation energy has:
a) the longest waves
b) the shortest waves?
8 Which radiation energy can our eyes detect?

Energy changes

We use energy in many ways – for example, to cook food, light our homes and move cars and buses. When energy is used it always changes from one form to another and some always changes into heat energy. For example, when you switch on a light, electrical energy is changed into light energy and heat energy. When you play a guitar, chemical energy in your body is changed into movement energy and sound energy. You can find out more about energy changes in Chapter 16.

9 Say what main energy change takes place in the following examples.
a) clockwork toy
b) boy kicking a football
c) boiling kettle on a gas ring
d) person walking upstairs

Figure 15.9 Energy changes occur when a guitar is played.

Wasted energy

When we turn on a lamp, it is because the light is useful to us. We do not use the heat that is produced so it is wasted. Sometimes that wasted energy can cause problems.
For example, some machines make so much noise (wasted sound energy) that people using them have to wear ear protection (Figure 15.10).

10 What is the wasted energy in each of the energy transfers in question **9**?

Figure 15.10 These workers' ears are protected from noise energy.

Fuels

Many substances are burned to release their chemical energy to provide heat and light. They are called **fuels**. Wood, coal, gas, charcoal, oil, diesel oil, petrol, natural gas and wax are examples of fuels. The heat may be used

Figure 15.11 In Nepal, ovens are often fuelled by wood.

to warm buildings, cook meals, make chemicals in industry, expand gases in vehicle engines and turn water into steam to generate electricity. Some gases and waxes are used to provide light in homes, caravans and tents.

Coal, gas and oil were all formed from plants and animals that lived millions of years ago, so they are known as **fossil fuels**.

Fossil fuels

Coal is formed from large plants that grew in swamps about 275 million years ago. These plants used energy from sunlight in the same way that plants do today. When they died they fell into the swamps. There was a lack of oxygen in the swamp water, which prevented bacteria growing and decomposing the dead plants. Eventually the plants formed peat. Later the peat became buried and was squashed by the rocks that formed above it. The increase in pressure squeezed the water out of the peat and warmed it. These processes slowly changed the peat into coal.

Tiny plants and animals live in the upper waters of the oceans and form the plankton. When they die, they sink to the ocean floor. Over 200 million years ago, the dead plankton that collected on the ocean floor did not decompose because there was not enough oxygen there to allow bacterial decomposers to live. The remains instead formed a layer, which eventually became covered by rock. The weight of the rock squeezed the layer and heated it. This slowly converted the layer of dead plankton into oil and methane gas. This is the gas that is supplied to homes as natural gas. Several fuels are obtained from oil.

11 What conditions helped fossil fuels to form?

Renewable resources

Unfortunately, the supplies of fossil fuels are limited and there will come a time when there are not enough to meet our needs. As a result, scientists are trying to develop alternative sources of energy from renewable energy sources such as the movement of the wind, the movement of waves and the tide, the movement of water from rivers (hydroelectricity) and the light of the Sun (solar power).

SUMMARY

- Energy is the property of something that makes it able to exert a force and do work (*see page 216*).
- Stored energy is called potential energy (*see page 216*).
- Movement energy is known as kinetic energy (*see page 216*).
- Chemical energy is energy that is stored in the chemicals from which a material is made (*see page 217*).
- Sound energy is transferred by waves in which atoms move backwards and forwards (*see page 218*).
- A battery gives electrical energy to electric charges, which allows them to move through a conductor as an electric current (*see page 219*).
- When a substance is heated, the particles it is made from move faster (*see page 219*).
- Electromagnetic energy is transferred by electromagnetic waves (*see page 219*).
- Energy can change from one form to another (*see page 220*).
- Some energy is wasted when it changes (*see page 221*).
- Substances that are burnt to release their chemical energy are called fuels (*see page 21*).

End of chapter questions

1 A group of students was investigating the potential energy in a nail 15 cm long. They suspended it above a block of soft clay, measured the distance to its tip, and then let it go. The students measured the depth to which the nail sank in the clay. The table shows their results for four experiments.

a) How do you think they measured the depth of the indent in the clay?

b) Plot a graph of their results.

c) How could you use the graph to predict the indent made by the nail from a height greater than 1 m?

Height of nail above clay/cm	Depth of indent/cm
25	0.9
50	1.6
75	2.3
100	3.0

2 A second group of students investigated the potential energy of a brass sphere, which was dropped from different heights into soft clay. They measured the diameter of the indent made by the sphere. The table shows their results for four experiments.

a) How do you think the students measured the diameter of the indent?

b) Plot a graph of their results.

c) How do these results compare with the results of the experiment described in question **1**?

d) Suggest a reason for any differences you describe.

e) Can the graph be used to predict indentations produced by falls from any height greater than 70 cm? Explain your answer.

Height of sphere above clay/cm	Diameter of indent/cm
5	1.0
20	1.7
50	2.2
70	2.5