Materials to repair teeth

Science content

Properties of dental materials, amalgam, polymer composite.

Science curriculum links
AT 1 Exploration of science
AT 6 Types and uses of materials

Syllabus links
- GCSE Science, Biology, Chemistry

Cross-curricular themes
- Health Education

Lesson time
1 hour
and homework

Links with other SATIS materials
401 Fluoridation of Water Supplies
606 Tristan da Cunha Dental Surveys
1106 Tin Cans

NERIS
Search on
DENTAL HYGIENE
and UPPER SECONDARY
Additional search term:
DENTAL SYSTEM

SUMMARY

The unit is about the properties of materials in the context of dentistry.

STUDENT ACTIVITIES

- ☐ **Part A** Information, data collection and interpretation: filling a tooth, materials for fillings, frequency of filled teeth.
- ☐ **Part B** Information and questions about amalgam fillings.
- ☐ **Part C** Information and questions about polymer composite fillings.
- ☐ Role-play situations.
- ☐ Multiple-choice quiz about looking after teeth.

AIMS

- ☐ To complement work on metals, plastics, materials and teeth
- ☐ To provide opportunities for students to practise a variety of data handling techniques including data collection, recording, interpreting and predicting
- ☐ To show that properties of materials determine their successful use and that these properties can be altered

USING AND ADAPTING THE UNIT

- ☐ It is not intended that students should do all the activities. The unit may be used in a variety of ways, either as an exercise on materials (omitting the activities and quiz) or as a stimulus to data collection and interpretation.
- ☐ The quiz is a light-hearted activity and an opportunity to reconsider dental hygiene.
- ☐ The unit presents an opportunity for some assessment of data handling skills at various levels in **Attainment Target 1** such as: *record findings in tables, construct a simple pie chart, construct a simple bar chart or line graph, make written statements of the patterns derived from the data, record data in tables and translate it into appropriate graphical forms, use experience and knowledge to make predictions in new contexts.*
- ☐ Instructions for demonstrating the making of dental amalgam are included in the teaching notes overleaf.

Authors **Rod Taylor**
Callum Youngston

First published 1991

Teaching notes

Part A – A dental check up

Activity A An analysis of the results may show up some interesting features. Students could be encouraged to write up the results in the form of an article for a newspaper or magazine.

Homework activity To increase the sample size it may be better to collect together the results for the whole class although this point may well emerge if students are made to evaluate their own results and compare their findings with others.

Part B – Repairing teeth using amalgam

Demonstration Making amalgam

A local dentist may be able to supply you with a sample of the powdered silver alloy. Most schools have mercury.

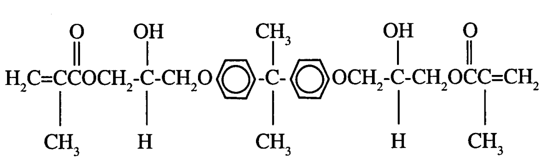
Mix roughly equal amounts of silver alloy with mercury using a pestle and mortar.

PRECAUTIONS: Remove any gold rings because mercury will amalgamate with gold very quickly. Mix over a large plastic tray in case of spillages of mercury. Any spillage must be completely cleaned up as prescribed for the use of mercury. Mercury vapour is poisonous. Only small quantities of amalgam are needed to demonstrate its putty-like nature when freshly mixed. Put amalgam under water until it is set before disposing of it.

Part C – Repairing teeth using polymers

This section deals with basic ideas about composite materials and polymers.

The chemical formula for Bis-GMA is:



Activity C – Role-play

The role-play scenes could be used as an alternative to answering questions Q1, Q6, Q7 and Q8.

Answers to the questions

Q1 *See figure 1.*

Q2 *Answers need to consider the taste, toxicity, strength and resistance to corrosion. Plasticine would be too soft (low compressive strength); cellulose filler (e.g. Polyfilla) has little resistance to abrasion; aluminium is difficult to work and is attacked by acids; gold is unreactive and used – but expensive.*

Q3 *Copper, tin, zinc, silver and mercury. Silver 64 %, tin 28 % approximately.*

Q4 *(a) bigger; (b) filling shrinks; (c) expands.*

Q5 *About 6 hours until graph B levels off. (Note that the horizontal scale to both graphs is logarithmic.)*

Q6 *Resistance to compression and abrasion, (also reflects light).*

Q7 *Blue light provides the energy to start polymerisation. (It initiates the formation of free radicals. The original polymer filling materials required ultraviolet light. Bis-GMA is activated by light of wavelength 470 nm which is not harmful at normal intensities.)*

Q8 *Polymer – appearance white to match teeth, long lasting, causes problems of shrinkage when used for large cavities in filling back teeth. (They can be overcome – a new technique is to make and cure the filling, allowing it to shrink, and then cement it into the tooth.)*

Q9 *Easily stored, easy to work, structural stability, resistance to corrosion by foods, high compressive strength, resistance to abrasion, no change in volume on setting, low thermal conductivity, appearance to match teeth, etc.*

Quiz

The quiz on page 7 may be printed separately. It may be used at the beginning or end of the unit. It is intended to remind students how to look after their teeth and may be set for homework.

Answers to quiz

1 **A**, 2 **C**, 3 **B**, 4 **C**, 5 **B**,
6 **C**, 7 **C**, 8 **A**, 9 **C**, 10 **A**.

Acknowledgements

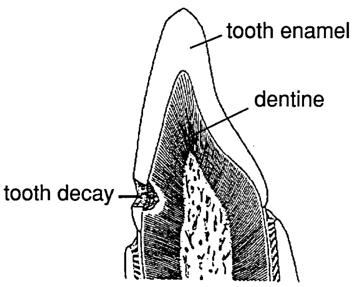
Figures 2 and 6 are reproduced by permission of 3M Health Care.

Materials to repair teeth

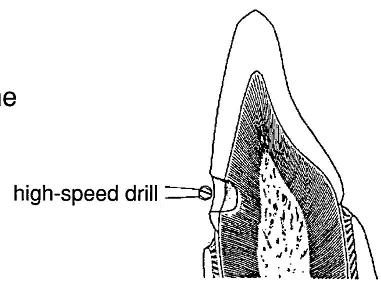
Part A A dental check-up

Most people don't enjoy going to the dentist. A check-up may find decay and the tooth will need to be repaired with a filling.

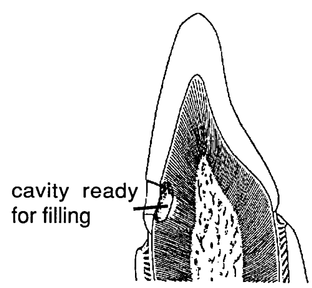
Figure 1 The stages in repairing a tooth



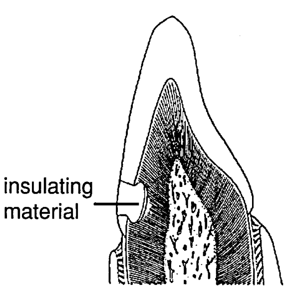
1 The tooth decay has eaten through the enamel and into the dentine. Once decay has reached the dentine it spreads rapidly and must be treated.



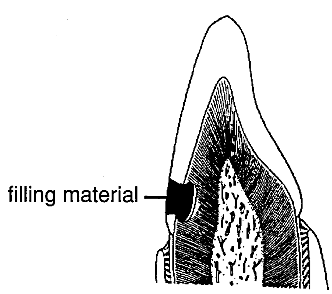
2 The dentist removes the decayed part of the tooth with a high-speed drill. The drill is water-cooled to stop overheating.



3 The bottom of the cavity is made bigger than the opening to anchor the filling and stop it from falling out.



4 If the cavity is deep, the dentist will line it with an insulating material to seal off the dentine.



5 The dentist fills the cavity with amalgam or polymer filling material.

The unit is divided into four parts.

Part A: Introduction to dental fillings and materials; a data collection survey.

Part B: Repairing teeth using amalgam – information and questions.

Part C: Repairing teeth using the polymer composite Bis-GMA – information, questions and scenes for role-play.

Quiz: A light hearted revision of dental hygiene.

Dentists use a wide range of materials:

- **metals** and **alloys** *for fillings and dentures,*
- **polymers** *for fillings and denture bases,*
- **polymer composite** materials *for fillings,*
- **elastomers** *for dental impressions,*
- **inorganic salts** *for dental cements,*
- **ceramics** *for porcelain crowns.*

Q1 *Imagine you are a dentist repairing the tooth shown in the diagrams. What would you say to a child aged ten to describe what you are doing?*

Filling materials have to be able to resist attack by acid in food and drink. They have to bear the enormous forces caused by chewing and withstand quick changes in temperature – from hot soup to ice-cream.

This unit considers two of the most common materials used by dentists to repair teeth – dental amalgam which looks silvery and a polymer composite which looks white.

> *Q2 Here is a list of materials. How would they meet the needs of filling teeth – what would be their advantages and disadvantages?*
>
> Plasticine, cellulose filler (used for cracks in walls), aluminium, gold

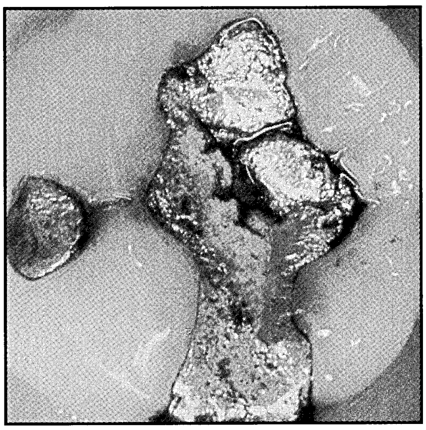


Figure 2 A tooth with an amalgam filling

Homework activity

Ask your family and friends if they are willing to take part in a survey of dental of fillings and age (Be tactful!).

Display your results in a suitable way.

Do the results show a link between number of fillings and a person's age?

Are there any other patterns in your results? If so, try to explain them.

Activity A – Data collection and interpretation

1 Use a mirror to look at your own teeth. Do you have any *amalgam* fillings? Note down how many.

2 Collect together the results for the number of fillings for each person in your class. Draw a table showing the results of the survey.

Number of amalgam fillings	0	1	2	3	4	5	6	7	8	9
Number of people										

3 Draw a bar chart or line graph to show the frequency of fillings in the class.

4 What is the most common number of fillings a person in your class has?

5 If you had surveyed the following groups of people, would you expect the results to be different?

Group 1 – another group of pupils but aged 11 or 12;

Group 2 – a group of adults aged between 35 and 45;

Group 3 – a group of pupils of similar age to yourself but the survey was carried out in 1960.

Give reasons for your predictions.

Part B – Repairing teeth using amalgam

What metals make up amalgam?

An amalgam is a mixture of solid metals with a liquid metal – usually mercury.

Dental amalgam has been used as a material to fill teeth for over 100 years. Amalgam fillings are made from *five* metals mixed in mercury. The dentist buys these metals as an alloy powder. Its composition is shown in the pie chart.

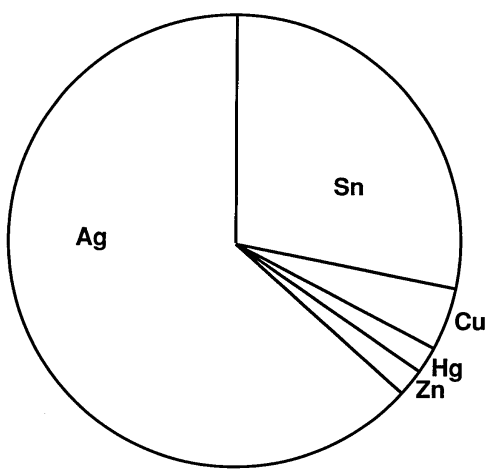


Figure 3 Composition by mass of alloy powder before being mixed with mercury to make amalgam

Each metal plays an important part in making the mixture suitable for filling teeth. For example, copper helps to make the mixture strong. Zinc protects the other metals from oxidation when the alloy powder is being manufactured. Being more reactive it combines with oxygen before the other metals can.

> *Q3 Look at the pie chart. Name the five metals used to make the alloy powder. Estimate and write down the percentage of the two metals which make up the bulk of the alloy powder.*

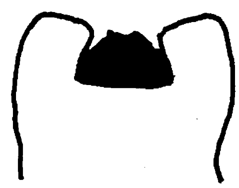
How is the amalgam made?

The dentist removes the decayed part of the tooth. The amalgam is made by mixing the alloy powder with mercury. Mercury has to be handled with great care because it is a poisonous liquid.

Fresh amalgam is soft like Plasticine and easily pushed into holes in teeth. In time, it sets rock hard.

On mixing the particles of alloy powder start to dissolve in the mercury to form a solution. At the plastic stage, the amalgam consists of untouched 'cores' of alloy surrounded by mercury. Gradually crystals form. The mercury is tightly held within the crystals and is therefore not harmful.

Materials change in volume as they 'set'. Ideally, material for fillings should not shrink too much. If they do, the filling may come away from the side of the hole and allow bacteria and food to get in the gap causing more decay. If on the other hand the filling expands too much, bits of filling may get broken off.


Too much shrinkage

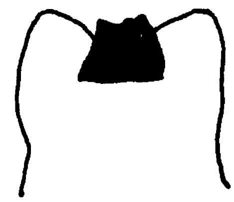
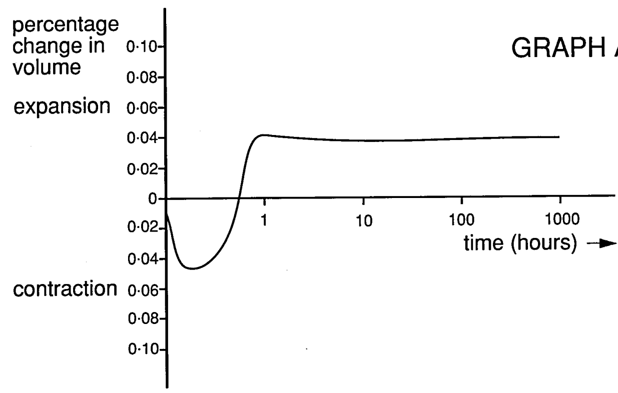

Too much expansion

Figure 4 The effect of shrinkage and expansion on how a filling fits the cavity

The two graphs labelled A and B show what happens to amalgam fillings over a period of time.



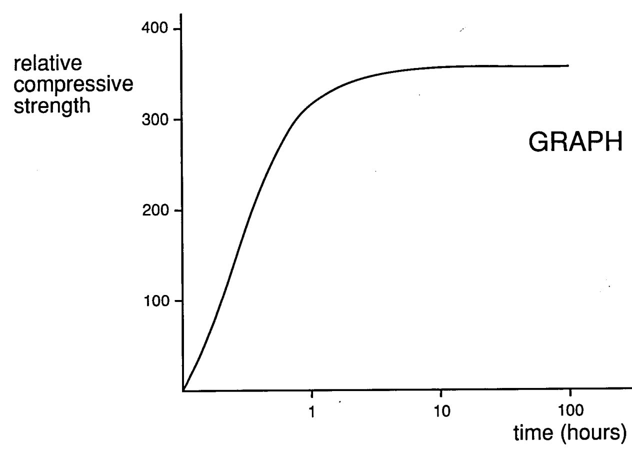


Figure 5 The changes in volume and compressive strength as an amalgam filling sets

Q4 Study graph A.
(a) Is the filling bigger, smaller or the same size after 1000 hours?
(b) What happens to the filling during the first 20 minutes or so?
(c) What happens after that?

Q5 Study graph B. The patient may ask 'how long should I wait before I eat normally?' What would be your answer if you were a dentist?

Dental amalgam is unreactive to attack by acid foods. When set, it has a compressive strength high enough to withstand the forces of chewing. If the amalgam is mixed correctly and the tooth filled carefully, an amalgam filling should last for several years.

However, there are problems with dental amalgam as a material to fill teeth. Like all metals, dental amalgam is a good conductor of heat. A large filling needs to be lined, otherwise the tooth is sensitive to hot and cold. Dental amalgam has a poor tensile strength – but on the whole this does not matter. The main problem for the patient is colour. For this reason dentists repair front teeth with a polymer material.

Part C – Repairing teeth using polymers

A polymer is a material with very long molecules. Plastics such as polythene, acrylic, nylon and polystyrene are all examples of polymers.

To repair teeth dentists need a very strong and rigid polymer which can withstand the harsh treatment that teeth get. The polymers used by dentists today were introduced in 1969. They harden only when the dentist shines blue light onto the filling.

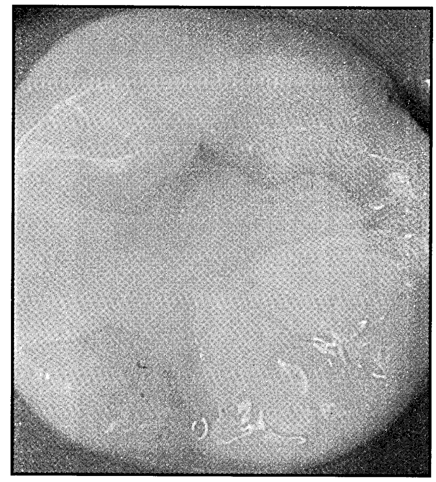


Figure 6 A tooth filled with polymer filling

What is the filling material made of?

The filling material is a **composite material**, that is, it is made of two parts – a chemical called **Bis-GMA** and very finely ground glass. At the start Bis-GMA is a thick colourless liquid. The mixture of Bis-GMA and ground glass is a fairly flexible paste and easily moulded into shape to fit the hole in the tooth.

What happens when blue light is shone onto the mixture?

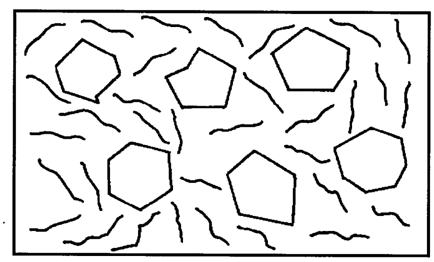
Bis-GMA consists of fairly short molecules. The molecules cannot react with the ends of other Bis-GMA molecules without the help of a little more energy. The dentist's blue light supplies energy of exactly the right frequency to start the chemical reaction.

Small Bis-GMA molecules (called the monomer) link together to form the polymer. This type of chemical reaction is called **polymerisation**. A very rigid three-dimensional structure forms, trapping the particles of ground glass. The material sets hard and looks white.

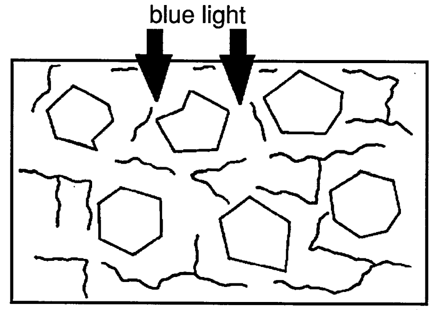
The diagrams in figure 7 show what happens.

> ***Q6*** *Suggest what properties the finely ground glass adds to the composite material.*
>
> ***Q7*** *Why does the dentist shine blue light on the filling?*

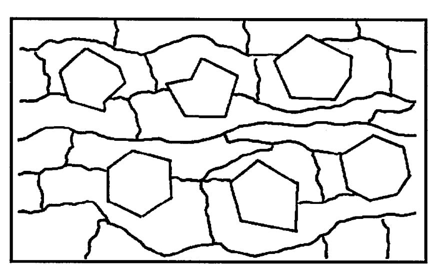
After drilling out the cavity for a polymer filling, the dentist uses a weak acid to dissolve the enamel around the edges. This leaves it with a microscopically pitted surface. The dentist applies the Bis-GMA monomer first so that it can flow into these pits and then applies the paste of the composite material. When it is cured, the filling bonds with the tooth enamel.



1 Very fine glass particles surrounded by short molecules of Bis-GMA.



2 Blue light starts the chemical reaction between the Bis-GMA molecules. The short molecules link together to form a polymer.



3 The 3-D structure of the giant molecule makes it very hard and rigid – an ideal material for fillings.

Figure 7 How the dentist's blue light sets a polymer filling

What are the properties of polymer fillings?

Most importantly for the patient, the filling looks good and does not become discoloured. Polymer fillings are strong, resistant to acids and to changes in temperature. Unfortunately they shrink slightly on setting so that large cavities in back molar teeth have to be built up layer by layer, curing each layer as it is added with blue light.

Fillings in teeth do not last for ever. Changes in temperature mean that fillings expand and contract very slightly. They may work loose, chip or wear away. Eventually they need replacing.

Evidence suggests that polymer fillings last as well as amalgam ones. They may in fact be better, since they bond to the tooth itself. However, polymer fillings have not been in use long enough to know for sure.

New materials for filling teeth are expensive. Much work was done on their development. Research continues to discover stronger and better materials to repair teeth.

Q8 Dentists often use polymer to fill front teeth, but amalgam to fill back teeth. Why?

Q9 Look back through the unit. Make a list of the properties that an ideal material for repairing teeth should have.

Activity C – Scenes for role-play

What would you do in the following situations? Think up some ideas before you act out the scene.

Scene one

A: You are a teenager going for a dental check-up. You need a tooth filled for the first time.

B: You are the dentist. Explain to your patient who has never had a tooth filled before what you will be doing.

Scene two

A: You are a teenager who has not been for a dental check-up for three years.

B: You are a dentist. You find several decayed teeth.

Answers to questions are given in the *Teachers' Notes*.

Quiz

So you think you know how to look after your teeth?

Here are ten quick questions about keeping your teeth and gums healthy. Choose an answer. When you have finished, check to see how well you did. Your teacher has the answers.

1 Which snack is worst for your teeth?

A toffee **B** celery **C** peanuts

2 Which drink is worst for your teeth?

A water **B** milk **C** lemonade

3 Which is most likely to cause tooth decay?

A salt **B** sugar **C** vitamin C

4 When should you clean your teeth ?

A once a day **B** twice a day **C** after every meal

5 When should you visit the dentist for a check-up?

A once a year **B** every 6 months **C** when you get toothache

6 Fluoride is added to toothpaste and drinking water to

A kill bacteria **B** remove plaque **C** make tooth enamel stronger

7 Brushing your teeth will not remove any

A bacteria **B** plaque **C** tartar

8 Which type of new toothbrush is best for cleaning your teeth?
A small head / soft bristles
B large head / hard bristles
C small head / hard bristles

9 Tooth decay is caused by
A bacteria eating away the tooth
B food particles getting stuck in between teeth
C bacteria breaking down food making an acid which attacks teeth

10 How often should you use dental floss?
A three times a week
B once a week
C when food gets stuck between your teeth

For each correct answer you score 1 mark. If you get the answer wrong you score 0.

Your score 0–3 I wouldn't be a tooth in your mouth!
4–6 Your teeth would feel happier if you knew a bit more.
7–10 Well done!

RADON in homes

Science content

Radioactivity, radioactive decay, background radiation, alpha radiation.

Science curriculum links
AT 1 Exploration of science
AT 8 Explaining how materials behave

Syllabus links
- GCSE Science, Biology, Physics,
- Geography
- Sixth-form General Studies

Cross-curricular themes
- Health Education

Lesson time
1 to 2 hours
(homework possible)

Links with other SATIS materials
1005b Radon – an investigation
204 Using Radioactivity
807 Radiation – how much do you get?

SATIS Audiovisual
Radiation around us

NERIS
Search on
RADON
or on RADIATION and ENVIRONMENTAL HEALTH

SUMMARY

A radioactive gas called radon finds its way into homes. The unit tells how scientists in the UK have become more aware of the problem and the risks it poses to health.

STUDENT ACTIVITIES

- ☐ Reading, answering questions based on the text, interpretation of graphical data.
- ☐ Discussion of the issues involved, reporting back to the class.
- ☐ Follow-up work which could involve creating community awareness of the problem – designing a poster, writing letters, giving talks etc. or measuring radon activity as described in SATIS unit 1105b.

AIMS

- ☐ To link with work on ionising radiations
- ☐ To show how scientific understanding of the radon problem has developed
- ☐ To increase awareness of the danger to health of radon and cigarette smoking
- ☐ To consider and discuss the social, moral, legal and economic implications of the radon problem
- ☐ To provide an opportunity for students to interpret their scientific knowledge to the wider community
- ☐ To provide students with the opportunity to take action on an issue concerning public health

USE

- ☐ The unit may be used as part of work on ionising radiations and their effects on living organisms. There are also links with work on health and pollution.
- ☐ The reading and text-related questions may be set for homework. The discussion and follow-up work may be omitted.
- ☐ Follow-up work suggests involving students with the wider community.

Author **Anabel Curry**

First published 1991

Teaching notes

The focus of attention on naturally-occurring radiation is turning from gamma radiation (which tends to pass through the body) towards alpha which, when lodged inside the body, is much more damaging. Radon is more widespread and poses a greater hazard than was once supposed.

For simplicity, the unit focuses on 'radon', actually radon- 222, which occurs in the uranium-238 decay series. Another isotope of radon, radon-220, is known as thoron and occurs in the thorium decay series.

The part of the uranium decay series containing radon is:

$$^{234}U \xrightarrow{\alpha} {}^{230}Th \xrightarrow{\alpha} {}^{226}Ra \xrightarrow{\alpha} {}^{222}Rn \xrightarrow{\alpha} {}^{218}Po \xrightarrow{\alpha} {}^{214}Pb$$

A becquerel is a disintegration per second. Thus a radon activity of 1 Bq/m^3 means that on average 1 atom of radon in a cubic metre of air decays every second. The relationship between 'activity' and 'dose equivalent' is complex. Dose is measured in sieverts. Further details are given in SATIS 807, *Radiation – how much do you get?*

Follow-up work

This topic gives students a genuine opportunity to disseminate information about the hazards posed by radon in homes. Students may come up with suggestions for designing posters, writing for the school magazine, giving talks to the school or possibly making an impact on the community at large.

They may go on to investigate radon levels around them as described in SATIS unit 1105b, *Radon – an investigation.*

Other resources

The National Radiological Protection Board (NRPB) is an independent statutory body. It publishes booklets and posters, some specifically designed for educational use. A new leaflet, *Radon – Questions and Answers*, provides simple and clear information about radon. Details are available from the Information Officer, NRPB, Chilton, Oxfordshire OX11 0RQ.

A booklet *The Householders' Guide to Radon* Department of Environment, HMSO, 1989, gives advice on radon-proofing homes.

Answers to the questions

In their understanding of radioactivity, students need to distinguish between 'radiation' (such as alpha, beta and gamma) and radioactive material (which gives off radiation).

The questions are based on information given in the text.

Q1 *Radon is a gas with no smell, taste or colour.*

Q2 *Stanley had become 'radioactive', implying contamination with radon (and its decay products). The radiation given off by the contamination set off the alarms at his place of work. The search for the source led to his home.*

Q3 *At 20 Bq/m^3, the risk of developing cancer is very low. (Casual passive smoking may pose a greater risk.)*

Q4 *(a) About 135*
(b) 2 packs

Q5 *Radon decays emitting an alpha particle which may damage living cells and lead to cancer.*

Q6 *(a) July*
(b) living rooms
(c) less

Q7 *Pressure inside homes is less than outside (because heating makes warm air rise and escape) and radon moves in. Draught stripping in modern homes prevents radon escaping.*

Q8 *Explain to him/her about the health hazard and that not all homes are at risk. Suggest that the radon level is measured. (Advice is available from the local authority or NRPB.) If the level is above 200 Bq/m^3, modifications should be carried out to the building to allow radon trapped under the house to escape. Seal around cracks and pipes; lay a plastic barrier over the ground floor; provide regular ventilation of the house.*

Acknowledgements

Jon Miles of NRPB and H. Eijkelhof of the University of Utrecht read and commented on the trial version.

Figure 2 is adapted from data in *Consumer Reports* July 1987.

Figure 3 after Green, Lomas and O'Riorden, NRPB.

Headlines from *The Independant*, 26 October 1989 and 20 January 1990.

RADON *in homes*

Alarm bells ring

Stanley didn't know it when he dressed for work on 2 December 1984 but this was the day his name would go around the world. He was to become famous. Stanley Watras was an ordinary sort of guy, a worker at a nuclear power plant near Philadelphia in the USA. In 1984, he became the centre of a mystery, a problem that nobody had suspected existed.

This unit contains material for reading, answering questions and opportunities for group discussion.

It may be used in association with SATIS unit 1105b, *Radon – an investigation,* which describes how to measure the levels of radon gas in homes.

On that December day Stanley walked into work and set the alarm bells ringing. Officials were perplexed. Was 'radiation' escaping from the plant or was there something wrong with the alarm system?

Stanley set off the alarms every time he went into work. Nobody else did.

Stanley was radioactive and it wasn't anything to do with the nuclear power plant. But had he *not* worked in the nuclear power industry, his problem might never have been known.

It took two weeks to track down the reason. Stanley's home had been built over a vein of rock containing uranium.

Uranium is a radioactive element. During its decay, it forms a radioactive gas called **radon**. Radon has no smell, taste or colour. It had seeped through the rocks into Stanley's home. The amount of radon had gradually built up and Stanley had been breathing it in.

The mystery was solved!

Q1 Why did Stanley Watras not suspect his home had radon gas in it?

Q2 What led to the discovery of radon in Stanley's home?

Radon: the search starts

Was Stanley Watras the only person with a high level of radon? Nobody knew.

Scientists got out their geological maps and looked to see who else might be living on top of uranium-rich rocks. They tested homes for radon and found it. Warnings went out to Americans believed to be at risk. They were advised to seal cracks in their basements and ventilate their homes.

As more homes were tested, radon was found far from any uranium-rich rocks. In fact, uranium occurs all over the Earth's crust and radon is almost everywhere; but its concentration is unpredictable. If radon reaches the surface soil it quickly disperses into the air. But being a gas, it can seep through cracks in the rocks and build up in individual homes.

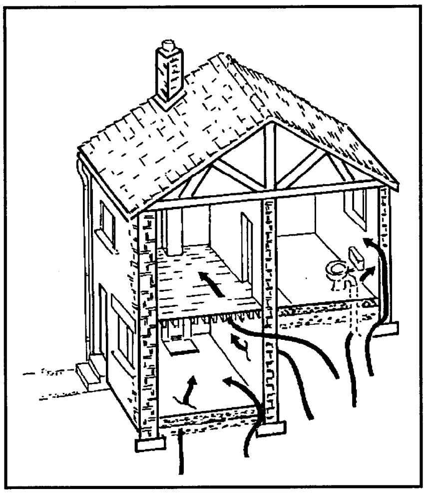


Figure 1 How radon seeps into a house

In the UK, scientists already knew that radon was a risk for miners in Cumbria and Cornwall. They had started looking for radon in homes in areas of granite rock, like Cornwall, Devon and around Aberdeen in 1980. They found it – sometimes in dangerous concentrations. But as in the US, amounts varied from home to home, depending on where and how the homes were built and ventilated.

The level of radioactivity of radon in the air is measured in **becquerels per cubic metre (Bq/m³)**. The average level of radon in UK homes is 20 Bq/m³. In the US it is about 50 Bq/m³. Outdoors the level of radon in air is a few becquerels per cubic metre. Radon is found in rocks, soil and dissolved in drinking water too.

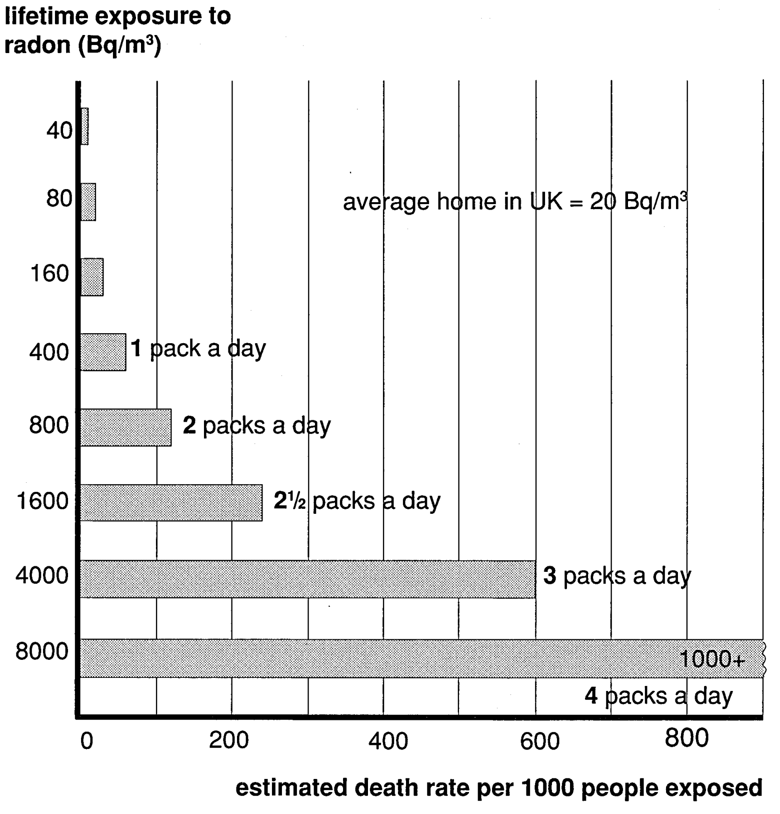
Scientists now believe that radon is a far greater risk to health than any other environmental pollutant – such as smoke and carbon monoxide in the air, pesticides and nitrates in food and water. Radon causes lung cancer. Only cigarette smoking is more dangerous!

The graph shows how your risk of lung cancer from radon compares with the risk you take with smoking. Stanley Watras was said to be receiving a dose of radiation from radon equivalent to smoking 135 packs of cigarettes a day!

Q3 The average home in the UK has a radon level of 20 Bq/m³. Does the graph suggest that this level is likely to lead to lung cancer?

Q4 A few homes have levels of radon as high as 800 Bq/m³. Out of 1000 people living in such homes,
(a) how many may die of lung cancer caused by radon?
(b) how many packs of cigarettes a day give the same death rate from lung cancer?

Figure 2 Radon and cigarettes: the death rate from lung cancer



Like any radioactive element, radon decays. Each atom emits an alpha particle. Radon decays to give other radioactive elements called **radon daughters**. They also emit alpha particles. When you breathe in radon and its daughters, some of the daughters stick inside the lung. If an alpha particle strikes a living cell, it may damage it. Damaged cells can lead to cancer.

Lung cancer from smoking kills about 40 000 people a year in Britain. It is estimated that radon causes a further 2500 lung cancer deaths. For smokers radon increases an already large risk.

Radon gas may be the cause of some cases of other forms of cancer, such as myeloid leukaemia. Scientists are carrying out further studies to see if this is so.

Radon enters houses because air pressure outside is a little higher than that inside. This is due warm air in the building rising. Wind flowing across chimneys and windows causes suction. Radon seeps in through cracks in walls and floors and often around the holes for water and waste pipes. Radon levels tend to be high in homes with basements.

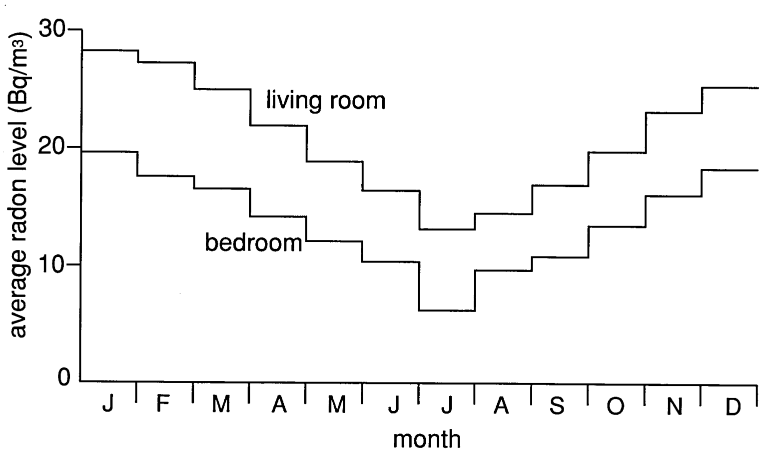


Figure 3 Variation in radon levels in living rooms and bedrooms during the year

Q5 *Draw a flow chart or cartoon explaining how radon causes lung cancer.*

Q6 *Study the graph showing radon levels in a typical British house.*
(a) In which month is the radon level lowest? Suggest why this is.
(b) Where are people exposed to higher levels of radon, in the living room or bedroom?
(c) Would a family living on the fourth floor of a block of flats be exposed to more or less radon than a family living in a typical house?

Facts about radon

- Radon is a naturally-occurring radioactive gas that is inactive chemically but soluble in water.
- Radon rises from the ground and collects in buildings. Householders who have levels of radon activity greater than 200 Bq/m^3 should 'radon proof' their homes.
- The radioisotope known as 'radon' is radon-222 and is part of the uranium decay chain.
- When radon-222 decays it emits an alpha particle.
- The half-life of radon-222 is 3.8 days.
- Radon is a gas, but radon daughters are solid isotopes, polonium-218, polonium-214, lead-214 and bismuth-214.
- In fact radon gas accounts for only 1% of the radiation dose from radon. Most comes from radon daughters. They account for more than half the dose of natural radiation that people receive.

Reducing the risks from radon

The Swedish Government introduced limits to radon in homes as long ago as 1980. The US recognised it had a similar problem after Stanley set off the alarms.

In 1987 the British Government provided help for householders if radon levels in their homes were above 400 Bq/m^3. With greater awareness of the dangers, the 'action level' is now set at 200 Bq/m^3.

Only a few years ago, the radon problem was thought to be limited to areas of granite rock in Devon, Cornwall and Scotland. The results of surveys show that high levels of radon may occur elsewhere. The search for radon in homes is widening to Somerset, Northamptonshire, Derbyshire, the Highlands and Islands of Scotland and Grampian region.

In an area of high radon levels not all homes will be affected. The level of radon depends on the materials from which the home is built and the way it is heated and ventilated. And levels can vary widely from day to day in just one house as the graph shows. So the level of radon inside a house needs to be taken over a period of time.

Householders at risk are offered a free survey. Those with high levels of radon in their homes are notified. They may apply for grants to radon-proof their homes. At present only people on low incomes receive money for improvements.

Radon-proofing usually involves putting in a ventilation system with a fan under the floor to allow radon to escape. Cracks and gaps around pipes must be sealed. A plastic sheet may be laid over wooden floors to stop radon from rising into the house. Modifications can cost £500 to £1,000.

Type of rock	Average radon concentration in homes in Bq/m^3
Granites	
SW England	285
Scotland	21
Sandstone	50
Chalk	26
Clays	15

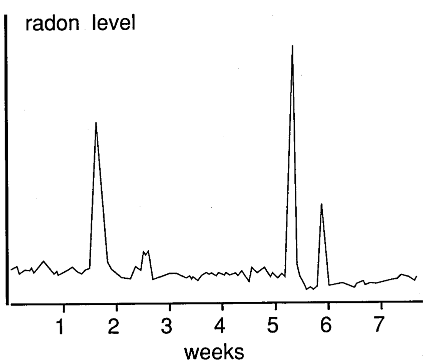
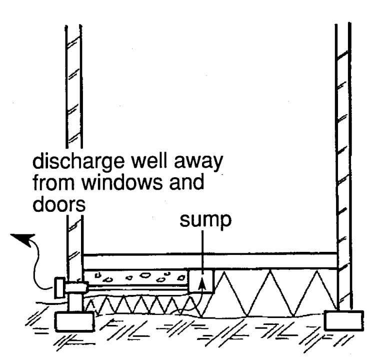


Figure 4 Graph showing how radon levels in a home may vary from week to week

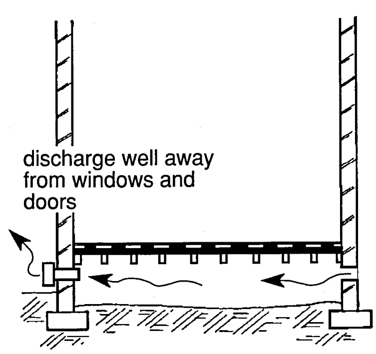
Q7 Explain why radon levels can build up in homes.

Q8 Make a list of practical advice you would give to an aunt, uncle or friend who lives in an area where radon levels in homes may be high.

Figure 5 Ways of 'radon proofing' a house



A house with a solid floor and a radon 'sump' dug underneath. A fan draws the radon away.



A house with a wooden ground floor and a fan to ventilate the area underneath.

The problem no one wants to face

In both the USA and the UK many of the people with high radon levels in their homes have done nothing about it.

> In Washington DC in the USA, a local television station promoted the sale of radon detecting kits through supermarkets. 60 000 were sold. The results showed that 14 000 homes had high radon levels. After 18 months less that 2500 homes had done anything to reduce the risk.

The scientific detective story that started with Stanley Watras is still unfolding. How long will it take before people in the UK recognise the dangers of radon? Students in schools and colleges have an important part to play in helping others to understand the problem.

Headlines from The Independent, *26 October 1989 and 20 January 1990*

Questions for group discussion

a *If homes have radon levels above 200 Bq/m³, householders are advised to radon proof their homes. How many people per 1000 may die at this level? (Look back at the graph on page 2.) How does it compare with the risk smokers take? Does this level of risk seem reasonable?*

b *When advised they have high levels of radon many householders do nothing to radon-proof their homes. Why do you think this is?*

c *Who should pay for surveys and building work to 'radon-proof' homes – homeowners, insurance companies, local or national government? If not the homeowners, would other people mind paying extra premiums or taxes to cover the bill?*

d *What sort of laws could the Government pass to limit the danger of radon in homes?*

e *How should the public be made more aware of the dangers of radon? Include in your suggestions something you can carry out for yourself.*

> **Organising the discussion**
> - *Work in groups of 3 to 6 students.*
> - Appoint someone to chair the group and to report back to the class if required.
> - *Note down the answers you decide on. You may need to use your ideas later.*

Answers to questions are given in the *Teachers' Notes.*

Follow-up

Carry out one or more of the suggestions you made in ***e*** above.

SATIS unit 1105b, *Radon – an investigation,* describes how to measure the levels of radon around you.

RADON – *an investigation*

Science content

Radioactivity, radioactive decay, background radiation, alpha radiation.

Science curriculum links

AT 1 Exploration of science
AT 8 Explaining how materials behave

Syllabus links

- GCSE Science, Physics,

Lesson time

3 hours
(2 lessons and 2 homeworks)

Links with other SATIS materials

1005a Radon in Homes
204 Using Radioactivity
807 Radiation – how much do you get?

SATIS Audiovisual

Radiation around us

NERIS

Search on RADON
or on RADIATION and ENVIRONMENTAL HEALTH

SUMMARY

The unit provides information for students to design and carry out an investigation to monitor radon levels in buildings or in the soil. The experiment requires students to count the alpha tracks with a microscope. There is a free service to schools for processing the detector, TASTRAK. Students may contribute their results to a national survey.

STUDENT ACTIVITIES

- ☐ **Part A** Planning the investigation. (Suitable for homework)
- ☐ **Part B** Making a radon detector, setting up the experiments, sending the TASTRAK for processing.
  Analysing TASTRAK after processing; recording data; writing a report.
- ☐ **Part C** Data interpretation. Questions.

AIMS

- ☐ To link with work on ionising radiation
- ☐ To develop awareness of radon as a radioactive gas, an alpha emitter and a major contributor to our background exposure to radiation
- ☐ To provide an opportunity for students to plan and carry out a scientific investigation
- ☐ To contribute to a national survey of radon levels

REQUIREMENTS

- ☐ clean yoghurt pots, cylindrical, (50 mm diameter and 70 mm high) from brands such as Chambourcy, Eden Vale, Ski, Sainsburys, etc.
- ☐ Blu-Tack, clingfilm, elastic bands
- ☐ pieces of TASTRAK (from address given here)
- ☐ microscopes (magnification × 200)
- ☐ scale for calculating field of view [Philip Harris Educational B 32200/9 (pack of 10 at £7.91)]
- ☐ small plastic bags and cooking foil (for keeping the TASTRAK while setting up the experiment)

The booklet, TASTRAK and the FREE PROCESSING SERVICE is available from Track Analysis Systems Limited, H H Wills Physics Laboratory, University of Bristol, Tyndall Avenue, Bristol, BS8 1TL. Tel. 0272-260353

Authors **Geoffrey Camplin**
Denis Henshaw

First published 1991

Teaching notes

The unit contains simple experiments to measure the activity of radon. They have been thoroughly tested with pupils aged between 7 and 16 years. It is suggested that students should have prior understanding of ionising radiation and the radon problem, possibly through using SATIS 1105a, *Radon in Homes*.

An ordinary yoghurt pot must be used with TASTRAK if an absolute radon activity is to be determined, since this type of pot has been calibrated by the National Radiological Protection Board. The calibration factor is given in this unit.

Pages 1 to 3 could be read in advance (perhaps for homework). Students may wish to negotiate with other groups in order to plan an effective survey. This could be a teacher-led class activity.

If students have difficulty in calculating the field of view of the microscope, the teacher may wish to give students this figure.

You are advised to have the TASTRAK processed professionally with the FREE SCHOOLS' PROCESSING SERVICE at Bristol University by Track Analysis Systems Limited (TASL). Send a stamped addressed envelope. This is financed by UKAEA under the guidance of TASL at Bristol University's Physics Department.

Please use this service.

The Exploratory in Bristol and Portway School are compiling a national map of radon levels. Data from your students' work will be welcomed. Please fill in the results together with a six figure Grid Reference of where they were taken on the form provided and post it to Dr G. C. Camplin, Portway School, Penpool Lane, Shirehampton, Bristol BS11 0EB. (Help for working out Grid References is given on Ordnance Survey maps or in geography textbooks.)

The detailed analysis of alpha particle tracks in TASTRAK can be found in the references. Only a basic description is given in the unit because of the highly mathematical nature of the analysis. These experiments have been taken from the booklet *TASTRAK: A New Plastic Track Detector for Teaching Radioactivity in Schools* – see Further Resources.

Further resources and references.

1 Camplin G. C., Henshaw D. L., Lock S. and Simmons Z., 1988 *Phys. Educ.* **23** p212–217 'A National Survey of Alpha Particle Radiation' (London: Institute of Physics).

2 Fews A. P. and Henshaw D. L., 1982 *Nucl. Instrum. Methods* **197** p517–529 (North Holland) 'High Resolution Alpha Particle Spectroscopy using CR-39 Plastic Track Detector'.

3 Henshaw D. L. and Camplin G. C., *TASTRAK: A New Plastic Track Detector for Teaching Radioactivity in Schools*, London: Institute of Physics (1987).

Answers to the questions

Q1 *Radon disperses into the air at the surface.*

Q2 *The histogram shows a peak frequency between 100 and 130 Bq/m³. The frequency drops off rapidly thereafter. A few homes had radon activities above the 'action level' of 200 Bq m³. No school had a zero result.*

Students should add a comment about their own result – whether it seems low, average or high.

Q3 *Portway School shows a peak frequency of around 50 Bq/m³ with no homes above the action level. Brookside Primary School survey included more homes and follows the same pattern. However several (29) homes have a radon activity above the action level, the highest being around 1079 Bq/m³.*

Q4 *Definitions may be found in a good physics textbook.*

Q5 *Alpha particles can travel no more than 50 mm in air. They will be unable to reach the TASTRAK through the mouth of the yoghurt pot 70 mm high (even if some pass through the clingfilm). They are unable to pass through the sides of the pot. Radon can diffuse in through clingfilm. The TASTRAK therefore detects only the alpha particles that result from the decay of radon (and radon daughters).*

Price for a pack of 30 pieces of TASTRAK is about £20.00 including VAT. Please ring for up-to-date prices. (TASTRAK scribed with one centimetre squares which can be used in a projector for counting is available at additional cost.)

RADON – an investigation

This unit describes how you may investigate how much radon is around you. And you can add your results to a national survey. *Read through parts A and B before you plan your work.*

Part A explains about radon and how TASTRAK may be used to detect the alpha radiation it emits.

Part B tells you how to make and use a radon detector.

Part C looks at data obtained by students in other schools.

Page 6 contains more information and questions.

SATIS 1105a, *Radon in Homes*, provides introductory information to the problem of radon.

Part A – What do you need to know?

Radon

There are many natural sources of radiation. But it is the **radioactive** gas, **radon,** which is particularly dangerous to health. It rises from the ground and collects in buildings. You can detect it by the **alpha radiation** it emits when it decays.

The experiments in this unit use a plastic called TASTRAK as detector. When an alpha particle enters the surface, it creates a trail of damage along its path. You cannot see the tracks until the plastic has been processed in an etching solution.

The tracks are up to 30 micrometres long and you need a microscope to see them. Alpha particles enter the plastic from different directions giving the tracks different shapes and sizes.

Counting the tracks tells you how many alpha particles hit the plastic and gives you a measure of the amount of radon around.

TASTRAK must be kept in the metallised plastic bag in a freezer or refrigerator until it is ready for use. This bag is 'radon proof' – alpha radiation from the environment cannot get in through the bag.

Facts about radon

- Radon is a naturally-occurring radioactive gas that is inactive chemically but soluble in water.
- Radon rises from the ground and collects in buildings. Householders who have levels of radon activity greater than 200 Bq/m^3 should 'radon proof' their homes.
- The radioisotope known as 'radon' is radon-222 and is part of the uranium decay chain.
- When radon-222 decays it emits an alpha particle.
- The half-life of radon is 3.8 days.
- Radon is a gas, but radon daughters are solid isotopes, polonium-218, polonium-214, lead-214 and bismuth-214.
- Radon gas accounts for only 1% of the radiation dose from radon. Most comes from radon daughters. They account for more than half the dose of natural radiation that people receive.

Planning your investigation

Here are some points to consider.

- ☐ How many detectors can your group or class make?
- ☐ Do you wish to measure radon in soil or in buildings or both?
- ☐ Do you wish to link your measurement to those of other groups in your class? Would it be better to survey just one spot or survey a building or locality?

Read through the instructions in part B before you draw up your plans.

Part B Investigating radon

How to detect radon

You can make a radon detector with a yoghurt pot, Blu-Tack, clingfilm and TASTRAK. It needs to be left in position for at least a week to record a reasonable number of tracks.

You will need
- a clean yoghurt pot
- Blu-Tack
- clingfilm
- piece of TASTRAK
- elastic band
- compass point or drawing pin
- plastic bag and cooking foil

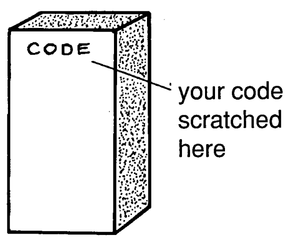


Figure 1 Preparing the TASTRAK

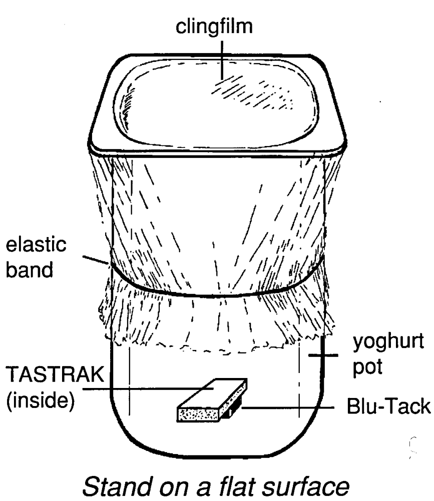


Figure 2 A radon detector

1 **Get your TASTRAK ready.** When you are ready to do the experiment, take the TASTRAK carefully from its 'radon proof' bag. Note that TASTRAK is brittle.

You will need to mark the TASTRAK to identify it as yours. Decide what code you will use.

Quickly but carefully use a compass point or pin to scratch *your* code on the TASTRAK surface at one end.

You can then put your TASTRAK inside a plastic bag while you prepare the site for the experiment. If you take it home, wrap it in a plastic bag and use cooking foil on the outside. (Do NOT wrap it in paper – paper is quite radioactive.)

2 **Make your radon detector.** Remove the TASTRAK from its plastic bag and fix it to the bottom of the yoghurt pot with 'Blu-Tack'. The side scratched with your code must be facing you as you look into the yoghurt pot. Cover completely the mouth of the yoghurt pot with a layer of clingfilm and fix it with an elastic band. Radon gets into the pot by diffusing through the sides and the clingfilm.

3 **Set up experiments.** You may set up experiments to measure the activity of radon:

a On the ground
Turn the yoghurt pot upside down and place it on the ground. Cover it with a large sheet of plastic to keep the rain off. Note the time and date of the start of the exposure.

b In the ground
Dig a hole about 8 cm deep and put in the yoghurt pot (upside down). Cover it with a large sheet of plastic to keep the rain off. Note the time and date of the start of the exposure.

c In a room
Place the yoghurt pot on a bookshelf or sideboard well away from open windows or sources of heat such as a radiator. Note the time and date of the start of the exposure.

4 **Expose the TASTRAK to radon.** Leave it for *at least one week.*

5 **Afterwards.** Once the exposure time has finished, remove the TASTRAK carefully. Rinse with distilled water and dry with tissue. Quickly put the TASTRAK into its **metallised** bag and seal with Sellotape. Note the time and date at the end of the exposure.

6 **Post for processing.** Pack the TASTRAK sample(s) in a well padded bag and return the sample(s) to the processing address given in the Teachers' Notes.

Analysing your results

When the TASTRAK has been returned from processing

You will need

- a microscope with magnification × 200
- a scale to calibrate the field of view

1 **Analyse the TASTRAK**

a Put the TASTRAK and scale on the microscope stage. Adjust the magnification and focus so that you can see the tracks clearly. The tracks are up to 30 micrometres in size.

b Use the scale to work out the area of your field of view – that is the area you can see. (Ask for help if you have difficulty.)

c Count the number of tracks you can see. Move the TASTRAK so that you are looking at another part of it. Count the number of tracks again. (It is best to choose areas to count at random – say a minimum of 10 and find an average.) Work out the average number of tracks per square centimetre of your TASTRAK.

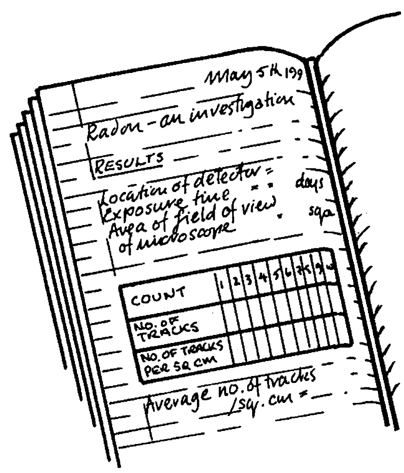


Figure 4 Working out the average

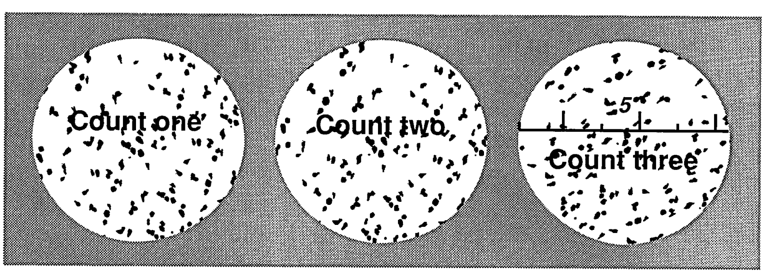


Figure 3 Counting the tracks through the microscope

2 **Calculate the radon activity** using this equation.

$$\text{Radon activity (in Bq/m}^3\text{ of air)} = \frac{5.7 \times \text{(tracks per sq cm)}}{\text{exposure time in days}}$$

3 Collect together all the results.

4 **Write a report.** In your report describe why you planned your investigation as you did as well as presenting your results. Are there any readings which you think should be repeated or any localities which should be investigated in greater detail? If so explain. What advice can you give from your results?

If you would like to add your results to a national survey of radon levels:

- find the six figure National Grid reference of the place where you took your reading from an Ordnance Survey map. Note it down.

A form for entering your individual or class results is provided. See that your result is entered correctly.

Part C – Looking at data

Since 1987, schools have carried out experiments similar to those described in this unit. The table gives their results for radon in the soil.

Type of experiment	Radon activity in Bq/m³	Number of samples
On the surface	114 ± 30	159
8 cm below the surface	460 ± 90	333

These are averages. In fact, the range of results they got was very much larger, often from 30 Bq/m³ to 1000 Bq/m³. Some values were higher than this.

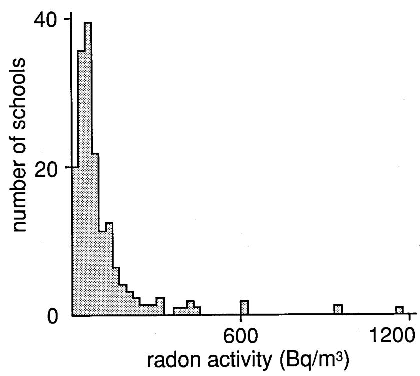
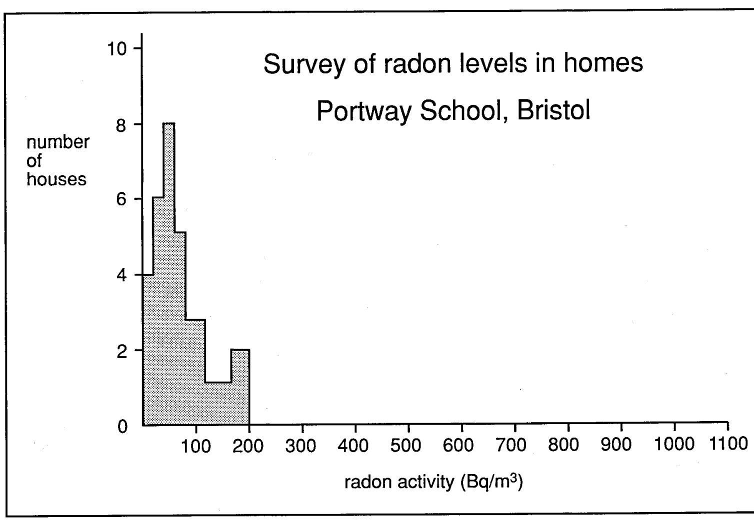


Figure 5 The data for radon activity on the surface of the soil (see table) drawn as a histogram

Two schools, Portway School (Bristol) and Brookside Junior School, Street (Somerset) carried out surveys in homes.

> ***Q1*** *Look at the table. Suggest why the radon activity on the surface of the soil was lower than that at 8 cm below the surface.*
>
> ***Q2*** *Describe the pattern shown by the histogram in your own words.*
>
> *Did you collect similar data in your own investigation? If so, comment on where your results fit in.*
>
> ***Q3*** *Look at the results of the two schools' surveys shown in Figures 5 and 6. Comment on each set of results. Would you recommend any householders to 'radon-proof' their homes?*



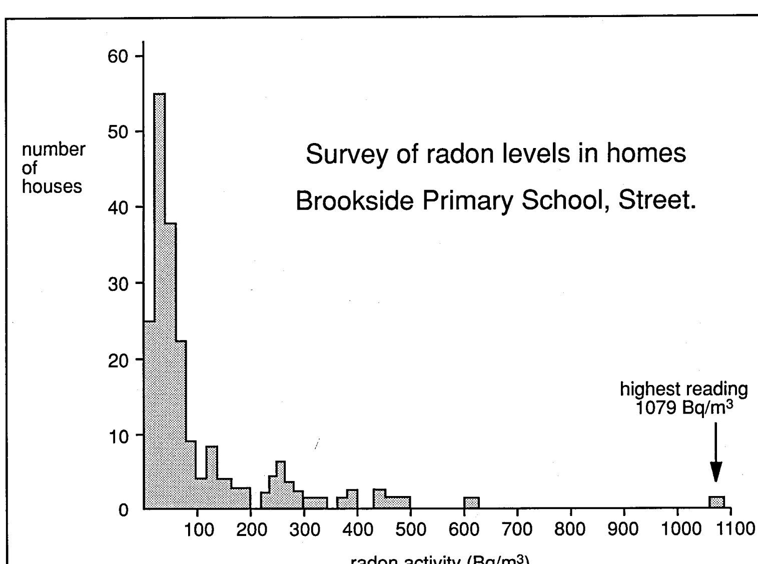


Figure 6 Survey results from two schools

Further information

Radon daughters

Although this unit focuses on 'radon', 99 per cent of the radiation you receive through radon is due to the 'decay products' of radon – those are other atoms further down the uranium decay series. They are also alpha emitters but with very short half-lives and are known as 'radon daughters'.

Facts about alpha radiation

- It consists of alpha particles (two protons and two neutrons).
- Alpha particles carry a charge of +2*e*.
- Their speed is around 10^7 m/s in air.
- They travel no more than 5 cm in air.
- They cannot pass through paper, metal or the skin covering the outside of your body.
- when they hit living tissue they produce ions which can change or destroy living cells. Changed cells may cause cancer.

Extra questions

Q4 Look up the meaning of the following terms which have been used in the unit and make yourself a glossary.
(A glossary is an alphabetical list of words or phrases with their definitions or explanations.)

alpha particle
a becquerel
decay chain
half-life
isotope
radioactive
radioisotope

Q5 Radon can diffuse through the clingfilm and pot. Explain why the yoghurt pot detector detects alpha particles from radon and radon daughters only (and not those of other radioisotopes).

Properties of TASTRAK

- TASTRAK records all naturally occurring alpha particles, low energy protons and heavy ions.
- TASTRAK is not affected by light, gamma-rays, X-rays, beta-particles and sea-level cosmic rays.
- TASTRAK is easy and safe to handle whether exposed to radiation or not.

The National Radiological Protection Board (NRPB)

The NRPB is an independent statutory body. It provides advice and services to government, local authorities, industry, environmental groups, trade unions etc.

If you would like to know more about radon in the environment you can get free leaflets such as *Radiation Doses – Maps and Magnitudes* and *Radon – Questions and Answers* from

The National Radiological Protection Board
The Information Officer
Chilton
Oxfordshire
OX11 0RQ

The Householders' Guide to Radon is published by the Department of the Environment – available from HMSO and booksellers.

Living with Radiation is published by NRPB – available from HMSO and booksellers.

Answers to the questions are in the *Teachers' Notes*.

RADON – *an investigation*

The results of our survey are

Grid reference (6 figure number)	Radon level (Bq/m^3)	Location (soil/room)	Dates	Name of student(s)

Post to

Dr G C Camplin
Portway School,
Penpole Lane,
Shirehampton,
BRISTOL BS11 0EB

Teacher's Name ____________________

School ____________________

School address ____________________

____

____

Postcode __________ *Telephone* __________

TIN CANS - are they made of steel?

Science content

Properties and uses of materials (steel, aluminium, tin), strength, density, electrical conductivity, rusting, gas pressure, recycling.

Science curriculum links
AT 1 Exploration of science
AT 5 Human influences on the Earth
AT 6 Types and uses of materials
AT 7 Making new materials

Syllabus links
- GCSE Science, Chemistry, Physics,
- Technology

Cross-curricular themes
- Environment
- Citizenship
- Economic Awareness

Lesson time
2 hours
(some homework possible)

Links with other SATIS materials
103 Controlling Rust
604 Metals as Resources
1004 Materials to Repair Teeth

NERIS
Search on
RECYCLING and CANS

SUMMARY

The unit is based upon a practical investigation of food and drink cans and leads students to consider how the materials and methods chosen for can making are related to the contents of the can. Lastly, students are asked to consider the problems involved in recycling cans.

AIMS

- ☐ To link work on the physical and chemical properties of aluminium, iron (steel) and tin to the design of food and drink cans
- ☐ To collect, record and make a critical evaluation of data
- ☐ To illustrate the recycling of aluminium, tin and ferrous metals
- ☐ To provide an opportunity for discussion of social, environmental and economic issues concerned with recycling

STUDENT ACTIVITIES

- ☐ Part A Canning and food preservation, tinplate and aluminium.
- ☐ Part B Investigation, use of a key and data collection about types of can. Follow-up information and questions.
- ☐ Part C Information and questions about recycling. Group discussion problem.

USE

- ☐ The unit builds on prior work on the physical and chemical properties of metals and on work about food preservation.
- ☐ Part B, the investigation, requires students to follow a key and is suitable for practical assessment.
- ☐ Work might be extended to investigate the corrosive effect of acid on samples of can material.

REQUIREMENTS FOR STUDENT PRACTICAL WORK

Each pupil or group of pupils will require

- ☐ access to a collection of food and drink cans and samples of iron, tin and aluminium. These should be checked for sharp edges.
- ☐ magnet
- ☐ simple conductivity test apparatus (e.g. battery, lamp, 3 connecting leads) or multimeter
- ☐ micrometer screw gauge (optional)

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Teaching notes

Cans are best supplied empty with lids/ring pulls removed. (Please check them for sharp edges.) Some can openers fold sharp edges so they are safer. If new cans are used, remove the paper labels and note the contents on the can with a marker pen.

Micrometer screw gauges are sensitive instruments reading to 0.01 mm. Students may need to be shown how to use them correctly – holding by the ratchet. The ratchet will slip when the grip of the jaws is just tight enough. Students should be able to measure the thickness of cans without splitting the wall as long as the side is slightly flattened.

Answers to the questions

Part A

Q1 *Heating kills any bacteria present in the food. The seal prevents further contamination.*

Q2 *Food will not decay but may break down and lose its flavour. Cans are best stored in a cool dry place. Cans will keep more than a year.*

Q3 *Tinplate is cheaper than other packaging metals. Tin protects steel externally, preventing rusting and iron dissolution internally. Aluminium is fairly cheap for packaging, does not corrode externally (but needs to be lacquered internally).*

Q4 *Steel is more expensive. (Aluminium £2,632 per m^3, tinplate £3,900 per m^3).*

Q5 *Cans with thinner walls are cheaper on raw materials (and lighter to carry).*

Q6 *Food cans are steel. About half all drinks cans are steel, the remainder are aluminium. In Britain steel drinks cans with captive ring pulls have aluminium tops.*

Q7 *Lacquering protects the metal can from chemical attack by the contents, especially from acidic foods and drinks.*

Q8 *Round shape, thick bases, shaped bases and necking, beading. (You can demonstrate the effect of beading by pleating a sheet of paper.)*

Q9 *Cooked foods.*

Q10 *Higher pressure inside than outside due to gas dissolved under pressure. Liquids are fairly incompressible.*

Q11 *Suggestions such as*

(a) strong enough to be resistant to damage during manufacture and transportation, easy to seal after filling, attractive, easy to open, resistant to corrosion by the drink etc.

(b) withstands high pressures during cooking, resistant to attack by contents, inexpensive, etc. The gas pressure from fizzy drinks helps to withstand external pressure.

Q12 *6%*

Q13 *Steel may be picked out by a magnet.*

Q14 *Save money on transporting waste to landfill and on landfill sites. After recouping capital costs of recycling plant, make money by selling the reclaimed metals.*

Discussion

Many developed countries, under pressure from environmental lobbyists or due to a shortage of landfill sites, operate comprehensive recycling schemes. Similar pressures are beginning to act in the UK. News items and a survey of local facilities may provide useful background to the discussion.

A video, *Steel – The Environmentally Attractive Metal* deals with the recycling of steel cans and is available on free loan from John May, British Steel Tinplate, PO Box 101, Velindre, Swansea SA5 5WW.

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TIN CANS – are they made of steel?

Part A – Preservation and packaging

The canning of food was invented about 200 years ago.

Heating food to a high temperature kills bacteria; and, as long as the can remains airtight, the food will not decay.

Cans came to be called 'tins', because they were always made of **tinplate**, that is steel coated with tin. Aluminium is now being used for cans too.

> ***Q1*** *Why does canning preserve food?*
>
> ***Q2*** *How long do you think canned food will remain in good condition?*
>
> ***Q3*** *Suggest why tin-plated steel and aluminium are used for cans.*

Cans are made in millions every day. So very small details of design can help manufacturers keep their costs down and improve the product for the consumer. For example, can makers are trying to use thinner metal. The walls of steel cans for fizzy drinks have been reduced in stages from a thickness of 0.10 mm to 0.095 mm and to 0.09 mm. The aim is for a can wall as thin as 0.08 mm or even 0.07 mm! And with the customer and the environment in mind, drinks cans are now made with captive ring pulls.

	Aluminium	Tinplate
cost per tonne	£940	£500
density in tonnes/m^3	2.8	7.8
strength	moderate	very strong
corrosion	attacked by salt acids and alkalis	outside may rust, inside attacked by some foods

Part A Canning for preservation and packaging.

Part B A practical investigation of the structure and materials used for can making.

Part C Recycling
- How are steel cans recycled?
- What are the economic and environmental benefits?
- How to encourage recycling – a problem for discussion.

> ***Q4*** *Which is more expensive, a cubic metre of aluminium or tinplate?*
>
> ***Q5*** *What are the benefits of making cans with thinner walls?*

Part B – The technology of tin cans

What are 'tin cans' made of? – an investigation

You will need

- empty food and drink cans *(beware of sharp edges, try to keep part of their labels on them to identify their contents and make sure they are clean)*
- a magnet
- apparatus to test if a can conducts electricity
- samples of the metals iron/steel, aluminium and tin for comparison
- a micrometer screw gauge (optional)

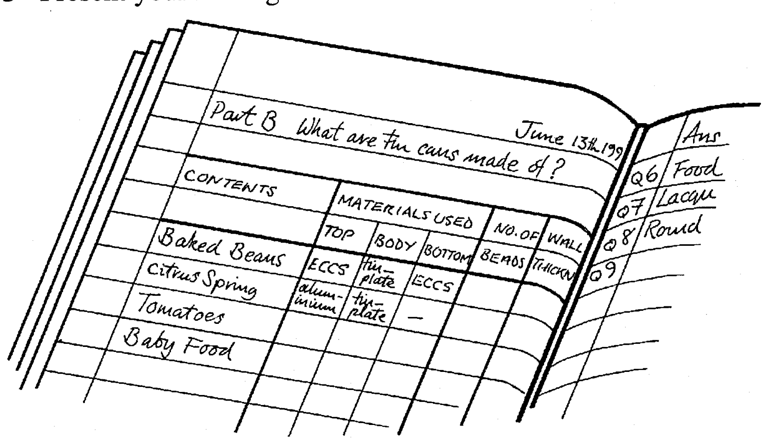
1 Collect together all you need for this investigation.

2 Examine the cans carefully. Be careful of sharp edges. Find out as much as possible about what materials they are made of and how they are constructed.

What should you look for? Here are some suggestions.

- ☐ What food or drink did the can contain?
- ☐ Identify the materials used to make *each part* of the can. You might use the key on page 3.
- ☐ Is the inside of the can **lacquered?** (Lacquer is often clear or golden coloured) You can find out by doing a simple electrical conductivity test – lacquers are non-conductors.
- ☐ How is the structure of the can made strong? Does it have a 'necked-in' shape? Does it have 'beads' in the body of the can? If so, count the number of beads. ['Beading' is the term used by the can-maker for the ringed or corrugated effect around some cans. (See the picture on page 4.)]
- ☐ How thin is the can wall? Flatten the can slightly and measure it if you have a micrometer screw gauge.
- ☐ How was the can put together?

3 Present your findings in a table.

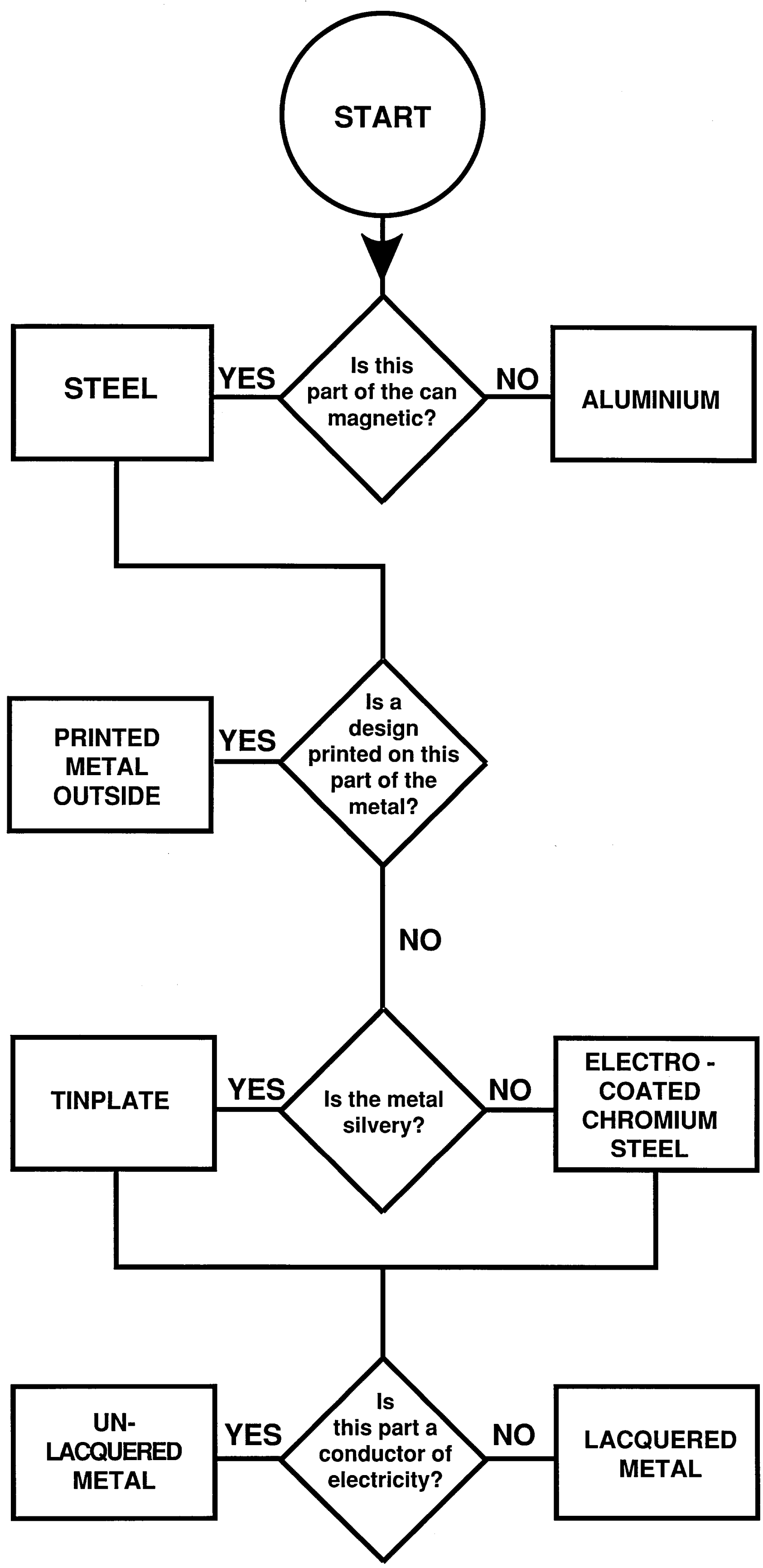


Q6 *What sort of cans (tinplate and/or aluminium) are used for*
(a) food cans,
(b) drinks cans?

Q7 *Suggest why the insides of cans are often lacquered.*

Q8 *What design details are used to make cans strong?*

Key for identification of metals in food and drink cans



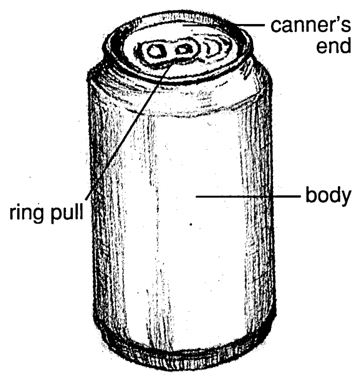


Figure 1 A seamless two-piece can

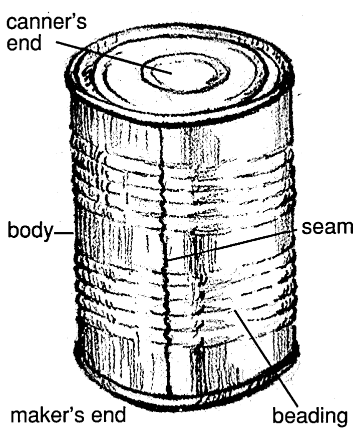


Figure 2 A three-piece can

The energy needed to make a 440 ml drinks can is

	MJ
Steel	5.0
Steel with aluminium end	5.6
Aluminium	5.1

An important use of steel

Tinplate is the major raw material for making virtually all food and petfood cans and about half of all drinks cans. In simple terms, it is a strip steel which is coated on both sides with a thin layer of tin. The tin is applied electrolytically.

Making tinplate is a long-established part of the steel industry in South Wales. There are plants at both Llanelli and Ebbw Vale.

The tinplate producer sells coils or flat plate to a can maker. The can maker produces an open top can for food or drink.

The cans together with their ends are sold to the cannery, where they are filled. The end is seamed on. The food sealed inside the cans is cooked. Cans have to withstand high pressures from inside at this stage and lower pressures inside after cooling. That is why many food cans are beaded to make them stiffer.

Fizzy drinks cans have a higher pressure inside than the atmospheric pressure outside.

> ***Q9*** *What are 'beaded' cans used for storing ?*
>
> ***Q10*** *Explain why it is difficult to crush a drinks can before it has been opened but easy when it is empty.*

The material can makers use does not depend on cost per tonne alone. Tinplate was originally used for making cans because it was easy to solder. Today, tinplate cans are almost all welded. Tinplate is stronger than aluminium and tinplate cans are relatively cheap to mass produce. Aluminium cannot be welded and is used for seamless cans only. They are expensive to produce in low numbers. Aluminium is attacked by all food and drink and all aluminium cans must be protected by lacquering inside.

Although most foods are packaged in tinplate cans, about half the drinks cans used in Britain are aluminium. Even the steel cans have aluminium ring-pull ends.

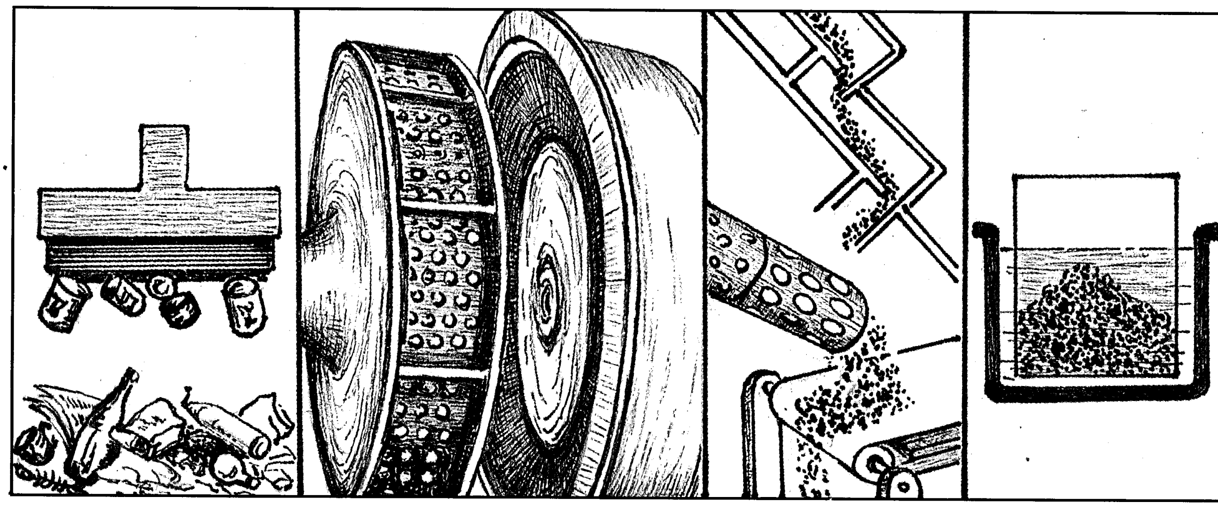
> ***Q11*** *Imagine you are working for a food and drink manufacturer. You are about to launch two new brands. What sort of can would you choose to hold*
> *(a) a fizzy peppermint drink,*
> *(b) cheese and onion-flavoured baked beans?*

Part C – Recycling cans

In Britain about 15 billion cans are used each year. Most are made of steel. In 1989 only 1050 million steel cans were recycled. (The proportion of aluminium cans recycled is much lower.)

Steel cans reclaimed from domestic rubbish are processed by the method outlined here. Local authorities who build recycling plants can sell the metal they reclaim. Land for rubbish tips is expensive and local authorities can save money by tipping less waste.

The steel recycling process



Step 1 – Magnetic Extraction
Steel cans are extracted from waste by a magnet.

Step 2 – Shredding
Cans are shredded to remove food scraps, labels, lacquers and aluminium ends from beverage cans.

Step 3 – Removing Contaminants
An air blast removes the lighter materials and a magnet separates steel from the rest of the waste.

Step 4 – Detinning
Contaminant-free steel (mostly tinplate) from step 3 is immersed in a strongly alkaline detinning solution. Tin is then separated from the steel in the tinplate by an electrolytic process.

Figure 3 Recyling steel cans

Steel which has to be detinned first has a value of about £35 per tonne and is sold for use as scrap in the charge of a steel-making furnace. Although there is only a small amount of tin on tinplate, tin is an expensive metal and that recovered by detinning is re-sold.

Aluminium is a good conductor of electricity and can be removed from rubbish using a linear motor to induce eddy currents in it. It throws itself off the conveyor belt. However, this technology is not yet widely used. Aluminium can be sent straight for remelting. It fetches around £700 per tonne.

Q12 What percentage of cans were recycled in 1989?

Q13 Why is steel easier to recycle from mixed household rubbish than other metals?

Q14 What are the economic arguments for recycling cans?

Organising the discussion

- Work in a small group.
- Appoint someone to chair the group and to report back to the class if required.
- Note down the answers you decide on.

A problem for discussion

How should people be encouraged to recycle all kinds of cans?

The following ideas have been used successfully in other countries.

- ☐ A deposit on all drink cans (and bottles). This is paid back on return to any food shop. The food shop sorts them for return and recycling. Sorting is often a part-time job for students.
- ☐ A law requiring local authorities to separate all empty cans from rubbish collections for recycling.
- ☐ An agreement for householders to sort out different kinds of cans and return them to a collecting point.

Try to add more ideas to this list.

a *What are the advantages and disadvantages of these ideas?*

b *Which scheme, or combination of schemes do you think should be used in the UK?*

c *How could you try to get your ideas adopted by other people?*

Answers to the questions are in the *Teachers' Notes.*