Are you made of stardust?

Science content
Chemical elements, stars, nuclear fusion, gravity, the collapse of stars.

Science curriculum links
AT16 The Earth in space

Syllabus links
- GCSE Science, Chemistry, Physics,

Lesson time
1 hour
or homework

Links with other SATIS materials
808 Nuclear Fusion
1207 Radio Telescopes
1208 Are there Fairies at the Bottom of the Garden?

NERIS
Search on
STARS and UPPER SECONDARY

SUMMARY

Clouds of gas and dust condense into stars. Stars evolve. Giant stars become supernovas to throw off layers of gas and dust for the cycle to begin again.

STUDENT ACTIVITIES

- ☐ Making a glossary (may be done by small group discussion).
- ☐ Reading and answering questions.

AIMS

- ☐ To link with work on the Earth in space, the origin of the universe and the solar system
- ☐ To introduce the cosmic cycle of the elements
- ☐ To provide opportunities for independent study

USING AND ADAPTING THE UNIT

- ☐ Students require prior knowledge of the structure of the atom in terms of electrons, protons and neutrons. They should be familiar with terms such as nucleus, atomic number, fusion, universe, constellation of stars, electromagnetic radiation and gravity.
- ☐ This is a challenging topic, suitable for able students towards the end of their GCSE courses.
- ☐ The unit is free-standing and may used for self-study.

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Glossary activity

Element A simple substance from which other substances are made by chemical combination. All atoms of an element have the same number of protons in the nucleus.

Nebula Seen as a fuzzy patch of light, a gas cloud in which stars are forming.

Gravity The effect of the force between two masses.

Nucleus (plural – nuclei) The small dense central part of an atom where protons and neutrons are located.

Nuclear fusion Involves collisions between two atomic nuclei to produce a heavier nucleus with the release of energy. The nuclei must have sufficient kinetic energy to overcome the repulsion of their positive charges (the coulomb barrier).

Electromagnetic radiation Waves of energy which require no medium for propagation. Electromagnetic waves travel at 3×10^8 m/s through space. Their characteristics depend upon their frequency.

Neutrino Neutral atomic particle (the analogue of the electron and positron). It is believed to be almost massless. Neutrinos interact weakly with matter and are very difficult to detect (see SATIS 1208, *Are there Fairies at the Bottom of the Garden?*). Neutrinos have been detected from the Sun and from the supernova seen in 1987.

Black hole Matter collapsed together, a region where gravity is so strong that light cannot escape.

Supernova A sudden explosion of a giant star when its core collapses inwards.

Red giant Medium-sized stars evolve into red giants when their hydrogen is used up. The core, now composed of helium, shrinks and becomes hotter while the outer layers swell. The helium fuses into carbon.

Cosmic Relating to outer space.

Acknowledgements

Leicester Space Centre assisted with the development of this unit.

Figures 5, 6 and 7 have been adapted from illustrations which first appeared in *New Scientist* magazine, London (3 February 1990, Inside Science No. 29) the weekly review of science and technology.

Further information

Helium, carbon and oxygen have particularly stable nuclides. Fusion reactions stop at iron which has the most stable nuclide of all. (For further information see 'binding energy' in an advanced physics textbook.)

The universe is believed to have started from a state of almost infinite density with an explosion, the 'Big Bang', ten to fifteen thousand million years ago. Before the evolution of stars, gas clouds in space contained only hydrogen with a little helium.

Answers to the questions

Q1 *Carbon, hydrogen and oxygen.*

Q2 *Betelgeuse and Rigel have disappeared. New stars have formed in the region of the nebula below Orion's belt.*

Q3 *(a) A star is a hot cloud of gas that radiates energy.*

(b) Stars 'shine' because they radiate energy in the visible part of the spectrum due to nuclear fusion reactions in their cores.

(c) No stars exist less than one tenth of a solar mass, presumably because such gas clouds do not reach a temperature high enough to initiate nuclear fusion.

Q4 *Ultra violet, visible light, infrared.*

Q5 *The debris from supernovas is thrown out into space and becomes incorporated into gas and dust clouds, eventually condensing into new stars.*

Q6 *As supergiants, Betelgeuse and Rigel will have relatively short lives before they become supernovas and disappear. New stars are forming in the area of the nebula.*

Q7 *H, He, C, N, O, Ne, Mg, Si, S and Fe.*

Q8 *Human beings are largely composed of the most abundant elements, H, C and O. However, the most abundant elements not included in humans are helium (He) and neon (Ne) which, being noble gases, do not readily form compounds.*

Q9 *ME → FOOD → ELEMENTS OF THE EARTH → DUST IN SPACE → SUPERNOVA → GIANT STAR.*

Are you made of stardust?

You are what you eat!

It is sometimes said that 'you are what you eat'. Every atom of your body was once part of something else. There are about 90 types of atom in nature – the **chemical elements**.

- Constructing a glossary – an activity involving reference books for individuals, pairs or groups.
- Information and questions.

Table 1 The types of atom in your body

Element	Percentage of atoms
hydrogen	59.0
oxygen	25.9
carbon	11.0
nitrogen	2.39
sodium	0.70
calcium	0.22
sulphur	0.13
phosphorus	0.13
potassium	0.04
chlorine	0.03
magnesium	0.01
iron	0.0004
Traces of iodine, fluorine, silicon, boron, cobalt, copper, manganese, molybdenum, vanadium and zinc.	

All these elements were made in the stars. They were built up from the simplest elements, **hydrogen** and **helium**. This unit explains how.

Q1 *Carbohydrates are the commonest foods you eat. What elements are carbohydrates made of?*

Glossary activity

The following terms are used in the text. Read through the unit and decide what they mean. Add more words to the list if you wish to.

It may help you to discuss the words with a partner or look them up in reference books.

element
nebula
gravity
nucleus/nuclei
nuclear fusion
electromagnetic radiation
neutrino
black hole
supernova
red giant
cosmic

What is happening in the stars?

Orion is a **constellation** or group of stars which you can see clearly in the sky at night. Figure 1 shows the stars in Orion in the winter sky. The brightest stars are the supergiants, Betelgeuse and Rigel. These are young stars. Below 'Orion's belt' is a fuzzy patch of light, a **nebula**. It is a huge cloud of gas and dust where stars are forming, 100 000 times the mass of the Sun.

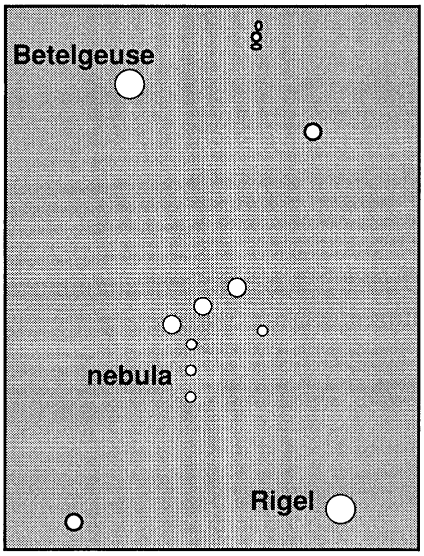


Figure 1 The stars in the constellation of Orion today

Figure 2 shows how Orion might look in ten million years time.

> *Q2 Describe* **two** *differences between the pictures.*

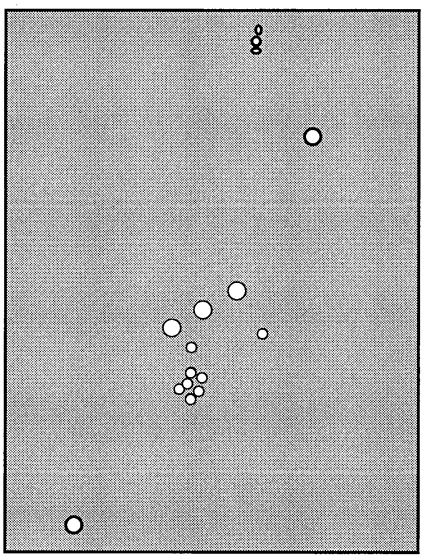


Figure 2 Orion as it might look in ten million years time

How do stars begin?

Let's look at where stars come from in the first place. Space is not completely empty. Between the stars there are clouds of molecules, mainly hydrogen. Other elements and compounds are present as well.

The largest clouds shrink under their own **gravity**. As they do so, the work done by gravity makes them hotter. Dense clouds of hot gas form.

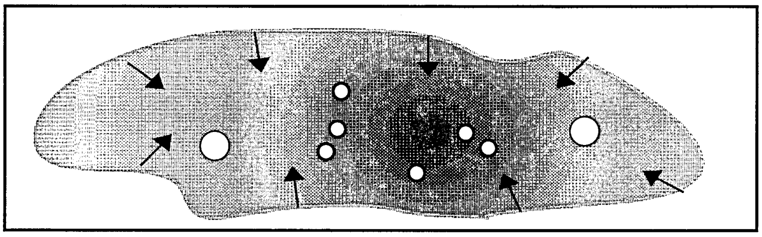
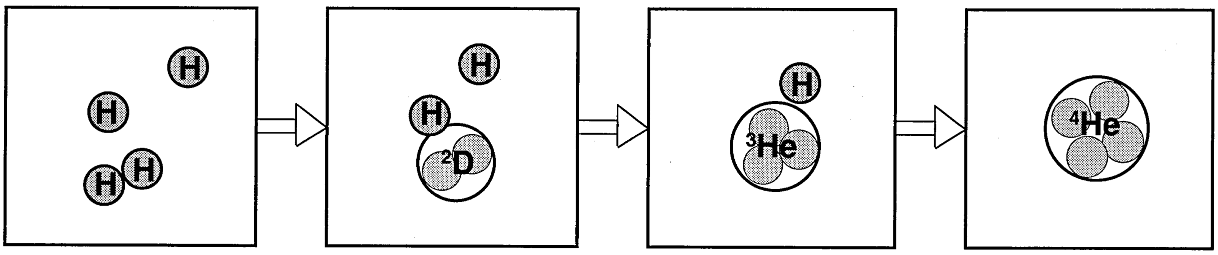


Figure 3 The birth of stars in a cloud of gas shrinking under its own gravity

Stars start to shine when the temperature reaches 10 million °C and **nuclear fusion** begins. Hydrogen nuclei bump into each other with enough energy to combine. They join or **fuse** forming first deuterium and then helium, giving out huge quantities of energy.



$^1H + {^1H} \rightarrow {^2D} + e^+ + \nu$

$^2D + {^1H} \rightarrow {^3He} + \gamma$

$^3He + {^3He} \rightarrow {^4He} + 2{^1H}$

e^+ is a positron
ν is a neutrino
γ is a photon of electromagnetic energy

Figure 4 Four hydrogen nuclei fusing to form a helium nucleus

Energy from the fusion reaction keeps the stars hot and prevents them collapsing further. Some energy is given out as **electromagnetic radiation** and as **neutrinos** – small particles with no charge and probably no mass.

Hydrogen fusion continues until most of the hydrogen is converted into helium. Small stars can shine for thousands of millions of years while the largest stars may last for only a million.

What happens when the hydrogen runs out?

What happens depends on the mass of the star.

The smallest stars (about one tenth of the mass of the Sun) stop producing energy, cool, and cease to give out light.

Bigger stars (0.4 to 8 times the mass of the Sun) go on to make heavier elements, up to carbon and oxygen, becoming **red giants** as they do so. When nuclear fusion reactions stop, they cool and fade from sight.

The largest stars (8 to 60 times the mass of the Sun) make the elements up to iron in their cores. Fusion reactions stop. A dying giant star will suddenly beome very bright. Astronomers call it a **supernova**. In a spectacular explosion, the core collapses inward under gravity. The outer layers fall in and 'bounce back', more elements being made in the shock waves. The outer layers of the supernova are flung far into space.

The collapsed core becomes a dense mass of **neutrons** or even a **black hole** where gravity is so strong that light cannot escape.

The elements made in supernovas spread out as dust in space. They mix with clouds of gas. The clouds shrink. New stars form and the **cosmic** cycle of the elements is repeated.

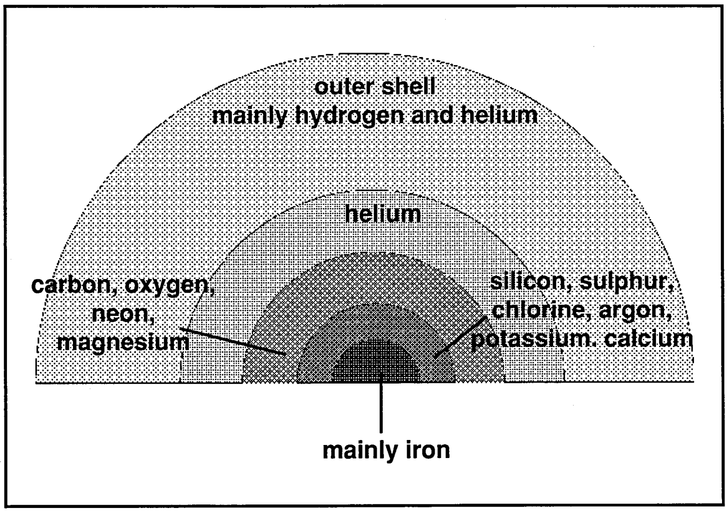


Figure 5 The layers of a giant star just before it explodes as a supernova

Table 2 The elements up to iron. All these are 'cooked' in the cores of stars. Heavier elements are made in the outer layers and in supernovas

Atomic number	Element	Symbol
1	hydrogen	H
2	helium	He
3	lithium	Li
4	beryllium	Be
5	boron	B
6	carbon	C
7	nitrogen	N
8	oxygen	O
9	fluorine	F
10	neon	Ne
11	sodium	Na
12	magnesium	Mg
13	aluminium	Al
14	silicon	Si
15	phosphorus	P
16	sulphur	S
17	chlorine	Cl
18	argon	Ar
19	potassium	K
20	calcium	C
21	scandium	Sc
22	titanium	Ti
23	vanadium	V
24	chromium	Cr
25	manganese	Mn
26	iron	Fe

What will happen to the Sun?

The Sun is thought to be about halfway through its life of 10 billion years. When the hydrogen in its core has been used up, helium fusion will begin and the outside layers will swell. The Sun will turn into a **red giant**. The fusion reactions will stop when the Sun's core has turned to carbon. The outer layers will drift away leaving a cooling white dwarf. Being composed of carbon, it will become a 'diamond in the sky'.

Q3 *(a) What is a star?*
(b) Why do stars shine?
(c) Suggest why there are no stars smaller than one tenth of the mass of the Sun.

Q4 *Give an example of the electromagnetic radiation that reaches us from the Sun.*

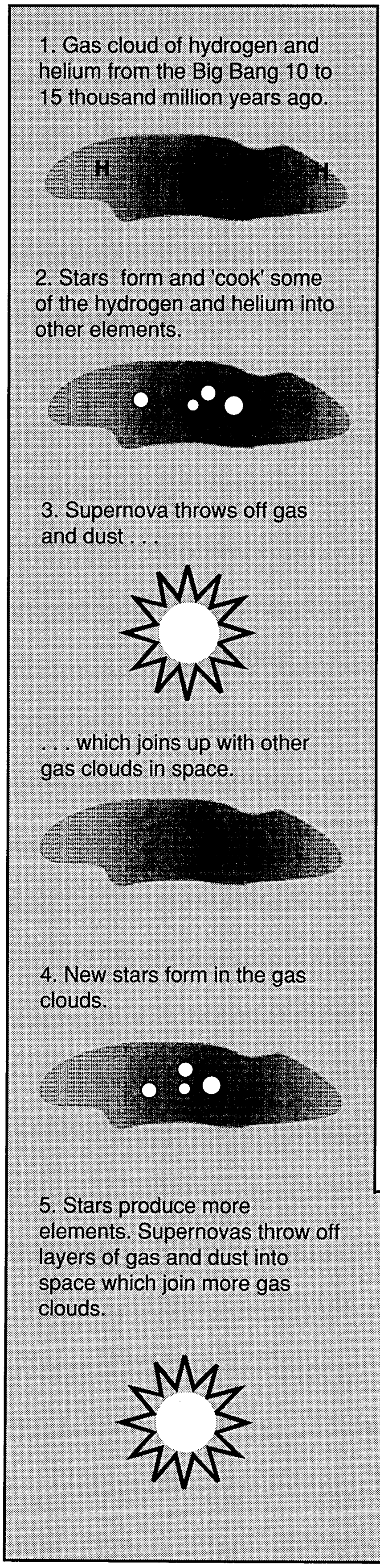
Q5 *What happens to the debris of a supernova?*

Q6 *Let's return to Orion in ten million years time. Look again at figures 1 and 2. Explain what has happened*
(a) to Betelgeuse and Rigel,
(b) in the region of the nebula.

Are you made of stardust?

Although *you* are young, the the atoms in your body are very, very old. The atoms in your hair, for example, may have come from an apple you ate for lunch, before that from the apple tree, before that from the earth, and so on.

Long ago, the same atoms were somewhere else in the solar system. But once upon a time, they were made in a star.



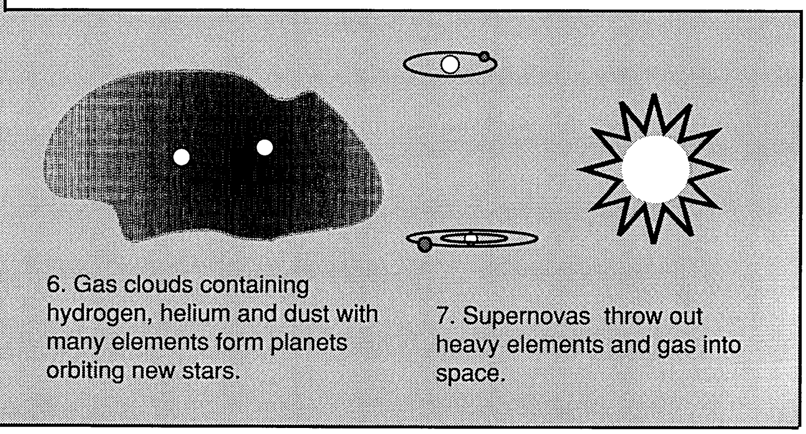


Figure 6 The cosmic cycle of matter through generations of stars

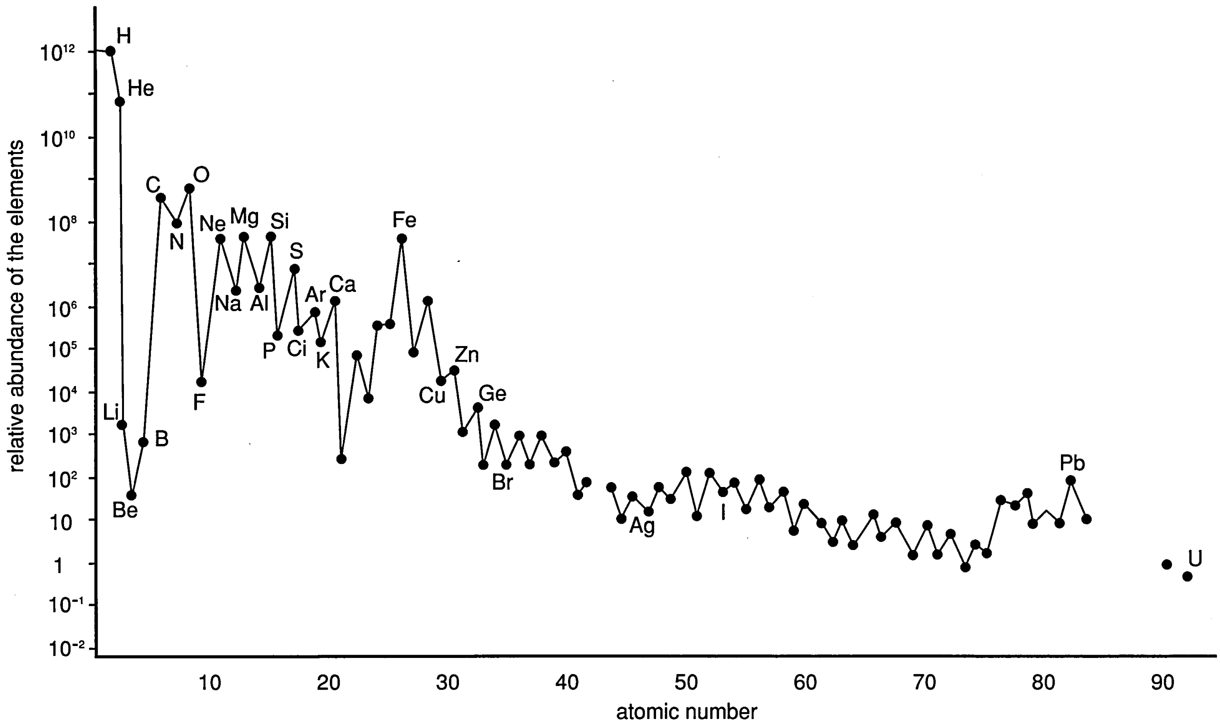


Figure 7 The relative abundance of elements in the solar system. Notice that the vertical scale increases in powers of 10. Each division is ten times greater than the last

Q7 *Look at figure 7. Which are the 10 most abundant elements in our solar system?*

Q8 *Compare the elements you gave in answer to question 7 with the elements in table 1. Comment on the similarities and differences between these lists.*

Q9 *Are you made of stardust? Draw a flow chart tracing the origin of the elements from which you are made back to a star. The flow chart has been started for you.*

ME → FOOD →

The source of energy of the stars, nuclear fusion, is the same source of energy as in the hydrogen bomb.

Fusion reactions give out huge quantities of energy. But can they be harnessed for peaceful use?

SATIS No. 808 considers the possibility of using nuclear fusion for generating electricity.

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

Bottled Water

Science content

Minerals, health, water purity, pollutants, ions, pH.

Science curriculum links

AT 3 Processes of life
AT 5 Human influences on the Earth

Syllabus links

- GCSE Science, Biology, Chemistry
- Technology

Cross-curricular themes

- Health Education
- Environment
- Economic Awareness

Lesson time

2 hours or more

Links with other SATIS materials

410 Fluoridation of Water Supplies

BBC Radio SATIS Topics 14–16

The Water Pollution Mystery

SUMMARY

Groups of students in the class form advertising agencies competing for an account to design a promotional campaign for a new brand of bottled water. The 'technical reports' and related questions may also be used separately.

STUDENT ACTIVITIES

Part A	Reading introductory information, group work and presentation: planning an advertising pitch for a new brand of bottled water.
Part B	Reading in French; questions about scientific vocabulary.
Part C	Questions for answer or discussion on the technical reports.
Part D	Research and discussion: hydrotherapy.

AIMS

- ☐ To complement and extend work on minerals in the diet by considering minerals dissolved in water
- ☐ To provide opportunities for collaborative work, analysing information and using it creatively
- ☐ To create awareness of scientific vocabulary in French
- ☐ To link modern understanding with historical views on hydrotherapy and health

USING AND ADAPTING THE UNIT

- ☐ Parts of this unit may be selected according to the ability of the students. Reading the technical reports may be set for homework along with the questions in part C.
- ☐ Work may be extended into a tasting session, testing the pH of bottled water samples, visits to shops and interviewing consumers.
- ☐ The BBC radio programme for SATIS No. 810, 'The Water Pollution Mystery', is about the purification of drinking water and provides useful information to support the technical report on 'Tap water' in this unit.

Author **Jane Vellacott**

First published 1991

Teaching notes

The material may be used in a variety of ways and is also suitable for cross-curricular work, linking economic understanding with health, science and creative studies. If time permits, aspects like packaging could be considered in greater detail, for example, the use of glass, plastic or carton containers.

Allow the class to divide into small groups (two to five students). The groups will become advertising agencies competing for the Park Springs' account. At the end, invite the best agencies to present their ideas to the rest of the class – as a simulation of the presentation to the directors of Park Springs.

Marketing strategies not suggested in the text could include an introductory offer, collecting labels to qualify for free gifts, marketing the water in earthenware containers based on an original, special displays, using other types of retail outlets such as newsagents.

Video, if available, provides a good medium for presenting a pitch.

Part B A medicinal mineral water? The passage and questions (a) to (f) require no prior knowledge of French. The aim is to show the similarities between scientific vocabulary in French and English and to illustrate some of the wider medicinal claims which have been made for mineral waters.

Part C Questions These questions are provided to support the technical information sheets if they are used for homework or independent classwork.

Part D This section could be used as a stimulus for class discussion, community studies and library research. If there is a spa nearby, the topic could be extended to link with local history.

Jane Austen's novel *Northanger Abbey* starts by describing the life style of eighteenth century gentry who went to Bath to take the waters.

Acknowledgements

The trial version of this unit was checked by Don Gerrard of Lloyd Le Carma Advertising Agency.

Figure 3 is reproduced by permission of Thames Water.

Figure 4 is reproduced by permission of Mary Evans Picture Library.

Answers to the questions

Part B A medicinal mineral water?

(a)

gazeuse	*gaseous*
bicarbonatée	*bicarbonate*
sodique	*soda (or of sodium)*
radioactive	*radioactive*
carbonate	*carbonate*
calcium	*calcium*
magnésium	*magnesium*
intestinales	*intestinal*
hépatique	*hepatic*
anémie	*anaemia*
arthritisme	*arthritis*
regazéifiée	*'re-gasified'*
gaz	*gas*

(b) *Bicarbonate of soda (i.e. sodium hydrogencarbonate), carbonate of calcium and magnesium (these must refer to calcium hydrogencarbonate and magnesium carbonate or magnesium hydrogencarbonate as calcium carbonate is very insoluble).*

(c) *Intestinal and liver complaints, anaemia, arthritis. No – medical recommendations such as these for advertising are not allowed by law in the UK.*

(d) *No. Radioactive emissions are now known to cause cancers.(See SATIS No. 803,* Radiation – how much do you get?*) Like other phenomena not properly understood, general medical efficacy was claimed for radioactivity. Although Source de l'Afrique is fictitious, such claims are made in certain countries.*

(e) *Yes. The level would depend on the local geology. Granites provide a high level of background radiation.*

(f) *Spring water is under pressure in the rocks and has gases dissolved in it. They escape as the pressure is released (like opening a bottle of fizzy drink). More gas (by implication carbon dioxide) must be dissolved under pressure to make the water effervescent again.*

(g) *Water from the spring gushes up at 42°C naturally effervescent with bicarbonate of soda, radioactive and rich in carbonates of calcium and magnesium. Recommended treatment for: intestinal and liver complaints, anaemia and arthritis. Drawn off and re-gasified with natural* gas.*

** implying re-carbonated with naturally-made carbon dioxide*

Part C

Q1 *Evian, Chiltern Hills, Park Springs and Perrier.*

Q2 *The brands in the list which are low in nitrates and low in other minerals are Evian, Scottish Spring Water, Park Springs.*

Q3 *No. A balanced diet provides plenty of minerals.*

Q4 *Lead, aluminium. (Copper is mentioned under acidity and is also toxic.)*

Q5 *Do not use bare aluminium cooking utensils, e.g. saucepans, teapots. (However, aluminium is an excellent material for cooking pots if coated with enamel or a non-stick surface because it has a low density, high thermal conductivity and relatively high specific heat capacity.)*

Do not poach foods wrapped in aluminium cooking foil. Check the contents of indigestion treatments and if they are high in aluminium, do not take them regularly. In the unlikely event that tap water is high in aluminium, use a water filter that removes aluminium ions. If the taste of filtered water is unpleasant, drink bottled water.

Q6 *As a short-term remedy, Mr and Mrs Jones could buy a water filter (on sale in chemists shops) which will remove lead ions (or persuade the water company to supply one). They are cheaper to use than buying bottled water, but levels of bacteria can increase while the water stands. Nevertheless it is an expense that Mr and Mrs Jones can ill afford. Mr and Mrs Jones could participate in community action to demand safer water supplies. It might be possible for the community to turn to law and force the water company to provide a safer supply.*

Part D

1 *For treatment of chronic ailments like gout, arthritis, rheumatism; hydrotherapy (in Germany you can have spa treatments on your health insurance, while in the USSR unions run health hydrotherapy centres), for therapeutic holidays or as part of the social season.*

2 *Spa in Liège province was a favourite watering place of royalty. Spa mineral water is now bottled and on sale in supermarkets in the UK.*

3 *Modern medical treatments are more effective. Hydrotreatments are very time-consuming.*