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 $^{3}H_2O$ 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.

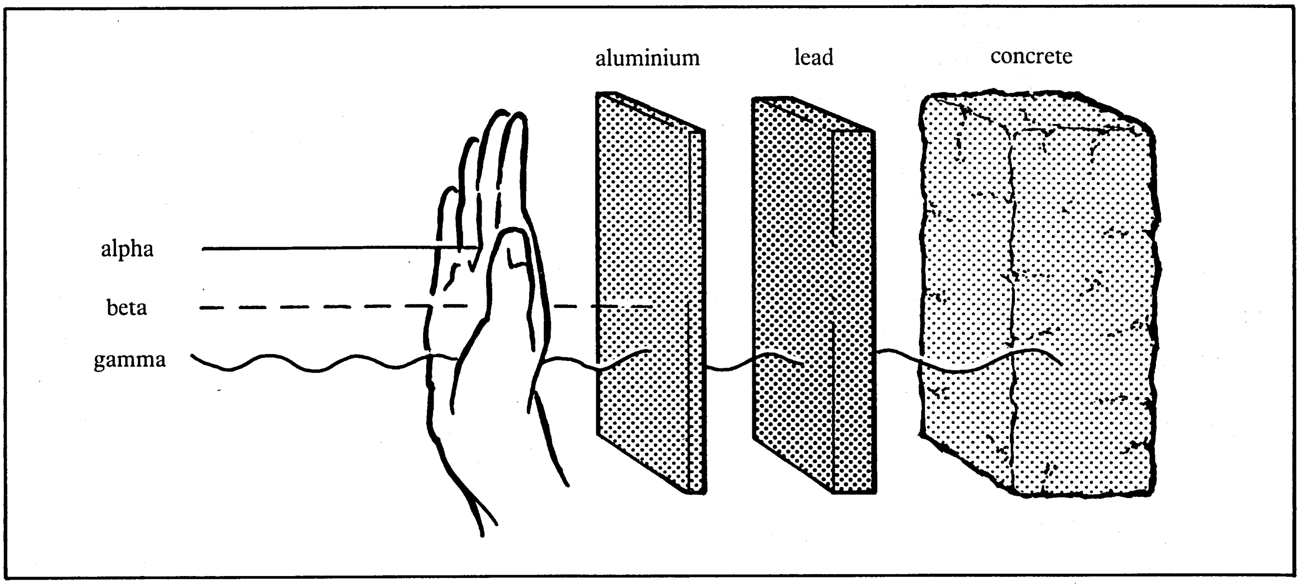

Figure 1 The penetrating power of different types of radiation.

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?*

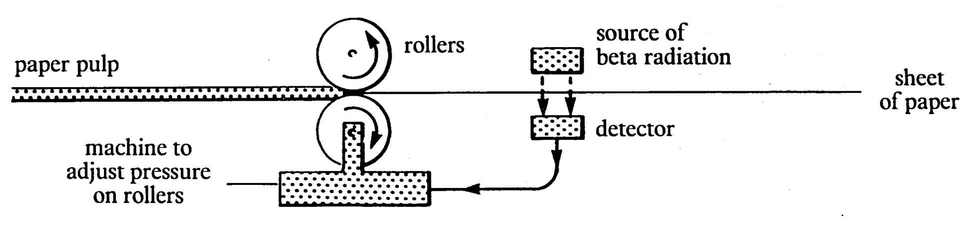

Figure 2 Using beta radiation to measure thickness

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?

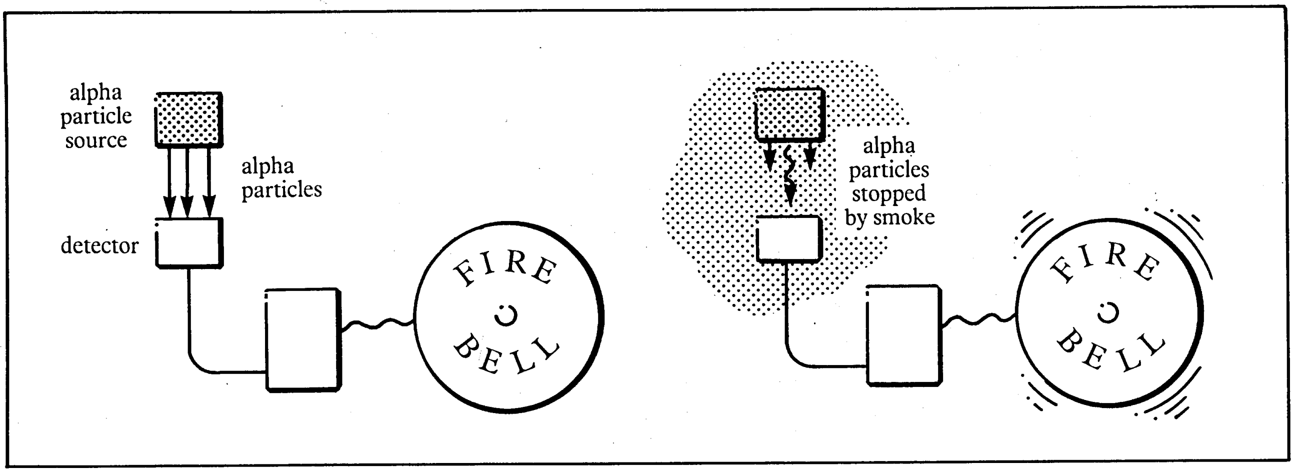

Figure 3 Using alpha particles in a smoke detector

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?

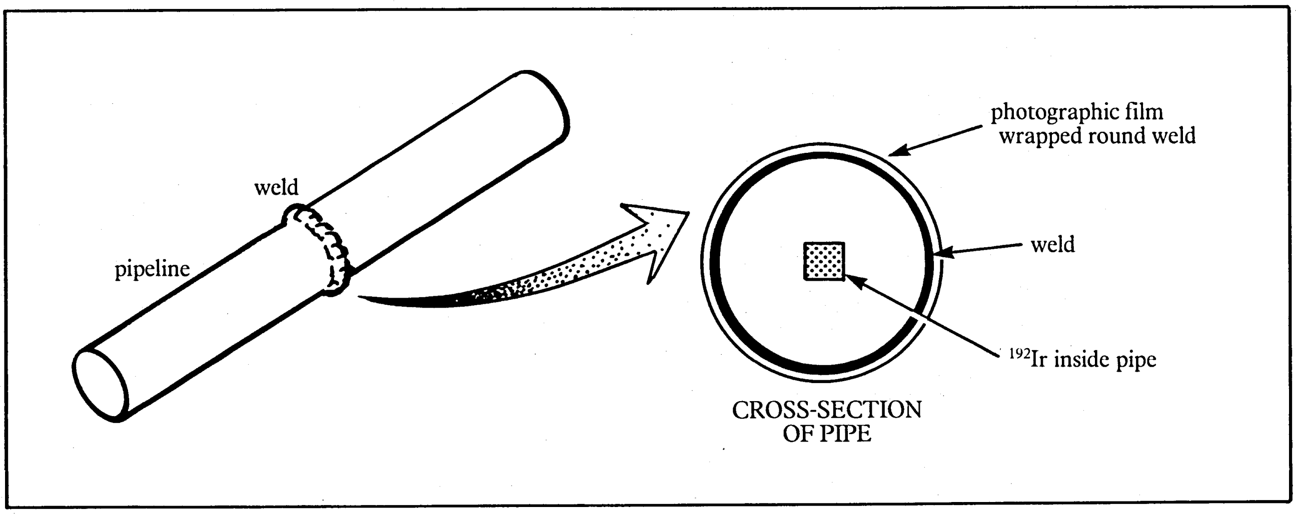

Figure 4 Using gamma photography to check a weld

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.

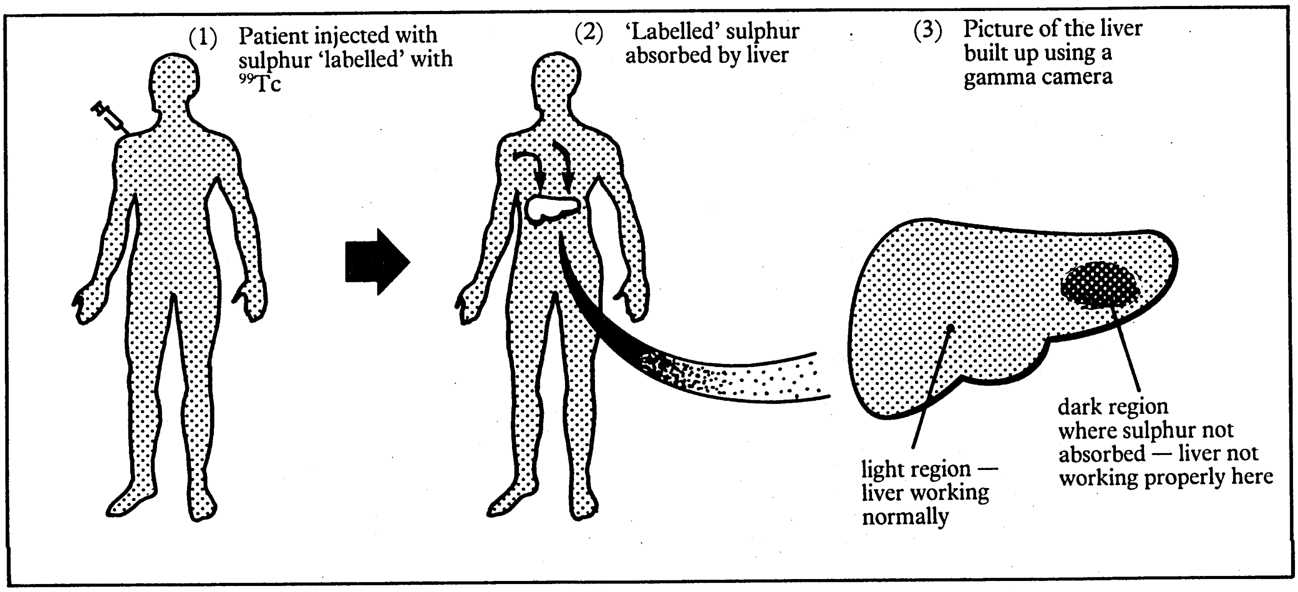

Figure 5 Using gamma radiation to investigate the liver

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.

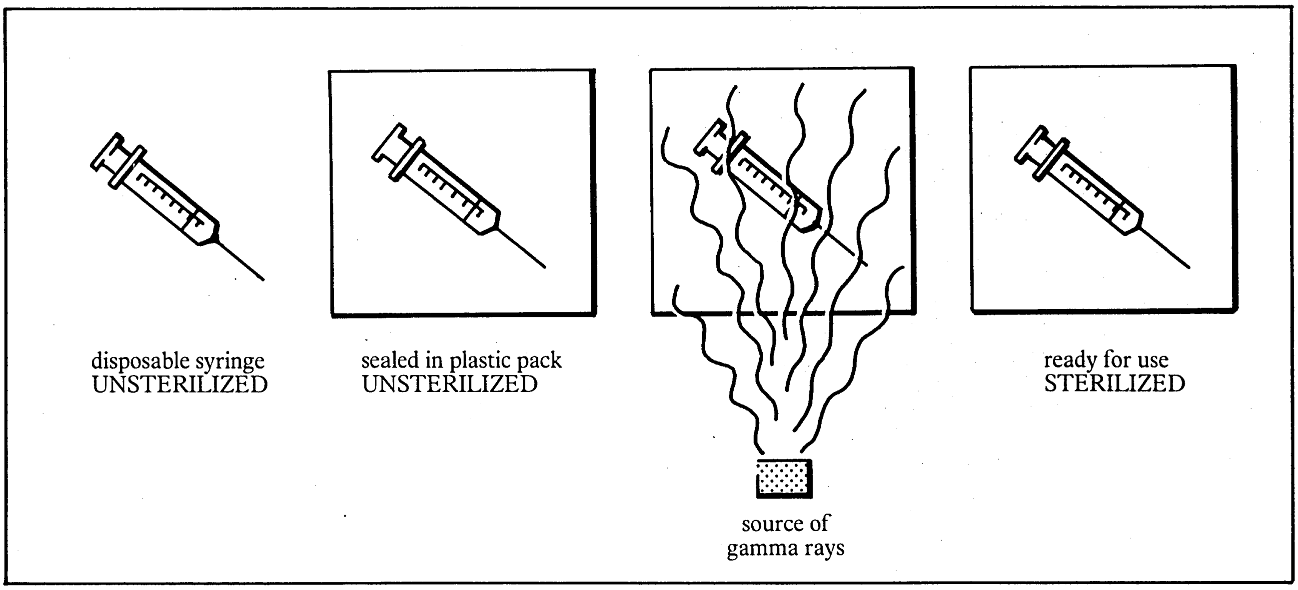

Figure 6 Sterilization using gamma rays

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.

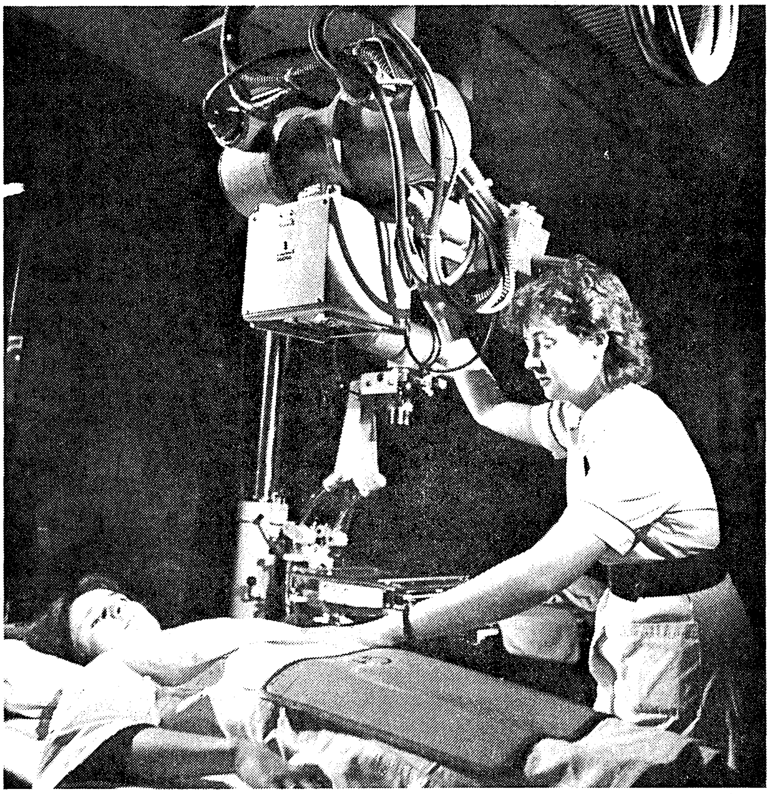

Figure 7 Using modern radiographic equipment to X-ray the spine, with careful protection to limit radiation dose to vital organs such as the ovary.

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?

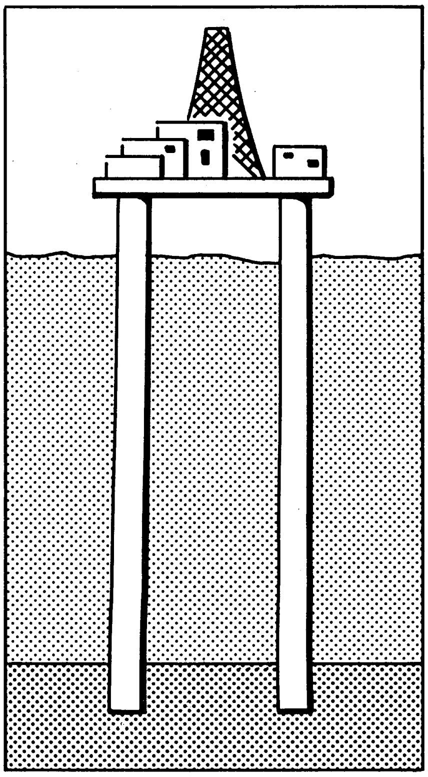

Figure 8 North Sea oil rig

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?

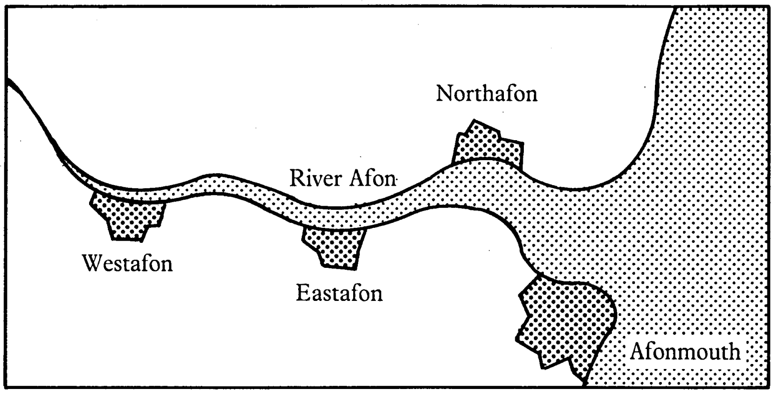

Figure 9 Shifting sands

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?

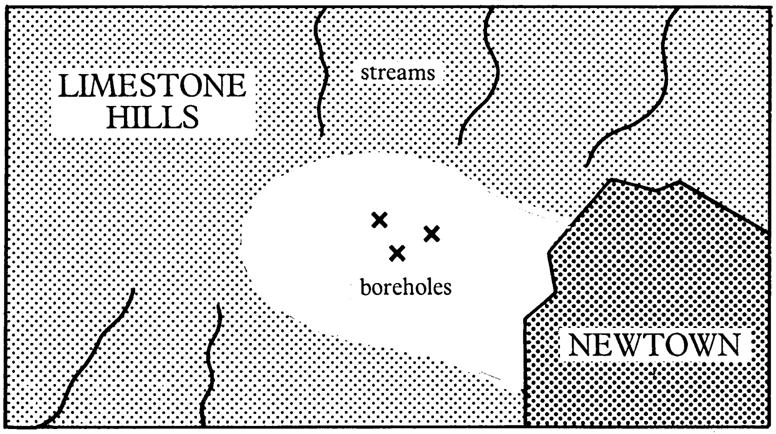

Figure 10 Tracing water