Nuclear Power

Contents: A structured discussion concerning the principles and issues behind the use of nuclear power.

Time: Homework plus one double period.

Intended use: GCSE Physics, Chemistry or Integrated Science. Most likely to be of use at the end of a GCSE course, in the fifth year, and could also be used at sixth-form level. Links with work on nuclear structure, radioactivity, nuclear fission, generation of electricity and energy sources.

Aims:

- To complement and revise prior work on atomic structure, radioactivity and energy supply.
- To develop understanding of the principles of nuclear fission, and its use in the generation of electricity.
- To develop an informed awareness of some of the issues concerned with nuclear power.
- To provide an opportunity to practise communication skills and to encourage students to enter into discussion.

Requirements:
For each member of the class:
1 copy of Introduction (sheet I)
1 copy of General Briefing Sheet (sheet GB)
1 copy of Test (sheet T)

For each group of five pupils:
1 copy of each of the Expert's Briefing Sheets (sheets EB1, EB2, EB3, EB4)
1 copy of the Chairperson's Briefing Sheet (sheet CB)

This structured discussion is intended to give a factual introduction to the generation of electricity from nuclear fission, and to help students weigh up some of the controversial issues related to nuclear power. It is designed for use after a conventional lesson or lessons on the nucleus or nuclear fission. The General Briefing Sheet is no more than a condensed summary.

Procedure

1. Give each student a copy of the General Briefing Sheet on nuclear fission. Allow them time to read and study it – this is best done for homework preceding the lesson.
2. Get them to do the test. This should take no more than 15 minutes. Go through the answers.
3. Form the class into groups of five. Each group should have a Chairperson, chosen for his or her potential for leading a discussion. If the class does not divide neatly into groups of five, have some groups of six.
4. Give the Chairperson their Briefing Sheet (CB). Give Expert's Briefing Sheets (EB1, EB2, EB3, and EB4) to the other four members of the group – a different sheet to each member. If any groups have six members, EB1 could be given to two people. Allow them time to study the sheets. If the timing of lessons permits, it is most effective if students are able to study their briefings beforehand, perhaps for homework.
5. Hand over the running of the group discussions to the Chairpersons. Avoid intervening if possible.

Other resources

The United Kingdom Atomic Energy Authority produce a wide range of resources, many of them free. They include leaflets, booklets, posters, audio-visual packs and films. Naturally, these materials put the case in favour of nuclear power. Details of these resource materials can be obtained from:

The Information Services Branch
UKAEA
11 Charles II Street
London SW1Y 4QP

The case against nuclear power is well argued in a number of publications from Friends of the Earth. They include books and audio-visual materials. Details can be obtained from:

Friends of the Earth Ltd
377 City Road
London EC1V 1NA

Acknowledgements Figure 1 (Introduction) supplied by the United Kingdom Atomic Energy Authority; Figures 2 and 3 (General Briefing) and Figure 1, (Expert's Briefing 2) are reproduced by permission from Science in Society, Book F, *Energy* (Association for Science Education); Figure 2 (Expert's Briefing 1) by permission from *Chemistry in Context* by G. C. Hill and J. S. Holman (Nelson).

NUCLEAR POWER

Introduction

Why does Britain have nuclear power stations?

Why are nuclear power stations built instead of coal-fired and oil-fired power stations?

Are nuclear power stations safe? Can a nuclear power station explode like a nuclear bomb? Do they give out radiation?

What can be done about the waste produced by nuclear power stations?

These are some of the questions we shall be asking as you use this unit. Before starting you need to know some of the facts about nuclear power. First, you will be given a General Briefing sheet which tells you about nuclear fission. After studying this you will do a short test to check your understanding.

After that you will be working as part of a small group. The group will discuss some of the questions and problems of nuclear power.

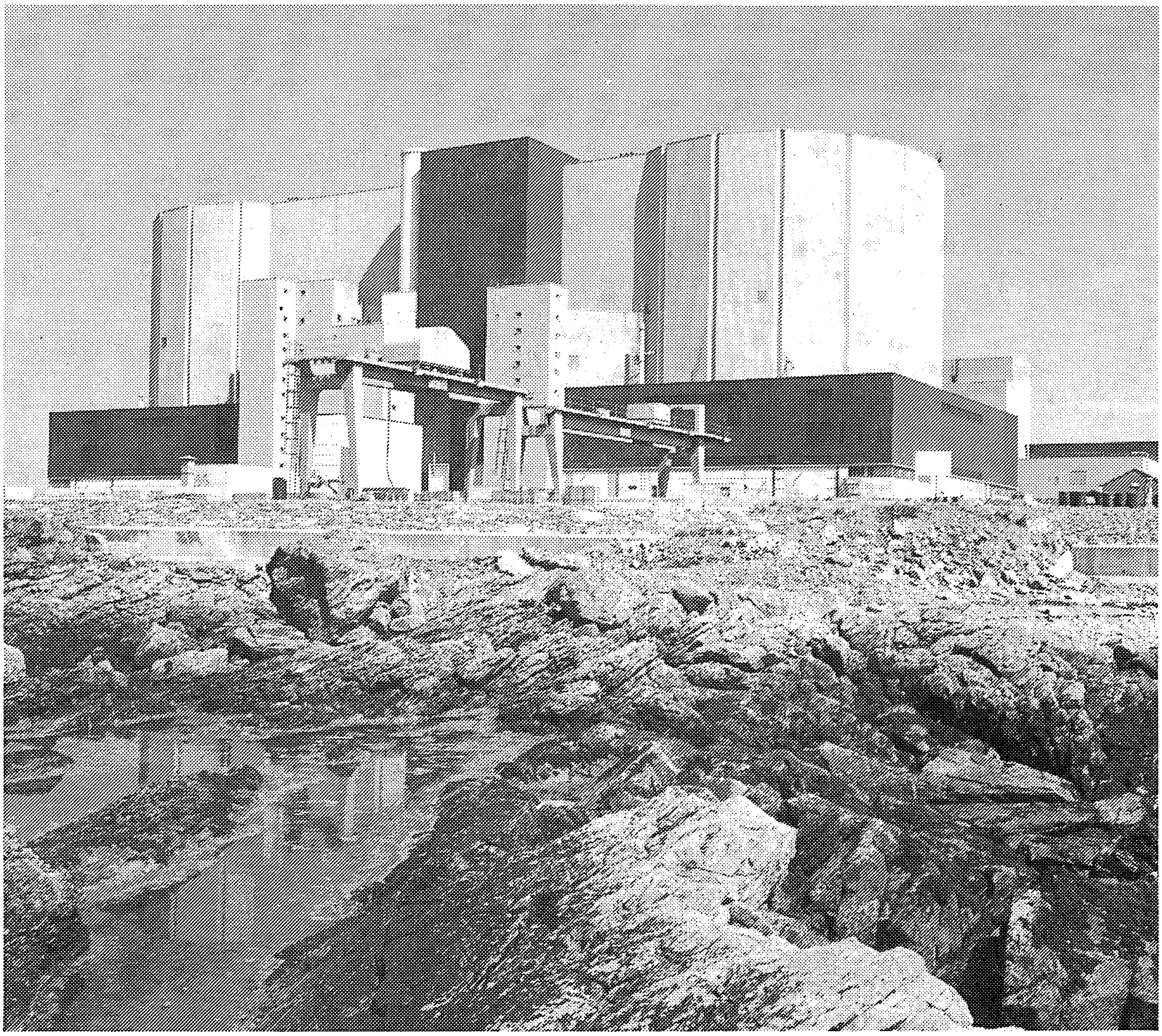


Figure 1 Wylfa Nuclear Power Station, in North Wales

Nuclear Power: General Briefing Sheet

This sheet is a summary of background information concerning nuclear fission.

What is nuclear fission?

Atoms are very small, but they are made of even smaller **sub-atomic particles**. These smaller particles are called protons, neutrons and electrons. At the centre of each atom is a tiny **nucleus**. The nucleus contains positively-charged protons and uncharged neutrons. Outside this central nucleus, the negatively-charged electrons move around (Figure 1).

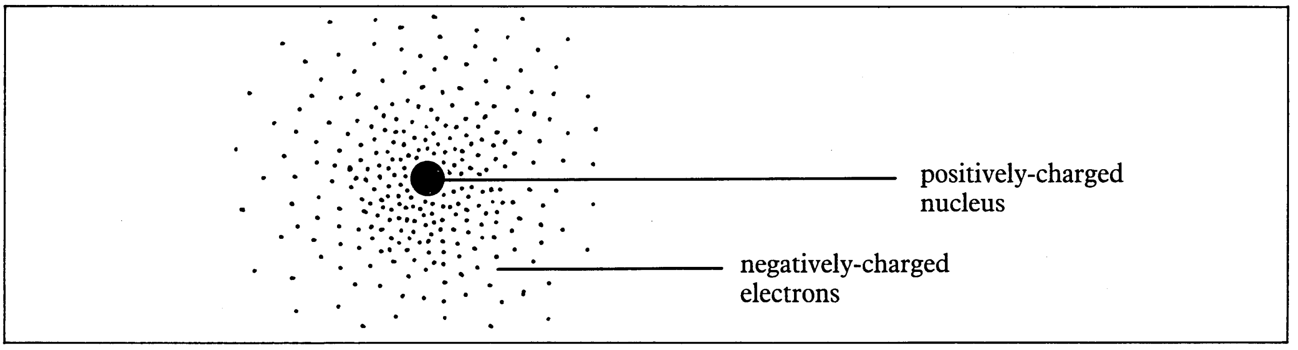


Figure 1 The structure of an atom

Radioactivity

Most of the atoms on Earth have a stable nucleus. This means the nucleus stays the same, and does not normally change. However, in a few atoms the nucleus is unstable. Unstable nuclei try to make themselves stable by throwing out particles or rays. The rays are called **radiation** and the atoms are said to be **radioactive**. A small amount of natural 'background' radiation, from rocks and from outer space, is around us all the time. But radiation can be dangerous to humans – it can cause cancer, deformed children and an illness called radiation sickness. Very large doses of radiation can kill.

What is fission?

Very large nuclei are often especially unstable. As well as giving out radiation, they may split into two smaller nuclei if they are hit in the right way. In the same way as a log can be split in two by hitting with an axe, these large nuclei can be split in two by hitting – with a neutron. This splitting in two is called **fission**. Nuclei that can be split in this way are described as **fissionable**.

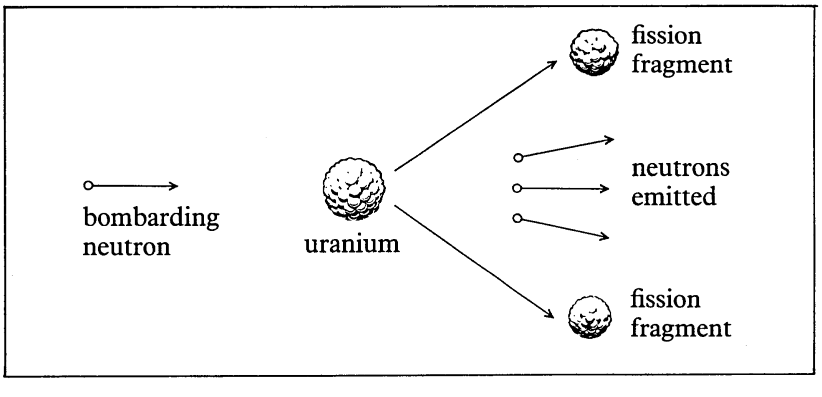


Figure 2 Nuclear fission

Most nuclear power stations use uranium as their fuel. Uranium is a metal whose atoms have very large nuclei. Some types of uranium atoms are fissionable. When this type of uranium nucleus is hit by a neutron, it splits into two smaller nuclei (Figure 2). These nuclei are radioactive.

As the nucleus splits, energy is given out. For a single uranium atom, the amount of energy is only tiny. But each gram of uranium contains many billions of atoms. For *one gram* of uranium, the energy released by fission of all the atoms would be as much as you could get by burning *2.7 tonnes of coal.*

When the uranium nucleus splits, it also releases two or three neutrons. These neutrons may hit other uranium nuclei. If they do, these nuclei may also split. This in turn gives out more neutrons, and so it goes on (Figure 3). This is called a **chain reaction**.

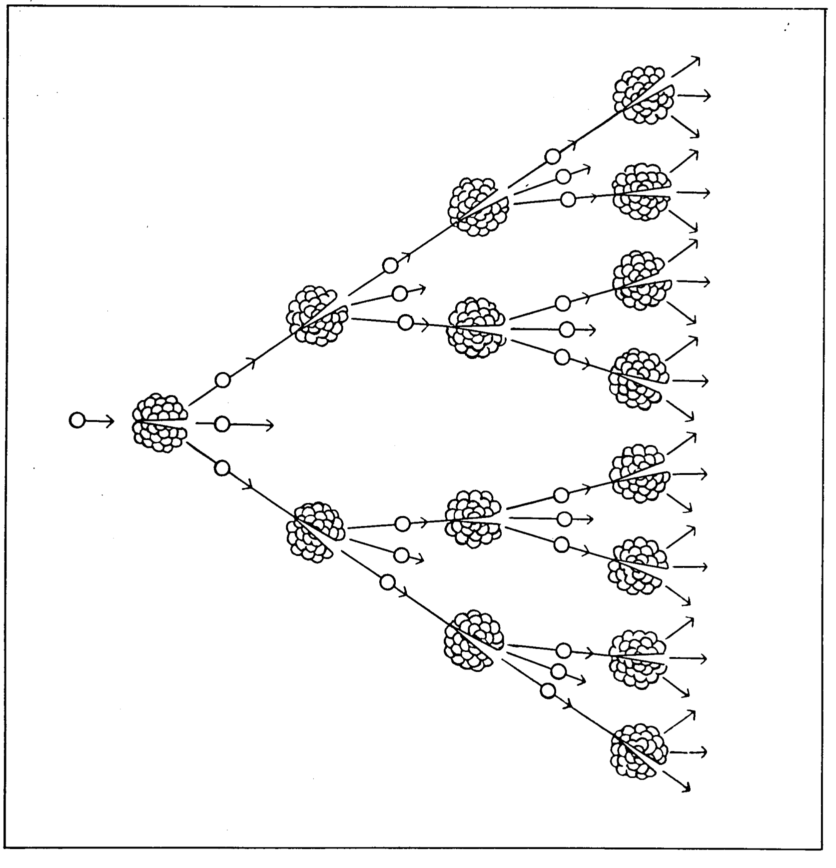


Figure 3 Nuclear fission: a chain reaction

Controlling nuclear energy

The chain reaction can move very quickly if it is not controlled. This is what happens in a nuclear bomb, like the one used in Hiroshima in the Second World War. In a fraction of a second, huge amounts of energy are released in the chain reaction. The result is terrible destruction.

In a nuclear power station, the fission reaction is controlled. This allows the energy to be released steadily. The central part of a nuclear power station is the **nuclear reactor**, which contains the uranium fuel. It also contains a **moderator** to slow down neutrons. This is important because slow neutrons stand a better chance of causing fission of uranium atoms. The moderator is often made of graphite.

The reactor also has **control rods**. These are made of a material which absorbs neutrons. Boron is often used. The control rods can be moved in and out of the reactor core. When they are right in, they absorb lots of neutrons. This stops the chain reaction. When the control rods are pulled out, less neutrons are absorbed. More neutrons are free to cause fission, and the chain reaction goes faster. Thus, by moving the control rods in and out, the fission reaction can be controlled.

Expert's Briefing sheet 1 has more information about nuclear reactors.

Isotopes of uranium

Uranium contains two different types of atom. Both have the same number of protons and electrons. But they have different numbers of neutrons. Atoms which have the same numbers of protons and electrons, but different numbers of neutrons, are called **isotopes**. The two isotopes of uranium are called uranium-235 (^{235}U) and uranium-238 (^{238}U). Table 1 shows the difference between them.

Table 1 Isotopes of uranium

Isotope	*Number of protons*	*Number of neutrons*	*Number of electrons*
uranium-235	92	143	92
uranium-238	92	146	92

Only ^{235}U will normally undergo fission. But only 0.7% of natural uranium is the ^{235}U isotope. The rest is ^{238}U, which does not undergo fission. Some reactors use natural uranium. Others use **enriched** uranium, which has had some of the ^{238}U removed. This increases the percentage of ^{235}U, and makes the uranium a better fuel.

Natural uranium cannot be used in atomic bombs. Bombs need highly enriched uranium. A nuclear reactor could never explode like a nuclear bomb, because the uranium used in the reactor is not enriched enough.

Test on nuclear fission

1 Which sub-atomic particles are found in the nucleus of an atom?

A protons and electrons
B protons and neutrons
C neutrons and electrons
D protons only
E neutrons only

2 A uranium atom can undergo fission if it is hit by:

A radiation
B a proton
C a neutron
D an electron
E another uranium atom

3 Which of the following is an example of nuclear fission?

A A uranium nucleus gives out radiation
B Two hydrogen nuclei join together
C A uranium nucleus absorbs a neutron
D A uranium nucleus splits up to give two smaller nuclei
E A uranium nucleus absorbs an electron

4 Nuclear reactors use uranium as a fuel. In what ways is uranium a different type of fuel from, say, coal or oil?

5 What job is done by the moderator in a nuclear reactor?

6 How do control rods control the fission reaction?

7 What is the difference between natural uranium and enriched uranium?

Nuclear Power: Expert's Briefing Sheet 1

What happens in a nuclear power station?

You will shortly be taking part in a group discussion on nuclear power. You are the only one in your group who has read this sheet, so you will be the expert on what goes on in a nuclear power station. After you have read this, the Chairperson of your group will be asking the kinds of questions a 'man or woman in the street' might ask. Try to answer them as simply as possible, in your own words. Draw diagrams if it helps your answers.

Briefing

All power stations are energy-converters. They convert heat to electrical energy. In a coal-fired power station, the heat comes from burning coal. In a nuclear power station, the heat comes from the fission of uranium.

Once the heat is released, it is used to boil water and make steam. The steam drives turbines, and the turbines drive electrical generators (Figure 1).

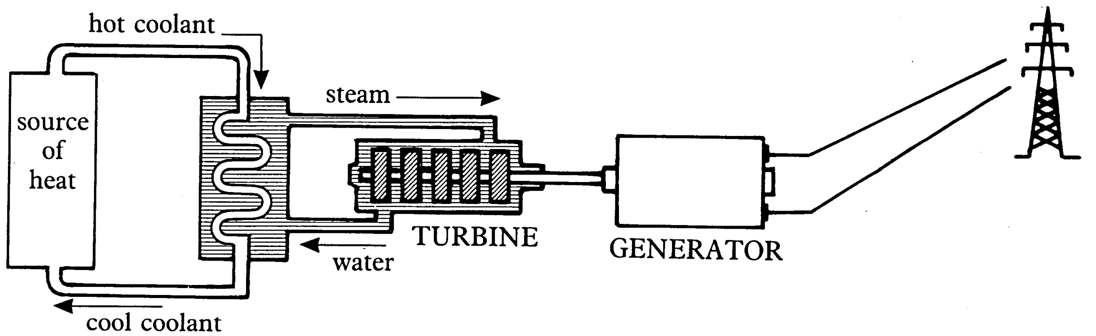


Figure 1 Generating electricity: the general plan.

Nuclear reactors

In a nuclear power station, the heat source is the nuclear reactor. Figure 2 shows a simplified reactor.

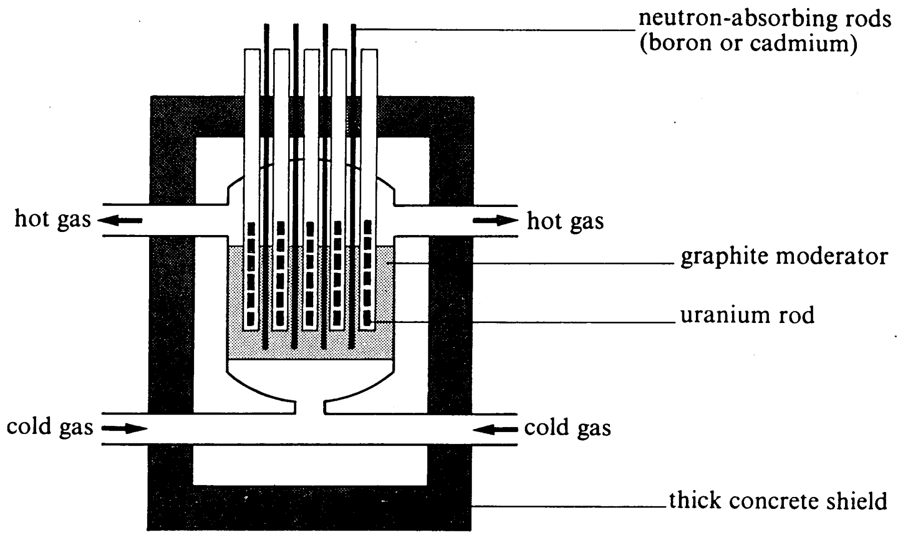


Figure 2 A simplified diagram of a nuclear reactor

The uranium rods are the fuel. The graphite **moderator** slows down neutrons. This makes the neutrons more likely to cause fission. The **control rods** absorb neutrons. By raising or lowering the rods, the fission reaction can be made faster or slower.

As the fission reaction takes place, heat is given out. The heat is taken away by a **coolant**. In the type of reactor shown here, the coolant is a gas – usually carbon dioxide. The hot gas is pumped away to the heat exchanger, where it turns water to steam. The steam drives the turbines which drive the electrical generators.

During the fission reaction, some dangerously radioactive substances are formed. A thick concrete shield stops radiation getting out.

Different types of reactor

Gas-cooled reactors Most of the reactors in British nuclear power stations are gas cooled, like the one shown in Figure 2.

Water-cooled reactors In the USA and many other countries, water-cooled reactors are used. As well as being a coolant, water is used as the moderator. Water-cooled reactors therefore have no graphite moderator. The job is done by the cooling water as it circulates through the reactor. The best known type of water-cooled reactor is the pressurized-water reactor (PWR).

Fast-breeder reactors These reactors use a different element, plutonium, as their fuel. As well as producing heat, these reactors can be used to turn ^{238}U into plutonium. This means they can 'breed' plutonium from ^{238}U. Plutonium is more useful than ^{238}U, because it is fissionable. The fission reaction does not need slow neutrons. 'Fast' neutrons can cause fission of plutonium. So far there is only one experimental fast-breeder reactor in Britain. It is at Dounreay, in the North of Scotland.

Nuclear Power: Expert's Briefing Sheet 2

What happens to nuclear fuel after use?

You will shortly be taking part in a group discussion on nuclear power. You are the only one in your group who has read this sheet, so you will be the expert on what happens to nuclear fuel after use. After you have read this, the Chairperson of your group will be asking the kind of questions a 'man or woman in the street' might ask. Try to answer them as simply as possible, in your own words. Draw diagrams if it helps your answers.

Briefing

Where does nuclear fuel come from?

The fuel for nuclear power stations is uranium. It is mined in various parts of the world, then sent to Britain. At Springfields in Lancashire the uranium is refined. Some of it is enriched to make it a better fuel. The uranium is then made into rods and sent to the power stations.

The uranium rods in a nuclear reactor last for several years. After this time the old rods are removed. They are replaced by new ones.

What happens to the spent fuel rods?

The old, spent fuel rods are very radioactive. They contain **fission products** – the smaller atoms formed when uranium atoms split. These fission products often have unstable nuclei which give off radiation. The rods also contain unused uranium and another element called **plutonium**. Plutonium is useful because it is fissionable. It can be used as a fuel in fast-breeder reactors. Plutonium can also be used to make nuclear bombs.

After they have been removed from the reactor, the spent fuel rods must be treated very carefully. They are first put under water in storage tanks for a few months. During this time, some of the most unstable fission products lose their power.

The fuel rods are now removed and sent to be **reprocessed** at Sellafield in Cumbria (see Figure 1). They make the journey by road or rail in strong, thick, heavily protected flasks. They are still very radioactive.

At Sellafield, plutonium and uranium are separated from the spent rods. They are used for fuel, and some plutonium may be used to make nuclear weapons.

The rest of the spent fuel rods is waste. Some of this waste will stay highly radioactive for thousands of years. At the moment the radioactive waste is stored in stainless steel tanks at Sellafield. Scientists are trying to find ways of safely disposing of it. One possibility is to turn the waste into a solid, glassy form. It could then be buried deep in the Earth, or dumped far out at sea.

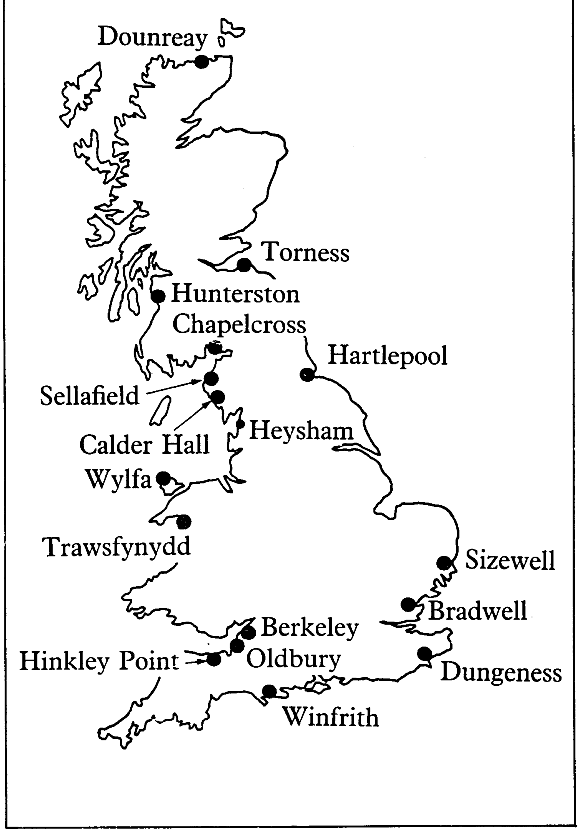


Figure 1 Map showing Britain's nuclear power stations

All this makes up the nuclear fuel cycle (Figure 2).

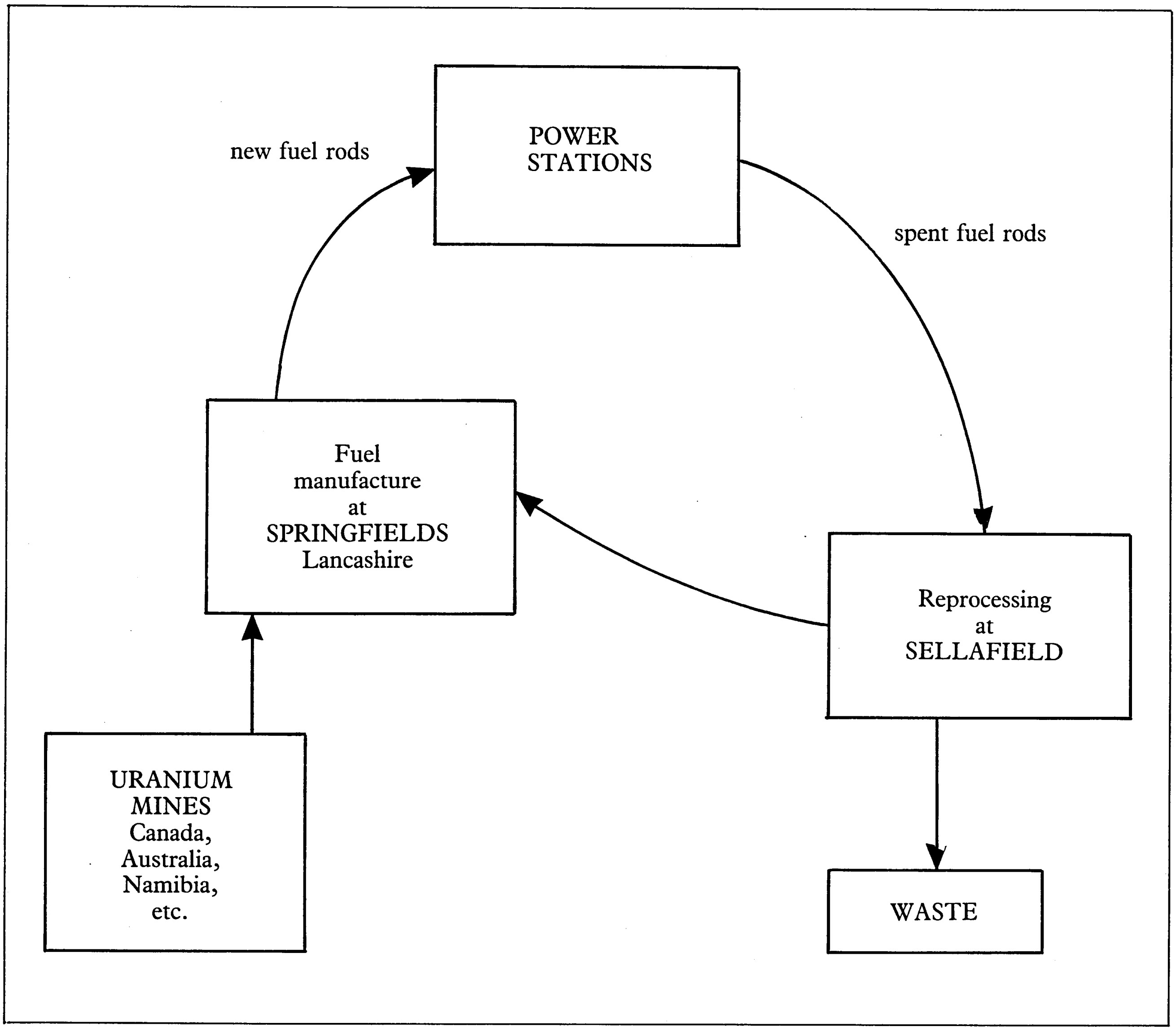


Figure 2 The nuclear fuel cycle

Nuclear Power: Expert's Briefing Sheet 3

Problems and risks of electricity generation

You will shortly be taking part in a group discussion on nuclear power. You are the only one in your group who has read this sheet, so you will be the expert on the problems and risks of electricity generation. After you have read this, the Chairperson of your group will be asking the kind of questions a 'man or woman in the street' might ask. Try to answer them as simply as possible, in your own words. Draw diagrams if it helps your answers.

Briefing

Electricity is a great benefit to our society – think what life would be like without it. But however electricity is generated, there are bound to be some problems and risks. This briefing sheet describes some of the risks of using nuclear energy. Coal is the other major source of electrical energy, and the risks involved in using coal are also described.

The risks of nuclear power

Risks from accidents Nuclear power stations cannot explode like nuclear bombs. But it is possible that a reactor could overheat and leak. This would release dangerously radioactive substances and people living nearby could be killed and injured. A major leakage accident happened at a power station in Chernobyl, Russia in 1986.

However, the Government safety rules for nuclear power stations are very strict. The Central Electricity Generating Board, who run the power stations, say the risk of a major accident is very low. But if one did happen, it would be very serious.

Risks from radiation and leaks Nuclear reactors contain some very radioactive materials. These give off dangerous rays. However, the safety precautions are so strict that very little radiation gets through the protective shields. Occasionally, though, a small leakage does occur by accident. For example, contaminated cooling water has been known to leak out from power stations.

Risks from waste Nuclear reactors produce radioactive fission products. These will stay radioactive for thousands of years. They are kept very secure in strong tanks, but no way has been found of disposing of them for good. Furthermore, transporting of nuclear waste from one place to another could be a hazard, though of course it is always transported in very strong containers.

Risks from terrorists Nuclear power stations produce plutonium. Plutonium can be used to make nuclear weapons. It is possible that terrorists could steal plutonium and try to make a bomb, although this would be a very difficult thing to do.

The risks of coal

Pollution of the air Many pollutants are given off by burning coal. As well as smoke, coal produces acidic gases. These include sulphur dioxide and nitrogen oxides. These gases cause acid rain, which damages trees, fish and buildings. The gases can also affect people's health. Because there are so many large coal-fired power stations, they produce a lot of pollution between them. But power stations are not the only source of acid gases. Cars and lorries produce them too, for example.

Burning coal gives off carbon dioxide. Some scientists are worried that the vast amounts of carbon dioxide given off by coal-burning may have a damaging effect on the atmosphere and the weather.

Risks of coal mining Mining is a dangerous occupation. Between 1982 and 1985 there were 26 accidental deaths in coal mines per year. Far larger numbers of miners risk dying of lung disease. Power stations use a large proportion of Britain's coal, so the risk to miners must be counted as a problem of coal-fired power stations. Uranium is also produced in mines, so the risks to uranium miners must also be considered. However, because uranium is such a concentrated energy source, it is mined in much smaller amounts.

Nuclear Power: Expert's Briefing Sheet 4

Britain's energy sources

You will shortly be taking part in a group discussion on nuclear power. You are the only one in your group who has read this sheet, so you will be the expert on Britain's energy sources. After you have read this, the Chairperson of your group will be asking the kind of questions a 'man or woman in the street' might ask. Try to answer them as simply as possible, in your own words. Draw diagrams if it helps your answers.

Briefing

Britain is more fortunate than many countries where energy is concerned. Coal, oil and natural gas are all found in Britain, or under the sea around the British Isles.

The graph in Figure 1 shows the changes in Britain's energy sources since 1950.

Of course, not all of Britain's energy is used to generate electricity. For example, a lot of oil is used for road transport. But nuclear power can *only* be used to generate electricity.

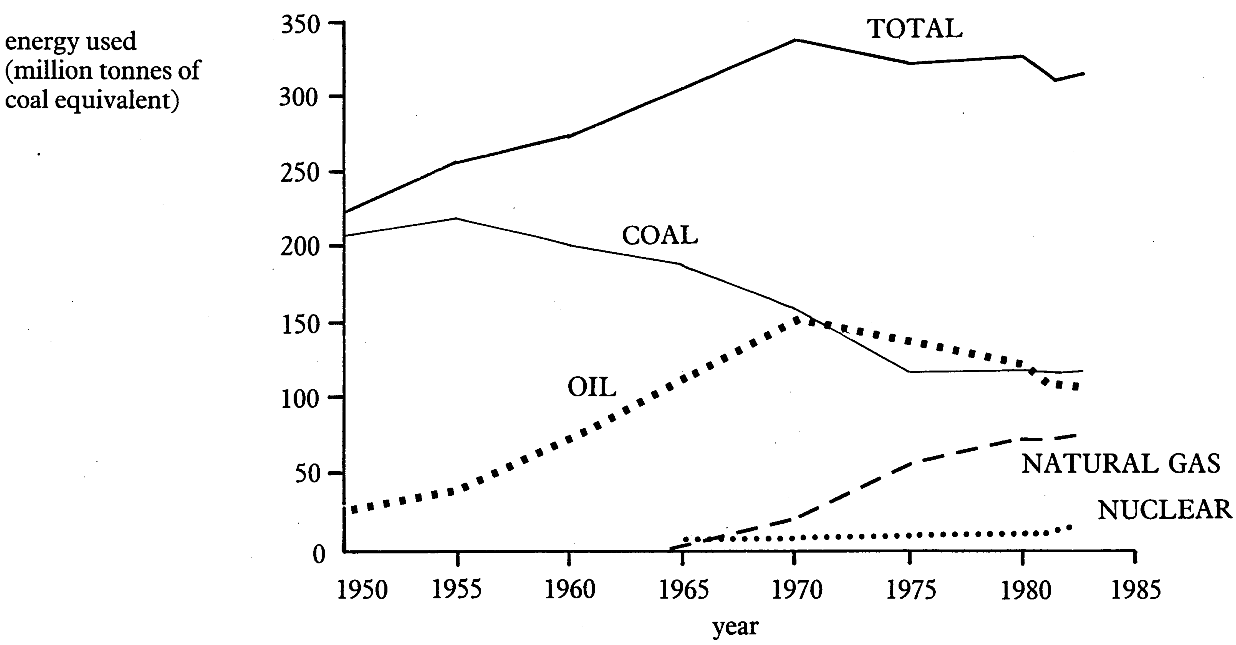


Figure 1 Britain's Energy Sources

In 1983 the percentage contributions of different methods of electricity generation were as shown in Table 1.

Table 1 Percentage contributions of different methods of electricity generation.

Coal	*Oil*	*Nuclear*	*Hydroelectric*
75%	8%	15%	2%

Nuclear power is reckoned to be cheaper than coal or oil for generating electricity.

How much fuel do we have left?

Britain's fuel supplies will not last for ever. Table 2 shows how long different fuels will last if they go on being used at the present rate.

Table 2 Estimated lifetimes of different fuels

Oil	30 years	
Natural gas	50 years	
Coal	300 years	
Nuclear fuel (world reserves)	50 years	(in normal power stations)
Nuclear fuel (world reserves)	2000 years	(using fast-breeder reactors)

The Government have to plan ahead. The older power stations are inefficient and expensive to run. Eventually they have to be replaced. The Government have to decide whether or not to replace them with nuclear stations.

They also need to look at the figures for how much fuel is being used, and how much is left. Look at the graph again. Suppose you had been planning ahead in 1970. What total energy use would you have *predicted* for 1983? What was the *actual* amount? How much energy do you predict we will use in 1995? Planning ahead can be difficult!

Possible energy plans

Britain has to plan ahead to the time when oil and gas run out. There are several possibilities.

1 *Save more energy* This can be done by using energy less wastefully. Cars can be designed to use less petrol. Houses can be better insulated so they waste less heat. New industrial processes can be less dependent on energy.

2 *Use alternative energy sources* Examples of alternative energy sources are solar power, wind power and tidal power. At the moment hardly any electricity is generated by these methods in Britain, because they have not been sufficiently developed.

3 *Build more nuclear power stations* You will shortly be discussing this possibility.

4 *Build more coal-fired power stations* Most of Britain's power stations are already coal-fired. The supplies of coal are large enough to keep even more going. About three-quarters of Britain's coal output is used to generate electricity. But coal has other important uses, such as steel-making and as a source of chemicals. In the future, as oil supplies run out, coal may be used to make liquid fuels to replace oil.

Of course, these different possibilities could be used *together*. In fact many people think it is a good thing not to be too dependent on one single source of fuel.

Nuclear Power: Chairperson's Briefing Sheet

You are Chairperson of a group of students. It is your job to ask questions and chair a discussion on nuclear power. Much of the success of the session depends on how well you do your job!

Everyone in your group will have read the General Briefing on nuclear fission. Each member (except for you) will also have read one Expert's Briefing. The Expert's Briefings are:

1 What happens in a nuclear power station?

2 What happens to nuclear fuel after use?

3 Problems and risks of electricity generation

4 Britain's energy sources

You will begin by asking some specific questions about nuclear power (see below). These questions will probably be answered by one of the Experts, though you should allow others to answer if they want. *Try to act as a 'man or woman in the street' who is trying to find out about nuclear power*. Encourage the Experts to answer in their own words – do not let them read out from the Briefing sheet! Let the Experts draw diagrams on paper, a blackboard or on an overhead projector if they want.

After the specific questions, you will raise some general points for discussion (see below). By this time, if the specific questions have worked properly, your group should have a reasonable idea of the facts behind nuclear power. Try to encourage everyone to enter into the discussion.

Specific questions

(The number after each question refers to the Expert who is most likely to know the answer.)

1 *The nuclear reactor produces heat. How is this converted to electrical energy? (1)*

2 *What is a PWR? (1)*

3 *What is special about fast-breeder reactors? (1)*

4 *How is radiation prevented from escaping from the reactor? (1)*

5 *Where does the uranium fuel for power stations come from? (2)*

6 *What happens when the fuel is used up? (2)*

7 *What happens to all the radioactive waste produced by power stations? (2)*

8 *Some people say nuclear reactors are dangerous. What are the possible dangers? (3)*

9 *Are there dangers from other types of power station? If so, what are they? (3)*

10 *How much of Britain's electricity is generated in nuclear power stations? (4)*

11 *What is the fuel in other types of power stations? (4)*

12 *Why do new power stations have to be built? Why can't Britain use the existing power stations already built? (4)*

13 *Apart from building nuclear power stations, what other possible ways are there of providing energy after oil and gas have run out? (4)*

General points for discussion

Encourage everyone to take part. Some of these may have already been covered in the 'Specific questions' session, in which case you could leave them out.

- Do we need to build nuclear power stations? Why can't we generate all our electricity from coal and oil?
- Are nuclear power stations as dangerous as some people say? Are other kinds of power stations just as dangerous?
- Would the money spent on nuclear power be better spent on saving energy or on developing alternative energy sources?
- What is the disadvantage of depending on only one energy source, such as coal or oil, for electricity generation?
- If you have time, draw up a list of the advantages and disadvantages of using nuclear power.

Hilltop – an agricultural problem

Contents: A data analysis problem-solving exercise concerning a trace element disease among farm animals.

Time: 2 periods.

Intended use: GCSE Biology, Chemistry and Integrated Science. Links with work on trace elements, plant nutrition and soil analysis.

Aims:

- To develop understanding of the importance of trace elements in plant and animal nutrition.
- To develop an awareness of the problems of animal disease and the economic use of land, the effect of the environment on farming and the role of scientists in helping farmers achieve better production.
- To develop skills in data handling and data analysis.

Requirements: Students' worksheets No. 110.

This material has been developed from a project initially designed for the Science in Society Project. The exercise is best carried out by students working in groups of two or three.

The unit is concerned with the effect of trace elements on the health of farm animals and a scientific study of the problems encountered. Students are asked to compare the concentration of metal ions in sick and healthy cattle and to select elements with significantly high or low concentrations in the unhealthy animals. Elements with particularly low concentrations in the unhealthy animals include copper, iron and manganese. Molybdenum stands out with a relatively high concentration in the unhealthy cattle.

Manganese is not known to have a specific function in animals. Copper and iron act as coenzymes, enabling specific enzymes to function properly. Iron is also present in haemoglobin.

Later in the unit, pupils study data concerning stream sediments. They should find that affected farms have high values for molybdenum concentrations. They should also notice that the affected farms have no particular deficiencies in iron, copper and manganese even though the unhealthy animals are deficient in these three elements.

This leads to molybdenum as the cause of the sickness and this is confirmed when shales are found to be the source rock for the molybdenum in the stream sediments and soils. Students will probably not appreciate the finer points of the sickness which teachers may wish to discuss as follows.

The symptoms displayed by the cattle are caused by copper deficiency. This suggests that molybdenum in the diet is preventing the uptake of copper. Further studies have suggested that molybdenum forms associations with proteins in the same fashion as copper though it is unable to act as an effective coenzyme. Thus copper is 'blocked' and the proteins cannot catalyse reactions which are essential for metabolism in the cattle.

Acknowledgement Photo on page 1 from Milk Marketing Board.

HILLTOP – AN AGRICULTURAL PROBLEM

Introduction – the problem at Hilltop

The Hilltop area is an imaginary part of the United Kingdom, though the information is based on real-life investigations. This unit involves studying data about the Hilltop area in order to understand why some farms in the area are losing money.

Map 1 on page 2 shows the nine farms in the Hilltop area and its four streams. The farms are similar in size and use similar farming methods. Five of the farms are successful in rearing cattle but four of the farms are unsuccessful and are losing money. These unsuccessful farms are:

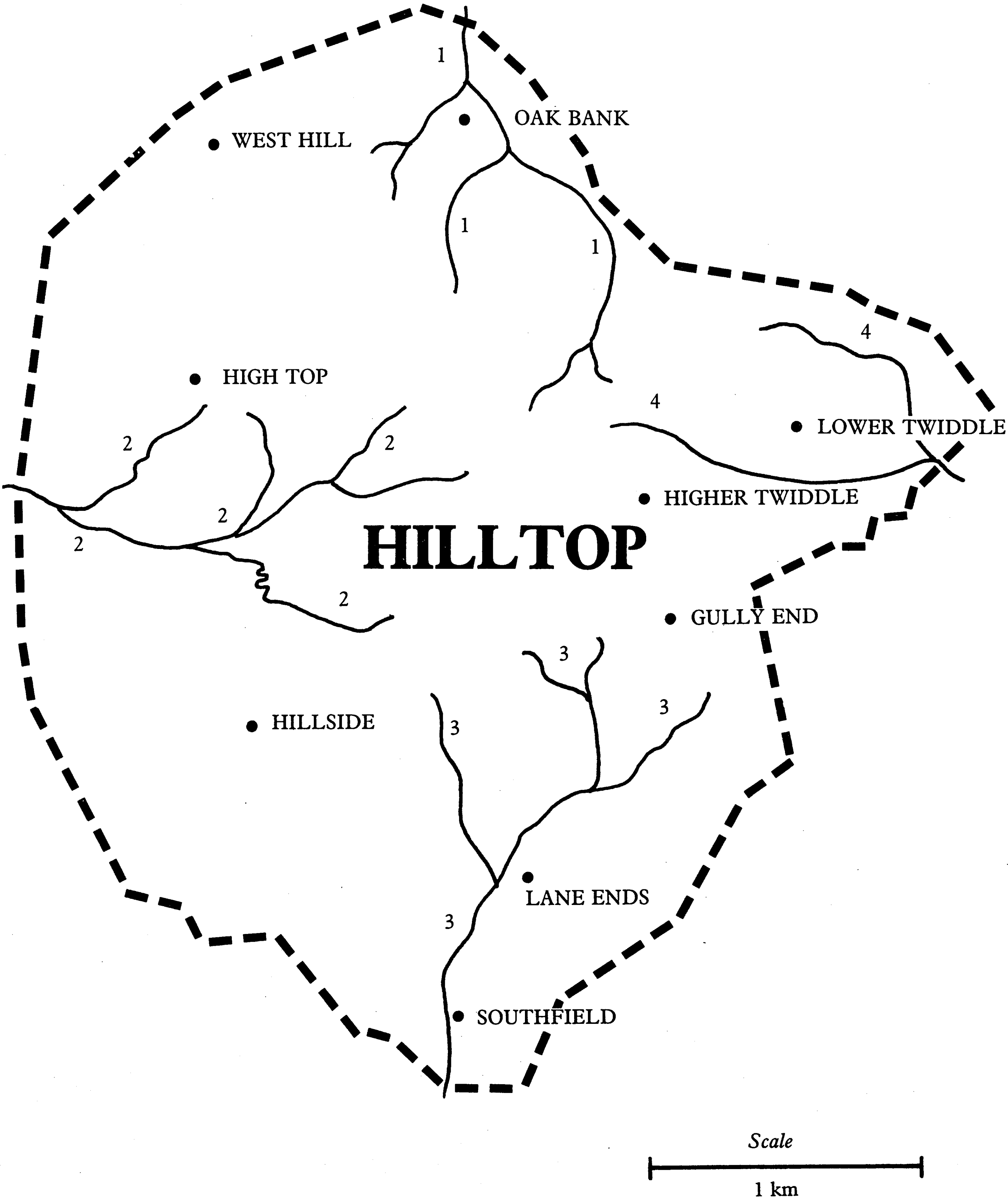
Lane Ends, Oak Bank, Southfield and West Hill.

Animals on these farms are underweight and do not grow healthily. The cows produce small, sickly calves and they give much less milk than they should. The unhealthy cattle have a dull coat and their hair tends to fall out. They develop a strange walk which farmers call 'staggers'.

The object of this study is to discover why the animals on some farms are affected in this way.

Question

1 Describe in your own words the problem you will be trying to solve in this unit.



Map 1 The natural drainage of the Hilltop farms

The streams are numbered 1 to 4.

Trace elements

All animals need traces of certain elements in their diet. Each element has a particular job to do in the body and may be vital for an animal's health. For example, in the human diet, iodine is an important trace element which helps the thyroid gland work properly. Some trace elements can be poisonous if their concentration is too high.

The sickness in the animals is due to either

(i) deficiency (too little) of certain trace elements, or
(ii) excess (too much) of a poisonous trace element.

Many trace elements build up in the liver, which acts as a kind of filter and a store for certain elements. Analysis of the livers of healthy animals provides a standard for comparing with other animals.

Table 1 shows the concentrations of various trace elements in the livers of healthy and unhealthy animals from the Hilltop area.

Table 1 The average concentrations (in p.p.m.) of various trace elements in the livers of healthy and unhealthy animals from the Hilltop area

Element	*Symbol*	*Concentration in parts per million (p.p.m.)* *Healthy animals*	*Unhealthy animals*
chromium	Cr	2.0	1.1
copper	Cu	70.0	16.0
iron	Fe	180.0	44.0
lead	Pb	0.05	0.05
manganese	Mn	40.0	12.0
mercury	Hg	0.01	0.01
molybdenum	Mo	3.5	24.0
nickel	Ni	4.0	1.3
zinc	Zn	4.0	3.0

Questions

2 *Compare the figures for healthy and unhealthy animals in Table 1. Which element(s) may be greatly deficient (at least 3 times too low) in the diets of the unhealthy animals?*

3 *Which element(s) may be present in excess in the diets of the unhealthy animals?*

From studies in other areas, the sickness was known to be caused by a deficiency of one of the trace elements in Table 1. This deficiency *might* be because there is too little of this element in the soil. But it could also be the result of another element blocking the uptake of a vital element.

The normal method of correcting deficiency of a trace element is to provide additional amounts of the deficient element. This is done either in fertilizers added to the soil or as chemicals in the animal's food.

Both methods of treatment were tried in the Hilltop area. Neither method improved the health of the animals. The next step was to carry out a geological examination of the area. Scientists examined the local rocks, soil and streams to find which elements were deficient or in excess in the soil. Deficiency or excess in the soil would be passed on to the grass eaten by the cattle.

Geology of the Hilltop area

Several years ago a thorough geological survey had been made of the Hilltop area.

Extracts from the geological survey of the Hilltop area

Extract 1 – Stream sediments

Analysis of stream sediments can be used to compare the elements present in different drainage areas. Elements that are found in the sediments of rivers and streams are also likely to be found in the grass. Samples were dug from the stream beds, dried and analysed. The samples were labelled according to the streams on Map 1. The results are shown in Table 2.

Table 2 Concentrations of elements present in the sediments of the different streams, in parts per million (p.p.m.)

Stream	*Cr*	*Cu*	*Fe*	*Pb*	*Mn*	*Hg*	*Mo*	*Ni*	*Zn*
1	2	40	280	30	180	0.5	34	3	60
2	1	32	170	4	140	–	4	1	16
3	1	94	420	44	310	–	60	4	81
4	2	54	340	28	220	0.5	5	2	74

Questions

4 *Which four farms are unsuccessful and losing money because of unhealthy animals?*

5 *Look carefully at Map 1. Which streams drain towards the unsuccessful farms?*

6 *Look carefully at Table 2. Are the streams draining towards the unsuccessful farms deficient in the element or elements listed in your answer to question 2?*

7 *Do the streams draining towards the unsuccessful farms have an excess of the element or elements listed in your answer to question 3?*

8 *What do you think is the cause of the problem?*

Extract 2 — The underlying rocks

Map 2 shows a geological map of the Hilltop area. Samples were taken from the different rock types in the area. The analysis of these samples is given in Table 3.

Table 3 Analysis of rock samples. (Values show the elements present as parts per million (p.p.m.))

Rock type	*Cr*	*Cu*	*Fe*	*Pb*	*Mn*	*Hg*	*Mo*	*Ni*	*Zn*
Limestone	0.75	4.2	120	3.5	160	0.03	1.25	0.65	4.5
Grit	1.10	3.7	65	40	145	0.03	1.80	1.3	3
Mudstones	1.20	5.6	165	5	125	0.04	3.5	1.45	2
Shales	1.45	7.7	175	4	137	0.03	62	1.5	2.5
Sandstones	1.50	11.5	200	5	157	0.04	5	1.8	6.2

Questions

9 *Consult Maps 1 and 2. (They can be viewed at the same time by holding them up to the light together, one on top of the other.) Which rock types may affect the streams draining towards the unsuccessful farms?*

10 *Now consult Table 3 and your answer to question 9. Which rock seems the most likely source of the element you suspect?*

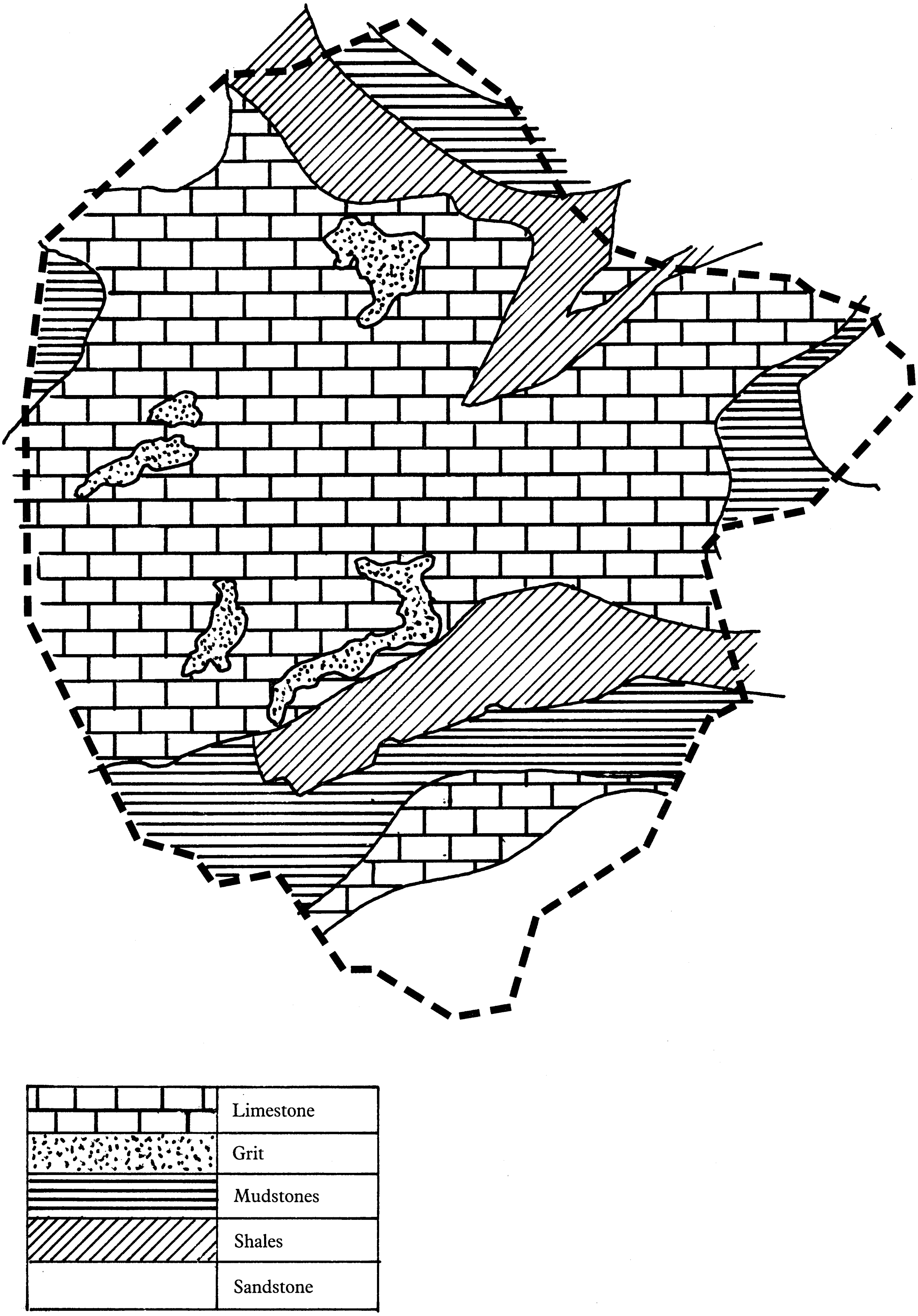
11 *State the basic cause of the sickness in the animals and explain how the rocks in the area are causing the problem.*

Easing the problem

Having found the element that was making the animals unhealthy, the scientists were unable to find a complete cure. However, they were able to help the farmers cut down the sickness in their animals.

Question

12 *What advice would you give to the farmers of the unsuccessful farms?*



Map 2 Geological map of the Hilltop area

SATIS 1

List of units in this book

The Association for Science Education
College Lane
Hatfield
Herts AL10 9AA