Using Radioactivity

Contents: Reading and problems concerning the medical and industrial applications of radioisotopes.

Time: 2 periods

Intended use: GCSE Physics, Chemistry and Integrated Science. Links with work on radioactivity, radiation and radiochemistry.

Aims:

- To complement and revise prior work on radioactivity and radiation
- To show the wide and diverse range of technological applications of radioisotopes
- To show the hazards of radiation
- To provide opportunities to practise skills in reading, comprehension and problem-solving.

Requirements: Students' worksheets No. 204

This unit is in three parts. Part 1, *What is radioactivity?* is a summary of theoretical background and can be omitted where appropriate. Part 2 is an account of some uses of radioisotopes, with questions. Part 3 is a series of problems to be solved using the radioisotopes specified in Table 2.

Notes on questions 1 to 6

In general, the radiation chosen for a particular application depends on the penetrating power needed. For example, medical investigations require gamma sources in order that the radiation can penetrate to the outside of the body. Short half-lives are important in nuclear medicine so that the isotope does not persist and cause damage to the body. Tc-99 is ideal in this respect and is used in over 80 per cent of nuclear medicine investigations. The gamma radiation it emits is of the right energy (140 keV) to get out of the body without doing too much damage. The isotope used is in fact Tc-99m, a metastable isotope which decays by gamma emission to the near-stable Tc-99 (half-life 10^5 years). Because of its short half-life, Tc-99m must be generated *in situ* from a parent isotope, Mo-99. The user purchases a 'technetium generator' containing Mo-99, from which Tc-99 can be separated when needed, using ion-exchange.

Notes on the problems

Problem 1 Use Sr-90 as a beta source in a thickness gauge.

Problem 2 Use Co-60 as a gamma source to sterilize the Petri dishes inside sealed packs.

Problem 3 Use Xe-133 as a gamma source to trace the movement of gas in the lungs.

Problem 4 Use Co-60 as a gamma source to check the concrete for flaws such as air pockets, placing the source on one side of the structure and a detector on the other. Small amounts of the isotope can also be added to the concrete itself to check the spread of concrete to fill the holes in which the legs are set.

Problem 5 Ir-192 is used to make 'radioactive sand', which is added to the river at different points. Checks are then carried out for gamma radiation at the places where the river is silting up. (Co-60 could in principle also be used.)

Problem 6 H-3 (tritium) is used to make 'radioactive water' which can be added in small quantities to the different streams in turn and used as a tracer.

Other uses of radioisotopes

There are many other uses of radioisotopes which space limitations prevent being mentioned in the students' materials. Some of the following may be useful background information for teachers:

Radioimmunological assays

This is an important way of measuring the level of a particular biochemical in the blood. For example, the level of human placental lactogen (HPL) in a blood sample from a pregnant woman can be found by attaching a radioactive 'label' (for example I-125) to an antigen. When the labelled antigen is added to the blood sample in a test tube, it forms an insoluble complex with the HPL which can be filtered off, washed and checked for radioactivity. The level of radiation is a very sensitive indicator of the amount of HPL present in the blood.

Static eliminators

Alpha emitters such as Po-210 can be used to remove static electricity. Static can be a problem, for example, in film processing where the presence of static makes dust stick to the film. A nearby alpha source causes ionization in the surrounding air thus providing a path through which the static can escape.

Oil well logging

The extent of an oil well can be found by pumping ^3H_2O into the well and measuring its spread.

Plant nutrient uptake

The rate at which plants take up phosphorus from the soil can be investigated using P-32.

Thyroid treatment and diagnosis

Iodine is taken up by the thyroid gland, and this can be used both in the treatment of thyroid cancer and in the investigation of thyroid disorders. The isotope used is I-131, a beta and gamma emitter.

Research applications

Radioisotopes have countless applications in scientific, medical, agricultural and other research fields.

Other resources

1 The United Kingdom Atomic Energy Authority produce a wide range of resource materials. Most of these materials are concerned with nuclear energy, but a few relate to radiation and the uses of radioisotopes. Available from:
   Information Services Branch
   UKAEA
   11 Charles II Street
   London SW1Y 4QP

2 The UKAEA have produced a film, *Using Radioactivity*, which runs for 22 minutes and gives good coverage of a range of uses of radioisotopes. Available on free loan from:
   Central Film Library
   Chalfont Grove
   Gerrards Cross
   Bucks SL9 8TN

Acknowledgement Figure 7 supplied by the United Kingdom Atomic Energy Authority.

USING RADIOACTIVITY

Part 1 What is radioactivity?

You will probably have already done some work on radioactivity in your physics or other science lessons, but here is a very short summary. Leave it if you are sure of the basic facts, and move on to Part 2.

Some atoms are unstable. Their nuclei rearrange to form more stable atoms, and at the same time give out **radiation**. These atoms are **radioactive** and are called **radioisotopes**. There are three main types of radiation: alpha, beta and gamma. Table 1 compares the three.

Table 1 Types of radiation

Type of radiation	*What it consists of*	*Penetrating power*
alpha	Positively charged particles. Each particle contains two protons and two neutrons.	Low. Stopped by paper.
beta	Negatively charged electrons.	Moderate. Stopped by a thin sheet of aluminium.
gamma	Electromagnetic waves.	Very high. Stopped by thick blocks of lead or concrete.

Figure 1 compares the penetrating power of the three different types.

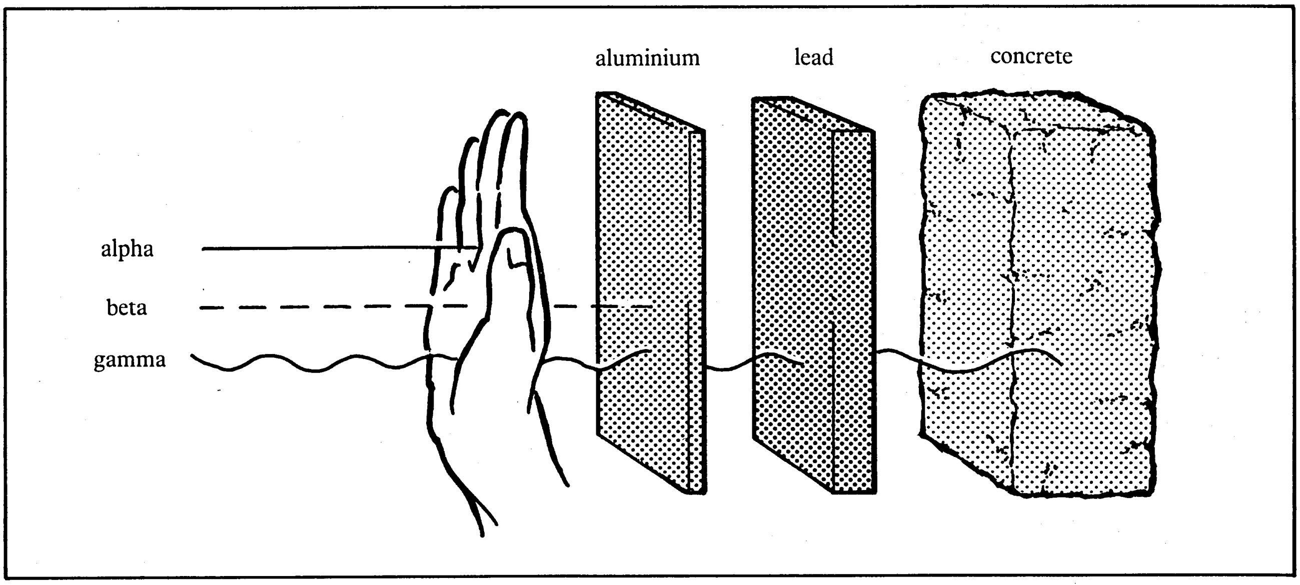

Figure 1 The penetrating power of different types of radiation.

Radiation is very easy to detect, using special instruments such as Geiger counters. Even tiny amounts of radiation can be detected. A Geiger counter actually counts every particle which enters it.

Half-life The amount of radiation produced by a radioisotope decreases with time. The time taken for the radioactivity to decrease to half its original amount is called the **half-life**. Very unstable radioisotopes have very short half lives, often less than a second.

Symbols for isotopes Each isotope has a symbol, showing which element it is. Because every element has several isotopes, each isotope also has a number. This is the **mass number** of the isotope — the number of protons and neutrons in its atoms. For example, an important isotope of carbon has mass number 14. It is called carbon-14, or ^{14}C.

As you will discover in the rest of this unit, the special properties of radioisotopes make them useful for solving all sorts of problems in industry, medicine and science.

Part 2 Radioactivity in use

Why is radioactivity so useful?

Several properties of radiation make it useful:

- Radiation is easy to **detect**, even in tiny amounts. This makes it easy to **locate** the radioisotopes that are giving out the radiation.
- Radiation can be very **penetrating**. It can be used to look inside solid objects, in the same way that X-rays are used.
- Radiation can destroy living cells. This makes it dangerous, but also useful for **sterilizing** things by killing micro-organisms.

Some examples of uses of radioactivity are given below. After you have studied them, you will find some real-life problems to try to solve using radioactivity.

Using radioactivity in industry

Radioactivity has many uses in industry. Here are a few examples.

Measuring thickness

When paper is being manufactured, it is important to get the thickness right. Beta radiation is passed through the paper, and detected the other side. The thicker the sheet, the weaker the beta radiation will be after passing through. This can control the rollers which decide the thickness of the paper (Figure 2). The source of beta radiation is often strontium-90 (^{90}Sr), half-life 28 years.

> *Question*
>
> *1 Why is beta radiation best in this case, rather than alpha or gamma?*

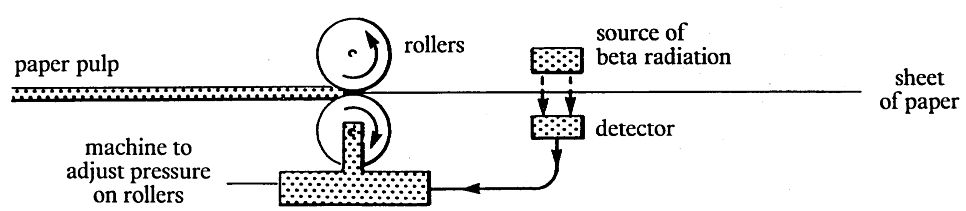

Figure 2 Using beta radiation to measure thickness

Detecting smoke

Alpha particles are very easily stopped, and this makes them useful in smoke detectors. Americium-241, with a half-life of 433 years, is often used as the source of alpha particles. Figure 3 illustrates how the system works.

Questions

2 *Why is alpha radiation best in this case, rather than beta or gamma?*

3 *Why is a radioisotope with a long half-life needed?*

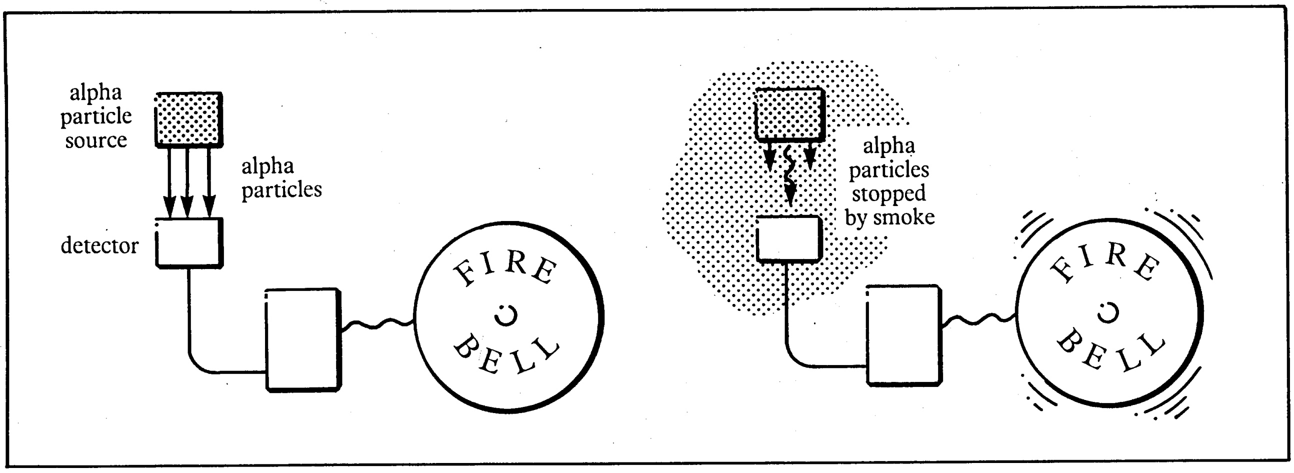

Figure 3 Using alpha particles in a smoke detector

Looking at the inside of structures

Gamma radiation can be used like X-rays to get pictures of the insides of solid objects. For example, when underground pipelines are laid, the sections of pipe are welded together. It is important to check that the welds do not have any faults inside. This is done using gamma ray photography (Figure 4). Iridium-192 (^{192}Ir), half-life 74 days, is often used as the source of gamma rays. Any faults in the weld show up when the film is developed.

Question

4 *Why is gamma radiation best in this case, rather than alpha or beta?*

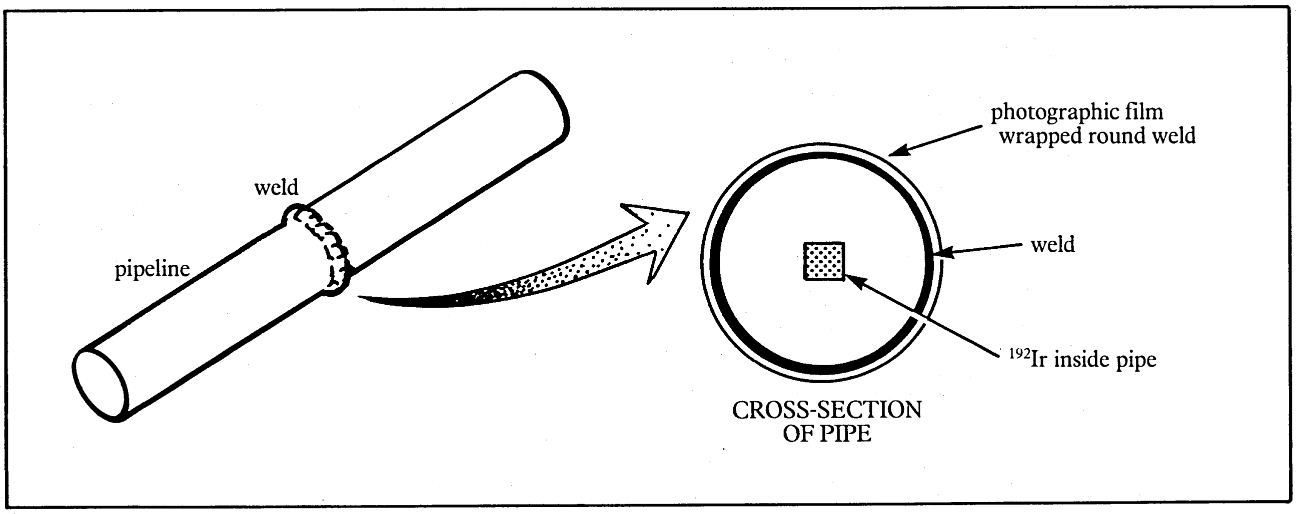

Figure 4 Using gamma photography to check a weld

Tracing movements

It is often important in industry to know where liquids and gases are travelling. For example, iridium-113 can be added to power station cooling water in tiny quantities. By looking for gamma radiation, scientists can tell where, and how fast, the cooling water has travelled through the many pipes in the power station.

Using radioactivity in medicine

Medical investigations

Radioisotopes are very useful for investigating the inside of a person's body without having to cut them open. The radioisotope most commonly used is technetium-99 (^{99}Tc). This gives out gamma rays and has a half-life of about 6 hours.

Figure 5 summarizes the way ^{99}Tc might be used to investigate a person's liver. One of the liver's many jobs is to remove unwanted substances from the blood. If a person is given small amounts of sulphur, the liver will remove the sulphur by absorbing it. If a small amount of ^{99}Tc is attached to the sulphur, it becomes slightly radioactive and gives out gamma radiation. The ^{99}Tc is a kind of radioactive 'label' on the sulphur. When the radioactive sulphur is absorbed by the liver, it can be detected using a gamma camera. The camera is placed over the liver, outside the body.

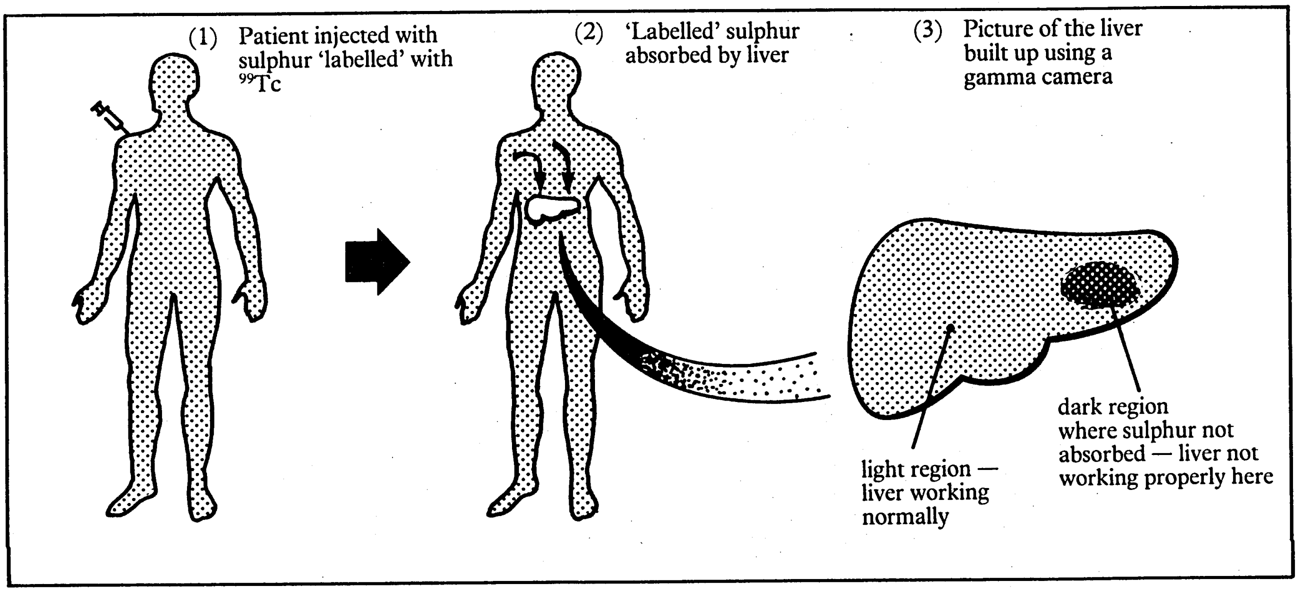

Figure 5 Using gamma radiation to investigate the liver

Atoms of ^{99}Tc can be attached to many different biological compounds, and used to trace the way these compounds are used in different parts of the body, such as the brain, kidneys, lungs and bones.

Questions

5 *Why is gamma radiation most suitable for this application?*

6 *Why is it important that the ^{99}Tc has a fairly short half-life of 6 hours?*

Sterilizing

To avoid infecting patients, many medical items have to be sterilized to kill bacteria and other micro-organisms on them. They are sterilized using gamma rays. Figure 6 illustrates the method.

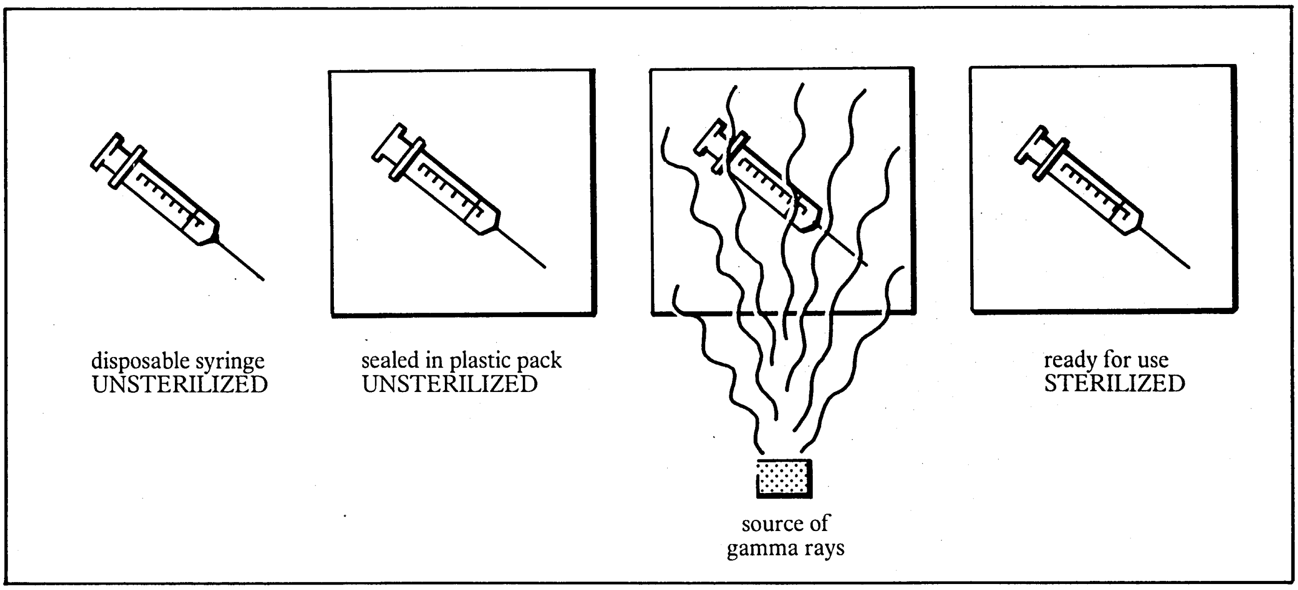

Figure 6 Sterilization using gamma rays

Treating cancer

Cancer cells are more easily killed by radiation than normal cells. By aiming gamma rays very accurately at cancerous growths, doctors can try to destroy the cancer without affecting the rest of the body. Gamma radiation from cobalt-60 (half-life 5 years) is often used.

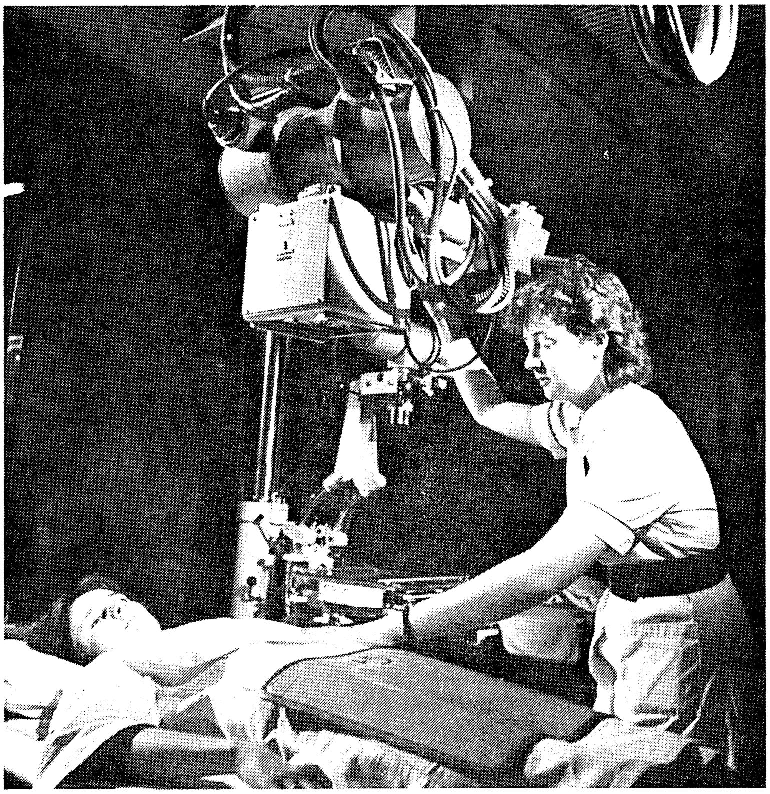

Figure 7 Using modern radiographic equipment to X-ray the spine, with careful protection to limit radiation dose to vital organs such as the ovary.

Using radioactivity safely

Radiation is dangerous because it kills living cells. Careful safety precautions must be taken when using radioisotopes. Strong sources of radiation are put behind lead or concrete screens. People who work with radioisotopes are checked each day to make sure they have not received too much radiation.

However, the amount of radiation we get from artificial radioisotopes is small compared to the natural radiation that comes from the rocks around us, from the Sun and from space.

Part 3 Solving problems using radioactivity

This section includes a list of problems that have been solved in real life using radioactivity. Each problem can be solved using a radioisotope from Table 2.

For each problem say:
(a) How you would use radioactivity to solve the problem (draw diagrams if possible)
(b) Which radioisotope you would use, and why.

The first problems are the easiest.

Table 2 Radioisotopes for solving the problems

Isotope	*Solid, liquid or gas*	*Type of radiation*	*Half-life*
polonium-210	solid	alpha	138 days
hydrogen-3	gas	beta	12 years
strontium-90	solid	beta	28 years
cobalt-60	solid	gamma	5 years
iridium-192	solid	gamma	74 days
xenon-133	gas	gamma	5 days

Problem 1 Polythene sheeting

Your company makes polythene sheeting by passing thick sheets of polythene through rollers. How will you make sure the sheeting is of even thickness?

Problem 2 Petri dishes

Your company manufactures plastic Petri dishes. They are used for growing bacteria in laboratories, so it is important that they are sterile when delivered to the customer. They cannot be sterilized by heating because the plastic would soften. What will you do?

Problem 3 Lungs

You are a hospital consultant specializing in treating breathing problems. You suspect that one of your patients has a blockage in an air passage in one of her lungs. How can you check?

Problem 4 North Sea oil rig

You work for an engineering company that builds North Sea oil rigs (Figure 8). The legs of the rigs are set into the sea bed with concrete. It is essential that the concrete contains no faults or air pockets, otherwise the rig may blow over in a storm. How can you check?

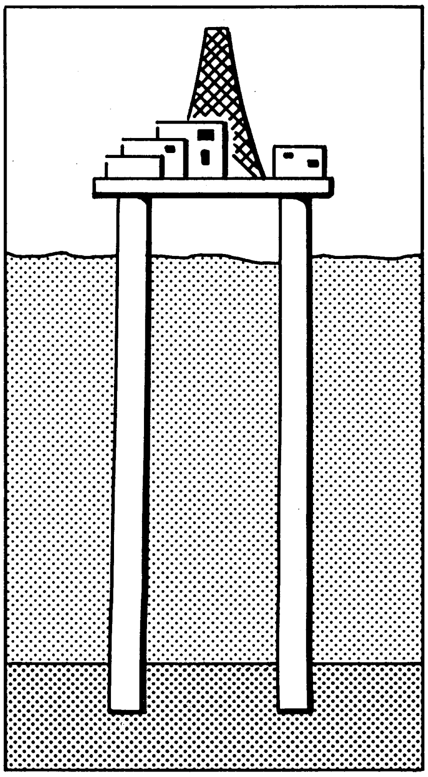

Figure 8 North Sea oil rig

Problem 5 Shifting sands

You work for the Afon River Authority. You have a problem because the river is getting blocked by silt (fine sand) near Afonmouth (Figure 9). How can you find out where the silt is being carried from?

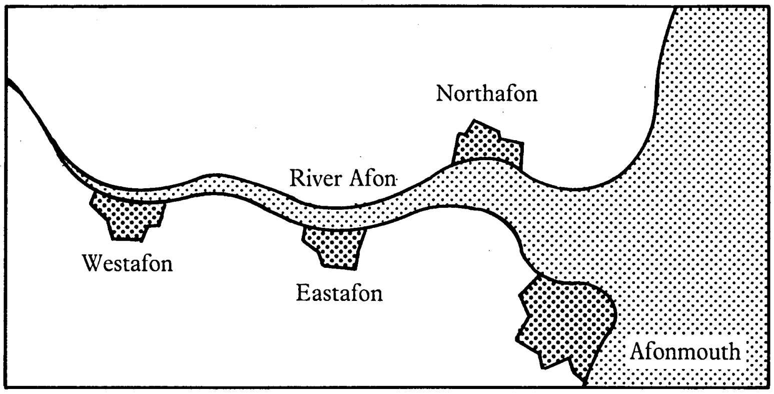

Figure 9 Shifting sands

Problem 6 Tracing water

You are Chief Scientist for the Newtown Water Company. The company gets all its water from underground boreholes drilled in the limestone rock. The surrounding limestone hills have several streams which suddenly disappear underground (Figure 10). Some of these streams feed the boreholes, though you are not sure which ones. You need to find out, so you can avoid pollution getting into the boreholes via the streams. What will you do to find out which streams feed the boreholes?

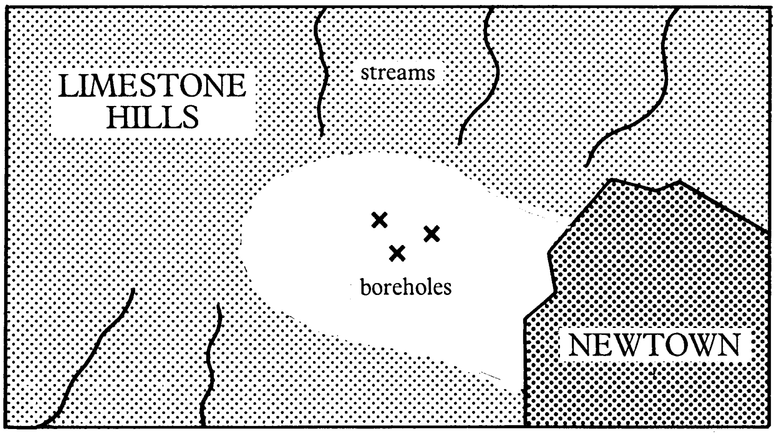

Figure 10 Tracing water

Looking at Motor Oil

Contents: Information and questions on the function of motor oil in an engine, and the problems involved in formulating an efficient oil. Optional practical work investigating the change of oil viscosity with temperature.

Time: 1 period or less without practical work; 2 periods or more if practical work is used.

Intended use: GCSE Chemistry and Integrated Science. Links with work on petroleum, hydrocarbons and alkanes.

Aims:

- To complement prior work on hydrocarbons and alkanes
- To show the varied functions of motor oil
- To show the role of scientists in designing and formulating a product such as motor oil
- To provide opportunities to practise skills in reading and comprehension, and certain practical skills, including accurate timing and safe heating of a liquid.

Requirements: Students' worksheets No. 205. For practical requirements, see below.

The unit is designed to stand alone without the practical work, but it is recommended that the experiment be used as well if this is at all possible. If apparatus is limited, it could be done as a demonstration.

Background information

Designing an oil

A multigrade oil is designed to be thin at low temperatures yet thick enough to be effective at engine operating temperatures. It does this by viscosity improvers, which are polymers of four types: polyisobutenes, polymethacrylates, ethene/propene copolymers and alkene/styrene copolymers. These are added to the 'base oil', which forms the basis of the lubricating oil blend. The polymers coil up at low temperatures and so increase the viscosity only slightly, but as the temperature rises they interact more strongly with the base oil and slowly uncoil, thus helping to counteract the decrease in viscosity of the base oil.

In the students' materials, the viscosity of oil is explained in terms of 'tangling' of molecules. The situation is of course more complex than this: viscosity is related to intermolecular forces, and longer chains have higher intermolecular forces due to their larger number of points of contact.

What jobs does an oil do?

Besides viscosity improvers, modern oils also contain other additives. These are summarised in the table below.

Job of additive	*Chemical type*	*Action*
Anti-oxidant	Phenols, arylamines	The compounds react sacrificially to terminate chain reactions that would result in deterioration of the oil due to oxidation.
Anti-wear	Compounds containing P or S	The additive is absorbed onto metal surfaces, helping to prevent wear should contact occur.
Corrosion inhibition	Organic compounds with N and S included. Basic detergents	The inhibitor acts to remove harmful species formed in the engine. For example, basic detergents neutralize acids formed in combustion.
Dispersant	Polar copolymers	The dispersant acts to keep solid particles in suspension until they reach the oil filter and are removed.
Anti-foam	Silicone fluids	Mechanical agitation causes foam, which these fluids break up as it starts to form.

During use these additives are gradually consumed, the viscosity improver molecules break down due to mechanical shear forces, and the oil becomes contaminated with wear debris, moisture, dust, combustion products and unburnt fuel. All these degrade its quality and limit its life, which in the case of car engines is normally about 6000 miles or six months. The engine may also burn some oil, which will make topping-up necessary — if possible, this should be done using the same oil in order to ensure that additives are compatible.

The practical

This practical is somewhat messy, and for this reason teachers may prefer to demonstrate it, though many trial schools found it an effective class practical.

Each group will require:

- measuring cylinder (250cm^3)
- beaker (400cm^3)
- motor oil
- thermometer (0 to 100°C)
- stopclock, accurate to 0.1s
- weighted sphere (see below)
- magnet
- tripod and gauze, bunsen burner, heatproof mat

The descent of a small sphere through oil is timed at different temperatures. The falling object must satisfy three criteria.:

- It must be a sphere, to ensure laminar flow
- It must be magnetic, to ensure ease of retrieval
- It must not be too dense, to ensure that its descent is not too rapid.

This last criterion precludes the use of such things as steel ball bearings, but a molecular models hydrogen atom (a solid plastic sphere of approximate diameter 1.5cm) with a self-tapping screw inserted has been found to give good results. (Trial results are given below.)

With the set-up described, times of 1.0 to 5.0s must be measured with reasonable accuracy, hence the need for an accurate stopclock.

The grade of oil to be used is not critical — any single or multigrade motor oil is quite satisfactory. The conditions of the experiment do not enable the difference in viscosity/temperature relationships between single and multigrade oils to be demonstrated. Heating the oil directly is not dangerous since motor oils have a high flashpoint, although any spills onto the gauze may cause some smoke.

Under no circumstances should the oil be heated above 100°C. Above this temperature any water present in the oil may vaporize explosively, with dangerous consequences.

Trial results using Shell Super Motor Oil:

Oil temperature/°C	24	32	41	51	58	68
Average time/s	4.11	2.76	1.97	1.56	1.43	1.22

Cleaning the apparatus

After the experiment the apparatus will be very oily and should be soaked for several hours in hot water with plenty of detergent.

Treatment of results

The relating of 'time to fall' to viscosity is treated very simply. It may be derived, if wished, from Stokes Law and the relationship $v = x/t$. Obviously the viscosity of oil falls as temperature rises, this fall being most noticeable in the range 20°C to 40°C.

Acknowledgements: Figure 1 is reproduced by permission of BP Oil Ltd; Figure 2 is reproduced by permission from Graham Hill and John Holman, *Science* (Nelson). Figure 4 is reproduced by permission of Burmah-Castrol.

LOOKING AT MOTOR OIL

A lot of people do not think very much about the oil in the engine of their family car. They know that the oil must be changed when the car is serviced, and that it sometimes needs 'topping-up' but that is usually about all. To carry on working properly with so little attention, oil must be carefully designed (or 'formulated') by scientists.

In this unit you will look at some of the ways an oil is designed. You may also do an experiment to test a motor oil's viscosity.

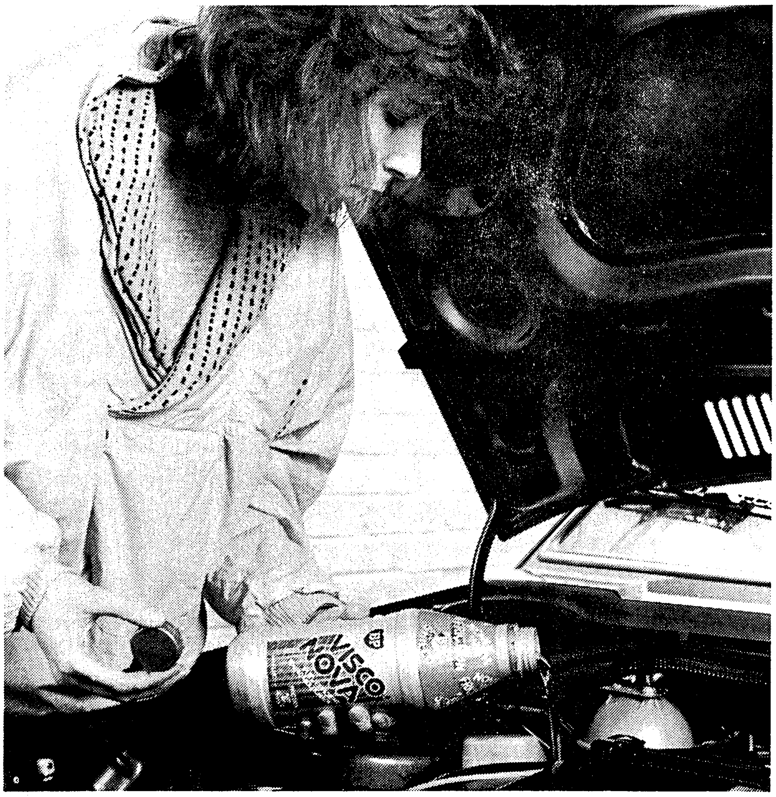

Figure 1 'Topping-up' the oil

Designing an oil

In a car engine, pistons move up and down inside cylinders. One of the main jobs of motor oil is to *lubricate* the pistons so they move smoothly (Figure 2).

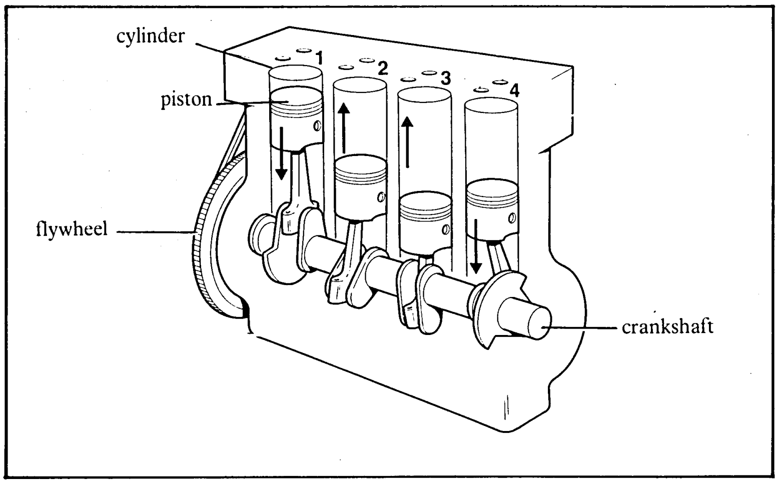

Figure 2 A four-cylinder petrol engine

Questions

1. *How does the viscosity of most liquids (for example, treacle) change when they are heated?*
2. *Why is it important for motor oil designers to know how the viscosity of motor oil changes with temperature?*

For good lubrication, the oil must have the right *viscosity* (thickness).

Your teacher may ask you to do an experiment to investigate the viscosity of motor oil. You will investigate how its viscosity changes with temperature. If you are doing the experiment, do not go on to the next section until you have completed it.

Viscosity and temperature

If you have done the experiment, you will know that

> **motor oil gets thinner (less viscous) at higher temperatures.**

Oil must work at a wide range of temperatures. In the icy cold of a winter's morning its temperature may be as low as minus 15°C. At the operating temperature of the engine it will be between 90°C and 100°C. Any change in viscosity affects the way oil behaves and how it lubricates the engine's moving parts.

> *Question*
>
> 3 *How will the oil's viscosity change over the temperature range from minus 15°C to 100°C?*

A thin oil does not 'cling' well to moving surfaces, but it is easy to circulate round the engine quickly. A thick oil clings well, but circulates sluggishly. This leads to the following advantages for thick and thin oil:

Thick oil
Better engine protection
Less oil used up
Quieter running

Thin oil
Easier cold starting
Faster circulation round the engine
Saves petrol.

> *Questions*
>
> 4 *Why do thin oils give easier cold starting?*
>
> 5 *Why do thick oils give better engine protection?*

To overcome the problem of the wide range of temperatures in which oil has to work, scientists have developed special oils called **multigrade** oils. A multigrade oil is specially formulated so that its viscosity does not change too quickly as the temperature rises. The oil is thick enough to coat and lubricate moving surfaces at high temperatures. At low temperatures it stays thin enough to make sure that the engine will turn easily.

How do multigrade oils work?

Motor oils contain a mixture of carbon compounds. Most of these compounds are alkanes with chains of about 30 carbon atoms. These chains get tangled up, which makes it more difficult for the oil to flow. The more tangling, the more viscous the oil will be.

Multigrade oils include special substances called **viscosity index improvers,** or **VIs** for short. The molecules in VIs behave in different ways at different temperatures (Figure 3).

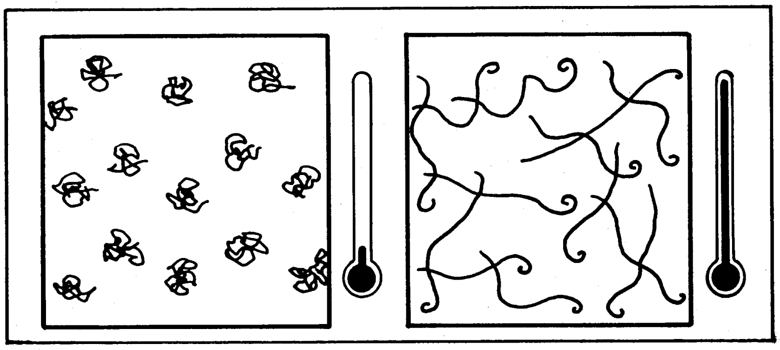

Figure 3 Molecules of VI at low (left) and high (right) temperatures

Question

6 How do VIs help to increase the viscosity of an oil at high temperatures, without making it too thick at low temperatures?

Measuring the viscosity of oil

Oil viscosity can be measured in many ways, but the best known system uses **SAE numbers.** (SAE stands for Society of Automotive Engineers, an American organization.) Single grade oils have one SAE number, 20, 30, 40 or 50. The higher the number, the higher the viscosity. Multigrade oils have two SAE numbers. The first (5W, 10W, 15W or 20W) shows the viscosity at minus 18°C. The 'W' stands for winter. The second number gives the viscosity at 99°C. Again the higher the number, the higher the viscosity. A typical multigrade oil would be rated 20W/50. The larger the range, the thinner the oil is for winter starting but the better lubricant it is at high temperatures.

Question

7 How would the SAE number of an oil change if the carbon chains in it were lengthened?

What jobs does an oil do?

1 *Lubrication* This is the most important job. A thin film of oil between moving surfaces is vital to prevent friction. Without the oil (a) the engine would be hard to turn; (b) the surfaces rubbing together would overheat; (c) the surfaces would wear away.

2 *Cooling* The oil must be able to remove heat from hot parts of the engine and transfer it to the cooling system.

3 *Taking away contaminants* As the engine wears, tiny particles of metal may be carried round the engine, causing damage. The oil must carry these particles to the oil filter, which traps them.

4 *Preventing rust and corrosion* When fuel burns, some of the things produced may be very harmful to the engine. For example, diesel fuel makes a small amount of sulphuric acid! The oil must react with these products to prevent corrosion.

5 *Forming a gas seal* The piston must form a tight fit in the cylinder so that no gases can escape. The oil helps to do this, by forming a gas seal.

No one substance could do all these jobs, and a good oil is a complicated mixture of substances. In fact, you could call it 'Liquid Engineering'!

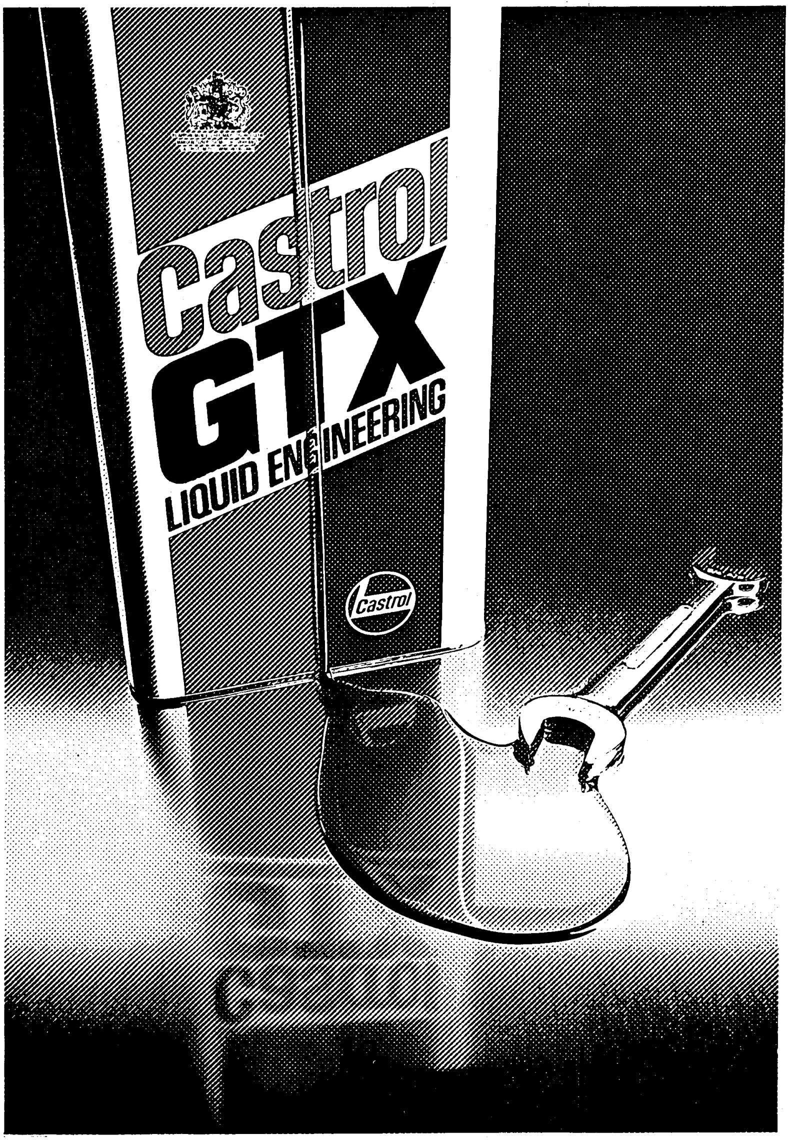

Figure 4

Questions

8 *Different jobs need different oils. What properties should oils for the following jobs have?*
  (a) *Oiling a sewing machine*
  (b) *Oiling a bicycle*
  (c) *Oiling a ship's propellor shaft?*

9 *Water flows well and is very cheap. Why is it not often used as a lubricant?*

Experiment: Investigating the viscosity of oil

In this experiment you will be looking at the way the viscosity of motor oil changes as the temperature changes.

You will need:
250 cm^3 measuring cylinder
400 cm^3 beaker
motor oil
thermometer (0° to 100°C)
digital stopwatch (with 0.1s accuracy)
weighted sphere
magnet
tripod and gauze, bunsen burner, heatproof mat.

What you do

A Pour oil into the measuring cylinder until it is about 1cm from the top of the cylinder.

B Take the temperature of the oil and record it in a table like the one below.

C You are now going to investigate how long it takes the weighted sphere to travel through the oil from the top of the cylinder to the bottom. Take the weighted sphere and hold it just above the surface of the oil in the cylinder. Drop the sphere into the oil, at the same time starting the stopwatch. Stop timing when the sphere reaches the bottom of the cylinder. Record how long it took for the sphere to travel from the top of the cylinder to the bottom.

D Using the magnet, bring the sphere back up to the top of the cylinder. Remove it, and repeat the experiment (Figure 5).

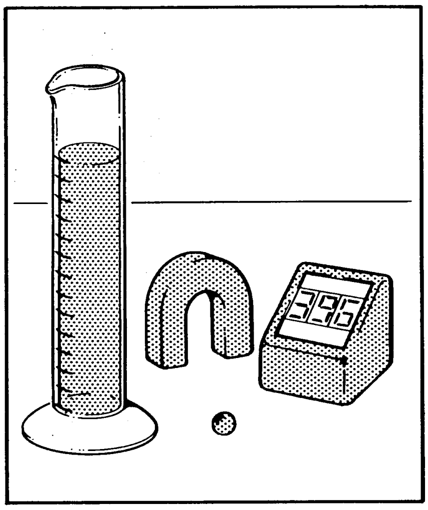

Figure 5 Equipment to investigate the viscosity of oil

You should do this until you have three results that agree quite closely. Work out the average of these three results, and record it in the table as follows:

Oil temperature/°C	*1st reading*	*2nd reading*	*3rd reading*	*Average*

E Now pour the oil into the beaker and heat it *gently* to about 30°C. Stir it gently with the thermometer while you heat it.

CAUTION — Wear goggles for heating and pouring

F Pour the oil back into the measuring cylinder to within about 1cm of the top, and record its exact temperature.

G Now drop the weighted sphere through the oil in the same way as before. Record the average time for this temperature in your table.

H Carry on heating the oil and timing the sphere at temperatures of about 40°C, 50°C and 60°C, recording the exact temperature of the oil in the measuring cylinder each time. **Do not go above 60°C.** Record all the results in your table.

> **CAUTION**
> At these higher temperatures you must be very careful with oil — hold the beaker with a cloth or paper towel when pouring, and be careful not to splash. If hot oil falls on you, quickly wash it off with lots of water. **Do not heat the oil above 60°C.**

I Now plot a graph of average fall time (y-axis) against temperature (x-axis) (Figure 6). Draw a smooth curve through the points.

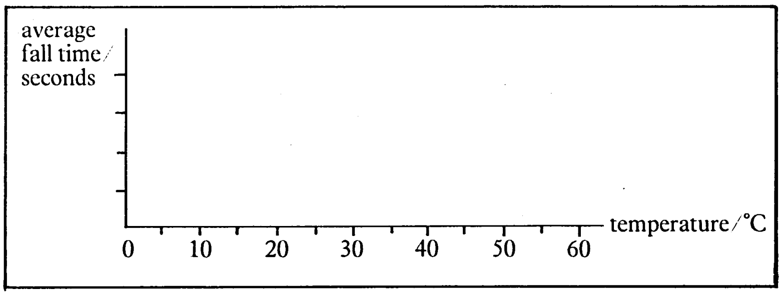

Figure 6

Looking at the results

The more viscous the oil, the longer the sphere will take to fall through it. This means that if the viscosity of the oil is large, the time taken for the sphere to fall is also large. So your graph represents the viscosity of the oil at different temperatures.

How does the oil's viscosity change as the temperature rises?

Test-tube Babies

Contents: Information and discussion questions on the problem of infertility and the technique of *in vitro* fertilization.

Time: 1—2 periods, depending on amount of discussion.

Intended use: GCSE Biology, Human Biology and Integrated Science. Links with work on human reproduction.

Aims:

- To complement and revise prior work on human reproduction
- To show the methods used to treat infertility, and the technique of *in vitro* fertilization
- To develop awareness of the benefits and some of the ethical problems associated with *in vitro* fertilization
- To encourage willingness to participate in group discussion, and to develop communication skills.

Requirements: Students' worksheets No. 206.

This unit is best used after the basic details of human reproduction have been covered. It is particularly useful for revision of work on reproduction.

The discussion questions are best tackled in groups of four or five, though teachers will appreciate that some students may be reluctant to participate because of their religious or cultural background.

Background information

This information may be useful when following up the discussion points.

1 *The Warnock Report** recommended that no human embryo be grown for longer than fourteen days outside the uterus. However, there was disagreement among members of the committee on the principle of embryo experiments, and on the length of time for which they should be permitted. Embryos grow more slowly in culture than they do in the uterus and so many scientists feel that it would be more appropriate to use a limit based on the stage of development rather than an absolute time limit. There is controversy among scientists themselves — some researchers see experimentation on human embryos as unnecessary, others as a vital procedure for the furthering of knowledge and clinical experitise.

2 A case occurred in Australia involving the frozen embryos of a wealthy couple. The wife had miscarried after the first *in vitro* fertilization and the couple were waiting to have another embryo implanted when they were both killed in an air crash. There were no close surviving relatives. The fate of the embryos — potential inheritors of a vast estate — caused a great deal of discussion. Suggestions included the destruction of the embryos, implanting them in a surrogate mother and allowing them to inherit, or allowing them to be adopted by new parents. Initially state officials accepted a recommendation that they should be destroyed but during the three months period left for further comment, the upper house of the Victoria State Parliament rejected this recommendation and left the way open for the two embryos to be adopted and implanted in a surrogate mother.

*Department of Health and Social Security, *Report of the Committee of Enquiry into Human Fertilization and Embryology.* Chairman: Dame Mary Warnock, DBE. HMSO, 1984, Cmnd 9314.

3 The possibility of making genetic changes *in vitro* raises many opportunities and issues. On the positive side, it might be possible to correct inherited genetic disorders, but students will no doubt be able to see many ghoulish possibilities on the negative side.

4 Artificial insemination and embryo implantation are common in livestock production. One technique for producing pedigree cattle involves giving a pedigree cow a 'fertility drug' to stimulate the production of several ova. The cow is then artificially inseminated with semen from a pedigree bull. The developing embryos are removed from the pedigree cow and implanted in the uterus of an ordinary cow, who thus gives birth to a pedigree calf.

Acknowledgements: Figure 1, London *Daily Mail.* Figures 2 and 3, reproduced from Graham Hill and John Holman, *Science* (Nelson).

TEST-TUBE BABIES

The first test-tube baby, Louise Brown, was born in 1978 amid great publicity. Behind the headlines is the unhappiness of many couples who are **infertile** and cannot produce a child of their own. 'Test-tube baby technology' now makes child-bearing possible again for infertile couples. But it also produces some tricky moral questions.

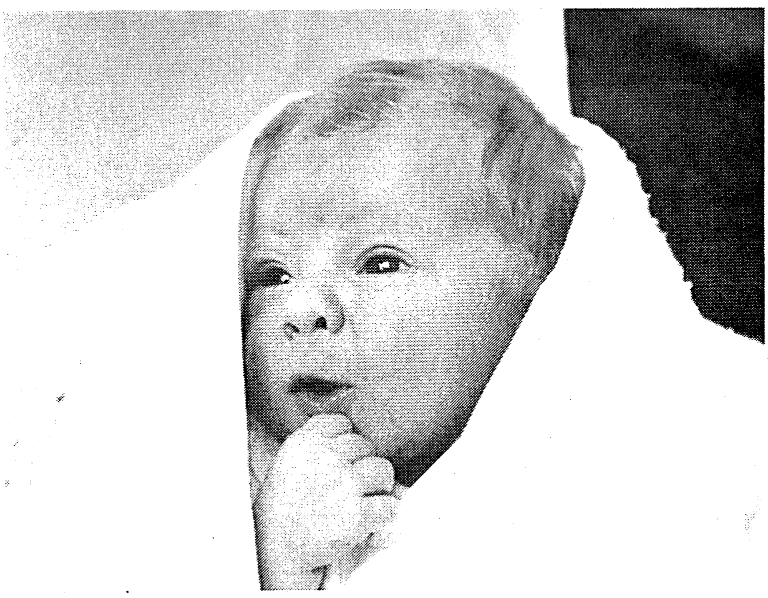

Figure 1 Louise Brown, the first test-tube baby

What causes infertility?

As many as one couple in ten has difficulty in starting or **conceiving** a baby. When 12 to 18 months have passed without a pregnancy occurring, most family doctors begin tests to find the cause of the infertility. There are many different causes. The investigations would probably go through four stages.

Stage 1 — Asking questions

The cause of infertility may lie with the man or with the woman.

The woman's menstrual history will be discussed. Does she have regular periods? If not, conception will be more difficult. The medical history of both partners will be examined. For example, if a man has had mumps since puberty he may be sterile and unable to make sperms. Questions will also be asked about the sexual activity of the couple. Some people have intercourse so rarely that conception is extremely unlikely! To give the best chances of an ovum and sperm meeting, it is best to have intercourse about the middle of the menstrual cycle.

Stage 2 — Simple examinations

The woman is given a simple examination. The doctor looks for any barrier to conception. For example, there might be a narrowing of the vagina, or a blockage cause by an infection of the vagina (see Figure 2).

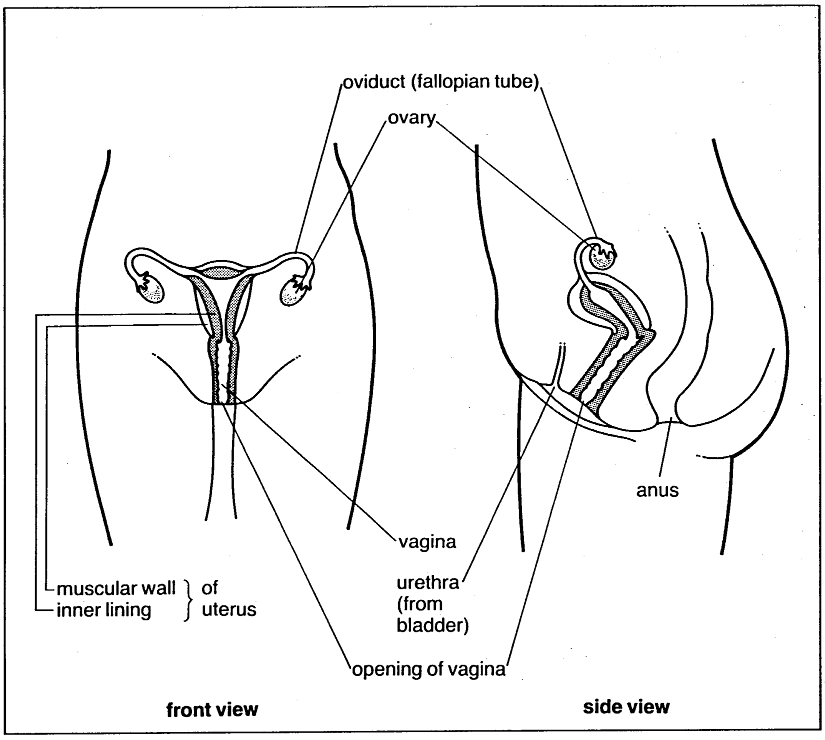

Figure 2 The main parts of the female reproductive system

The male partner may also be examined — and perhaps advised to buy some baggy underpants! Wearing of tight pants and trousers for long periods raises the temperature of the testes too high for best sperm production. Loose clothing can remove the problem.

Figure 3 shows the main parts of the male reproductive system.

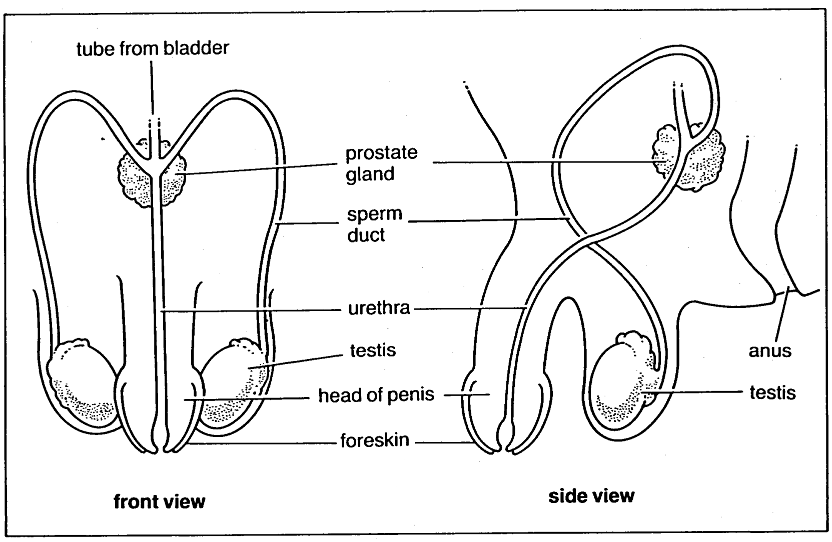

Figure 3 The main parts of the male reproductive system.

The man's sperm may be examined under a microscope. It is usual for about 20 per cent of sperm to be abnormal. If a higher percentage are abnormal, then the man's semen will be tested further. The man may be found to produce fewer sperms than normal. This is called a low **sperm count.** In this case, semen may be collected at intervals. The sperm can be frozen until there are enough healthy sperms to artificially inseminate the woman. (Artificial insemination is when sperm are introduced into the vagina artificially, instead of during intercourse.)

Stage 3 — Checking ovulation

The next stage is to check whether the woman is actually producing eggs — **ovulating.**

The woman charts her ovulation by taking her temperature first thing each morning. The body temperature normally rises during ovulation. She takes these records with her when she goes to see a hospital consultant.

If ovulation is not occurring, this is the stage when 'fertility drugs' may be used. These increase the chances of ova ripening and being released. If ovulation appears to be occurring normally, then the woman may be asked to attend the hospital shortly after having intercourse. The vagina and the opening of the uterus are then checked to see if healthy sperm are present.

Stage 4 — Final examinations

If the sperm are normal, the levels of hormones in the blood of the woman will be measured. This gives a second check on whether she is ovulating. At this stage, if all else seems normal, the oviducts (egg tubes) are checked to see if they are blocked. The most common cause of blocked tubes is infections in the uterus and the tubes. Once the tubes are blocked they cannot usually be unblocked. The only solution here is ***in vitro* fertilization** (*in vitro* means 'in glass'). A better known name for *in vitro* fertilization is 'test-tube babies'.

What is a test-tube baby?

It would be better described as a 'petri dish baby'. The ova and sperm meet in a petri dish, not a test tube.

The stages in the process are shown in Figure 4 on the next page. The woman is given a fertility drug to make sure that as many ova as possible ripen in her ovaries. The ova are then removed by an operation. They are placed in a special solution in a petri dish. Sperm from the man are added and fertilization of several of the ova takes place. The fertilized ova are then allowed to develop for several days, forming small balls of cells. These tiny embryos are replaced in the mother's uterus. If the operation succeeds, one or more of them will develop into a normal baby. The extra embryos may be frozen and stored, used for experiments, or destroyed.

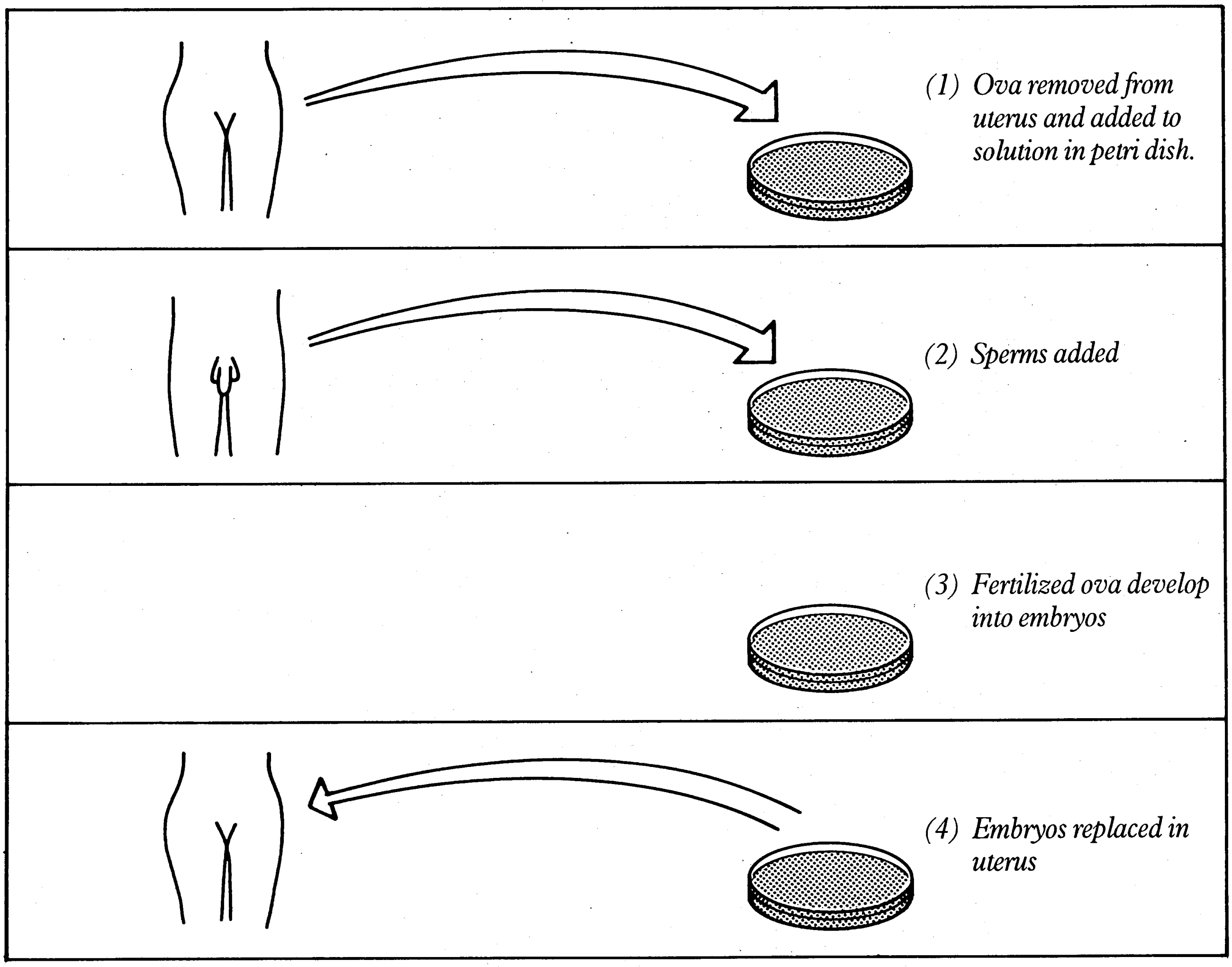

Figure 4 In vitro *fertilization*

The technology that makes test-tube babies possible can bring hope to many childless couples. But it also raises difficult questions for doctors, scientists and society. The government set up the Warnock Committee to look at these questions, and to suggest whether new laws should be made. The questions asked could affect us all. What do *you* think about these difficult points?

The following questions are best discussed in small groups.

The following questions are best discussed in small groups.

Points for discussion

- Embryos can be very useful for medical research on things like transplant surgery and cancer treatment. During *in vitro* fertilization more embryos are produced than are needed. Should these 'spare' embryos be used for medical experiments? If you feel it is acceptable, should there be an age limit after which experiments must cease?
- What about **surrogate motherhoood?** This is where one woman carries a fertilized egg for another woman who is infertile. Should this be allowed?
- Embryos can now be successfully frozen. This means parents need only donate ova and sperm once, but can space their family over several years.
  However, suppose the parents are killed or die. What should happen to the embryos? They could be implanted into a surrogate mother. They could be used for experiments, or they could be destroyed. A difficult decision — what do *you* think?
- When an egg and a sperm meet outside the body, doctors have the chance to examine the chromosomes of the cells. This means that in the future genetic changes might be made before the embryo is implanted into the mother. Genes in the embryo's cells could be removed or replaced. What advantages and problems might this bring?
- To produce a test-tube baby uses up a lot of medical time and resources. Many other areas of the Health Service desperately need money and resources. Do you think money used for test-tube babies is well spent?
- These methods can also be used in animals. What advantages can you see in freezing sperm and using artificial insemination and 'test-tube babies' in the animal world?