6 Inside the atom

Imagine something so small that you can't see it, even with the most powerful microscope. How could you possibly find out what was actually inside it? That was the challenge faced by great thinkers and scientists for centuries. Yet twenty years before scientists were first able to see an image of an atom, they had a very clear idea of what was inside. The quest to find out what was inside the atom is one of the greatest detective stories of all time. And the quest continues as scientists try to find out what's inside the building blocks of the atom.

OVERARCHING IDEAS

- Patterns, order and organisation
- Form and function
- Stability and change
- Scale and measurement
- Matter and energy

SCIENCE UNDERSTANDING

All matter is made of atoms which are composed of protons, neutrons and electrons; natural radioactivity arises from the decay of nuclei in atoms.

Elaborations

Describing and modelling the structure of atoms in terms of the nucleus, protons, neutrons and electrons

Comparing the mass and charge of protons, neutrons and electrons

Describing in simple terms how alpha and beta particles and gamma radiation are released from unstable atoms

THINK ABOUT ATOMS

- How did a plum pudding help scientists gain an understanding of atoms?
- How did Lord Rutherford find out that the atoms in solid gold are mostly empty space?
- What causes radioactivity?
- Does 'radioactive' always mean 'dangerous'?
- How is uranium used in a nuclear reactor?
- What's the connection between radioactivity and fossils?
- How is radioactivity used in the treatment of cancer?

This image shows the radioactive emission of alpha particles from inside the atoms of radium. The discovery of radium by Marie and Pierre Curie in 1898 allowed other scientists to use alpha particles to explore the structure of atoms.

YOUR QUEST

Do you have the inside information?

All substances are made up of tiny particles. You probably already know quite a lot about the particles inside substances. This knowledge is the first step in your quest to find out why substances behave the way they do.

THINK

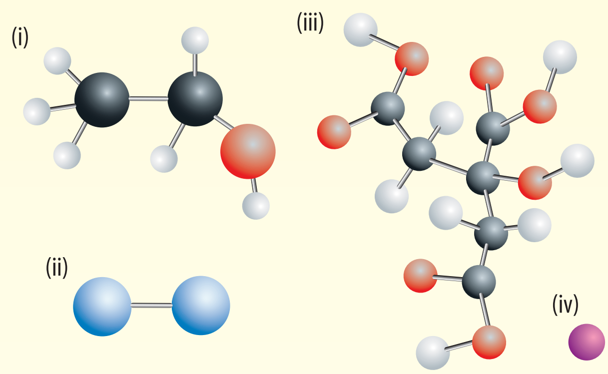
Answer the questions below to find out how much you already know about the inside story on substances.

1 The substances around you and inside you can be placed into three groups — elements, compounds and mixtures.
   (a) Which one of these groups contains substances that are made up of only one type of atom?
   (b) Which one of these groups is the least likely to be found naturally in the Earth's crust?
   (c) What is the difference between a compound and a mixture?
   (d) Arrange the substances listed below into the three groups of substances to complete the affinity diagram below right.

2 Elements, compounds and mixtures are made up of tiny particles called atoms and molecules.
   (a) How is a molecule different from an atom?
   (b) List two elements that can be made up of molecules.
   (c) List two compounds that are made up of molecules.
   (d) Name one compound that is not made up of molecules.

3 Name three particles found inside an atom.

4 Which of the diagrams below represents:
   (a) an atom of an element
   (b) a molecule of an element
   (c) a molecule of a compound?



gold
blood
carbon dioxide
diamond
iron
sea water
air
chocolate thick shake
copper
table salt
soil
ammonia
concentrated hydrochloric acid
pure water
calcium
brass
sodium hydroxide
oxygen

SUBSTANCES

Elements	Compounds	Mixtures

Chemical building blocks

Most of our knowledge about the 'building blocks' of matter that we call atoms is less than 100 years old. But the idea that matter was made up of atoms was first suggested about 2500 years ago by the great philosopher and teacher Democritus. Since then, various theories and models of the atom have been accepted, rejected and modified. The flowchart below shows some of the important developments in our knowledge of the atom.

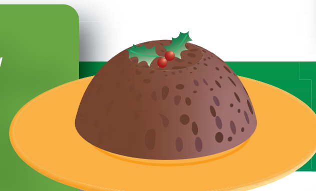
The current model

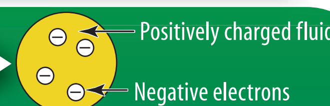
The model of the atom accepted today consists of a tiny, dense **nucleus**, made up of **protons** and **neutrons**, which is surrounded by **electrons**. It provides us with an explanation of many observable phenomena. However, it is likely that the model will continue to change or become more detailed as scientists continue with their research.

About 400 BC: Greek philosopher Democritus first suggested that all substances consisted of tiny indestructible particles called atoms.

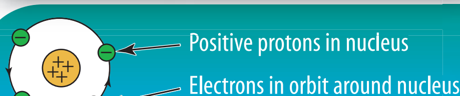
1808: John Dalton's atomic theory proposed that:
- all matter consisted of tiny particles called atoms
- atoms could not be divided into smaller particles
- atoms of the same element were alike
- atoms combined in simple whole number ratios.

1897: English scientist Sir J. J. Thomson explained that the atom contained negatively charged particles called electrons. His model suggested that atoms were positively charged spheres with negatively charged electrons embedded in them like the fruit in a plum pudding.

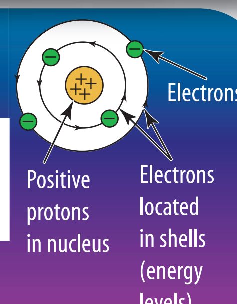




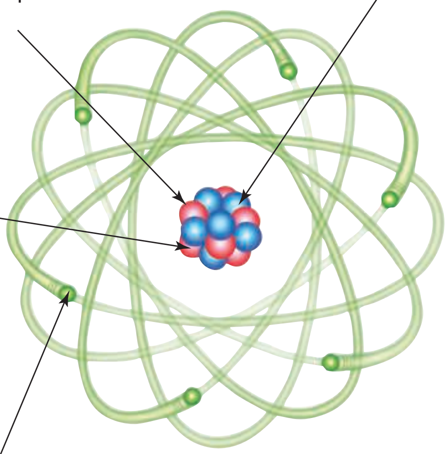
1911: Lord Rutherford proposed that the atom consisted mostly of empty space with a dense nucleus containing positively charged protons in the centre. Negatively charged electrons orbited the nucleus. Although Lord Rutherford's model of the atom was essentially the same as today's accepted model, its one flaw was that it proposed that the orbiting electrons would eventually lose energy and spiral in towards the nucleus.



1913: Niels Bohr, a scientist who had studied with Rutherford, modified the model by suggesting that electrons orbit the nucleus at different energy levels. Only electrons with specific amounts of energy could exist at each level. His model proposed that electrons could move from one level to another by gaining or losing 'packets' of energy. Although Bohr's model explained why electrons did not spiral in towards the nucleus, it did not explain all of the known properties of atoms.



1932: Sir James Chadwick discovered that the nucleus contained particles called neutrons, as well as positively charged protons. Neutrons had no electric charge and a mass about the same as a proton.

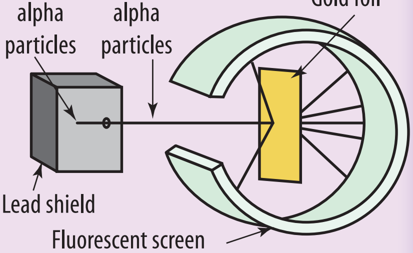


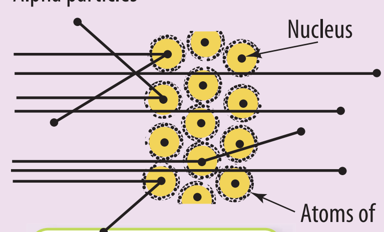
HOW ABOUT THAT!

Even the largest atoms are less than one billionth of a metre across. That's a millionth of a millimetre and about 1/20 000 of the diameter of the finest of human hairs.

HOW ABOUT THAT!

Lord Rutherford's model of the atom was based on experiments in which he fired tiny positive alpha particles at very thin sheets of gold foil. Most of the particles went straight through the gold foil and very few were reflected back. He explained that the few particles that were reflected back were repelled by a very small, positively charged nucleus in the atoms of the gold. Most of the alpha particles, he said, continued through the foil because each gold atom consists mainly of empty space. Lord Rutherford said later that his observations were about as credible as if you had fired a 16-inch shell at a piece of tissue paper and it had come back and hit you!





An enlarged view of the gold foil experiment.

UNDERSTANDING AND INQUIRING

REMEMBER

1 Describe, with the aid of a labelled diagram, the modern view of the structure of the atom.
2 Name the three important particles that make up an atom.
3 How are protons different from neutrons? How are they similar?
4 Describe the differences between protons and electrons.

THINK

5 Is the current model of the atom a theory or a fact? Explain your answer.
6 Was John Dalton's statement that atoms are indivisible correct? Explain.

INVESTIGATE

7 Find out more about one of the following scientists and describe their contributions to our knowledge about the structure of the atom. In your report you need to include:
- full name, place of birth, date of birth and death
- a brief description of the type of work the scientist did in his/her lifetime
- their contribution to our understanding of the structure of the atom
- the technology available to the scientist that enabled him/her to make the discovery
- a description of how relevant the scientist's theory is to today's understanding of the structure of the atom.

Choose from: John Dalton, Sir William Ramsay, Marie Curie, J. J. Thomson, Henry Moseley, Max Planck, Eugen Goldstein, Lord Rutherford, Frederick Soddy, Sir James Chadwick, Niels Bohr, Louis de Broglie.

8 Dalton stated that atoms were indivisible; that is, they were the smallest particle possible. However, today we know of many particles smaller than neutrons and protons. Find out more about some of these particles and how they are investigated.

work sheets
6.1 Chemical building blocks
6.2 How big is an atom?

6.2 OVERARCHING IDEA

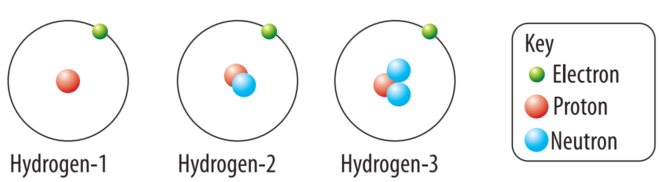
Stability and change: Inside the nucleus

At the centre of every atom is a tiny, solid core called the nucleus. Within the nucleus, protons and neutrons are usually held together by incredibly strong forces. Some of the mysteries of radioactivity can be unravelled by taking a closer look inside the nucleus.

Neutrons and isotopes

All atoms of a particular element have the same number of protons. However, often the number of neutrons in atoms of the same element is different. Such atoms have the same atomic numbers but different mass numbers. Atoms of the same element with different mass numbers are called **isotopes**. Most elements exist as two or more isotopes. These isotopes all have the same chemical properties, but slightly different masses.

Hydrogen, for example, has three isotopes. Each of the three isotopes has one proton. However, the different isotopes have 0, 1 or 2 neutrons respectively.



The three isotopes of hydrogen. Hydrogen-2 and hydrogen-3 are also known as deuterium and tritium respectively.

NAMING ISOTOPES

In symbols, isotopes are represented as ${}^{A}_{Z}E$, where:

A = the mass number; the sum of the number of neutrons and number of protons in the nucleus

Z = the atomic number; the number of protons in the nucleus

E = the symbol of the element.

In words, isotopes are described by using the element name and the mass number. For example, the isotope of hydrogen that has two neutrons has a mass number of 3 and an atomic number of 1. It is therefore represented as ${}^{3}_{1}H$ or, in words, hydrogen-3.

WHAT DOES IT MEAN?

The word *isotope* is derived from the Greek words ***isos***, meaning 'equal', and ***topos***, meaning 'place'. It came about because even though each isotope of the same element had different numbers of neutrons and therefore different weights, they occupied the same place on the periodic table of the elements.

STABLE OR UNSTABLE

In most atoms, the protons and neutrons found in the nucleus are held together very strongly. The nuclei of these atoms are said to be **stable**. However, in some atoms the neutrons and protons in the nucleus are not held together strongly. These nuclei are **unstable**. Consequently, some isotopes of elements are stable and some are unstable. Isotopes that are unstable decay to form other elements. These isotopes are said to be radioactive and are called radioactive isotopes, or **radioisotopes**. For example, two isotopes of carbon, carbon-12 and carbon-14, have identical chemical properties. However, the nucleus of carbon-14 is not stable and disintegrates naturally. Carbon-12 is a stable isotope while carbon-14 is a radioactive isotope.

Element	Symbol	Number of protons	Number of neutrons	Stable or radioactive?
Carbon-12	${}^{12}_{6}C$	6	6	Stable
Carbon-14	${}^{14}_{6}C$	6	8	Radioactive
Uranium-235	${}^{235}_{92}U$	92	143	Radioactive
Uranium-238	${}^{238}_{92}U$	92	146	Stable

Natural and artificial radioactivity

Natural radioactivity is radioactivity emitted from matter without energy being supplied to atoms. There are about 50 isotopes that emit radioactivity naturally. They exist in the air, in water, in living things and in the ground. Most radioactive isotopes (about 2000 in total) are made radioactive artificially by bombarding their atoms with sub-atomic particles like protons and neutrons.

eBook plus **eLesson**

Smashing atoms in CERN
Watch an episode of *Catalyst* from ABC TV to find out more about the matter inside atoms.

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The National Medical Cyclotron in Sydney is used to make artificial radioisotopes for use in hospitals.

Three of a kind

The energy emitted by radioactive substances is called **nuclear radiation** because it comes from the nucleus. Lord Rutherford showed that there were three different types of nuclear radiation: **alpha particles**, **beta particles** and **gamma rays**.

ALPHA PARTICLES

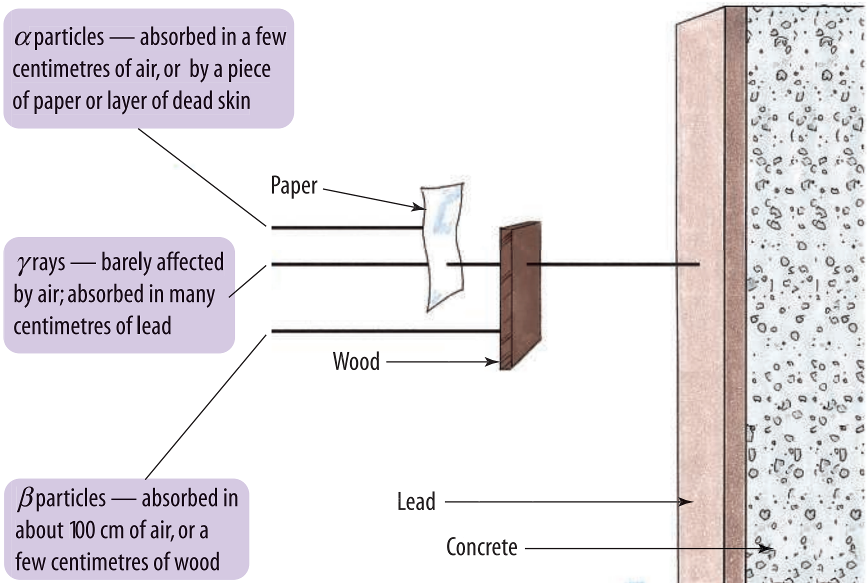
Alpha particles are helium nuclei that contain two protons and two neutrons. Alpha particles are positively charged. They cannot travel easily through materials and can be stopped by a sheet of paper or human skin. They pose little hazard to the external body but can cause serious damage if breathed in, eaten or injected. The symbol for alpha particles is α.

BETA PARTICLES

Beta particles are the same size and mass as electrons, can have a negative or positive electric charge and can travel at speeds as high as 99 per cent of the speed of light. Beta particles can penetrate human skin and damage living tissue, but they can not penetrate thin layers of plastic, wood or aluminium. The symbol for beta particles is β.

GAMMA RAYS

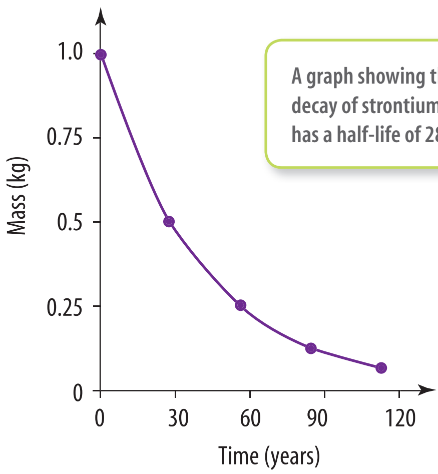
Gamma rays are not particles, but bursts of energy released after alpha or beta particles are emitted. Gamma rays travel at the speed of light and are highly penetrating. They can cause serious and permanent damage to living tissue and can be stopped only by a thick shield of lead or concrete. The symbol given to gamma rays is γ.



The different penetrating powers of alpha (α), beta (β) and gamma (γ) radiation

The lives and half-lives of radioisotopes

The nuclei of different radioactive substances decay at different rates. Some radioisotopes decay in a few seconds, while others take thousands of years. The time taken for half of all the nuclei in a sample of a radioisotope to disintegrate or decay is known as its **half-life**.



A graph showing the radioactive decay of strontium-90, which has a half-life of 28 years

There are three naturally occurring isotopes of uranium; uranium-238, uranium-235 and uranium-234. Each of the isotopes spontaneously disintegrates or decays, producing alpha particles and gamma rays. Each isotope has its own half-life; that is, the time taken for the concentration to fall to half its initial value. Half-lives can vary from microseconds to billions of years. The half-lives of each of the uranium isotopes are more than a billion years.

Number of half-lives	Fraction remaining
1	$\frac{1}{2}$
2	$\frac{1}{4}$
3	$\frac{1}{8}$
4	$\frac{1}{16}$

In the background

We are all exposed to background radioactivity every day. Fortunately it is quite safe. Most of it comes from naturally occurring radioactive elements in the Earth's atmosphere and crust. A smaller amount comes from outer space in the form of **cosmic radiation**, mostly in the form of high energy protons emitted by stars, including the sun. The word cosmic comes from the Greek word *kosmos*, meaning 'universe'. The Earth's atmosphere protects us from the dangers of cosmic radiation. There are even small amounts of radioisotopes in the human body, including hydrogen-3 (tritium), carbon-14 and potassium-40.

HOW ABOUT THAT!

French physicist Henri Becquerel accidentally discovered radioactivity while investigating the fluorescence of uranium salts in 1896. When he developed a photographic plate that had been in a drawer near his bench top, he found that it had been fogged up by radiation from the uranium salts.

This effect of radioactivity is now used in a protective device worn by people who work with radioactive materials. The 'fogging' of the film in this device measures the amount of radioactivity they have been exposed to.

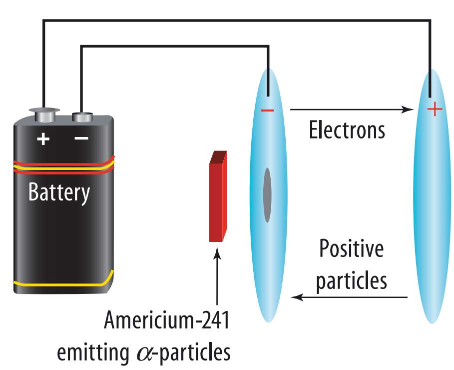
Becquerel was the first scientist to report the effects of radioactivity on living tissue. He suffered from burns on his skin as a result of carrying a small quantity of the element radium in his pocket.

Smoke alarms

Inside a smoke alarm, in the ionisation chamber, there are two plates that are oppositely charged. There is also a tiny amount of americium-241, which has a half-life of 432 years. Americium-241 atoms emit alpha radiation. The alpha particles knock electrons off the molecules in the air. This creates positive particles and free electrons. The positive particles are attracted to the negative plate, and the electrons are attracted to the positive plate. A small current is set up.

When smoke particles are drawn into the smoke alarm, they attach themselves to the positive ions, making them neutral and disrupting the current. This change is sensed by the detector and the siren sounds.

What happens in the ionisation chamber?



UNDERSTANDING AND INQUIRING

REMEMBER

1 How are isotopes of the same element different from each other?

2 In the symbol ${}^{A}_{Z}E$, what is represented by
   (a) the letter A
   (b) the letter Z?

3 Why are the isotopes of some elements radioactive?

4 Write down the type of nuclear radiation described by the following statements.
   (a) A radioactive particle that has the same size and mass as an electron
   (b) A radioactive particle that is made up of two protons and two neutrons
   (c) The type of radiation that can penetrate the human body and can be stopped only by a thick shield of lead or concrete
   (d) A radioactive particle that can travel almost at the speed of light

5 What electric charge is carried by an alpha particle?

6 How are we protected from cosmic radiation from outer space?

USING DATA

7 A scientist wished to determine the type of radiation emitted by a radioisotope. She had three materials (paper, plastic and lead) and an instrument called a Geiger counter, which detects nuclear radiation. She covered the radioisotope with each of the three materials and measured the radiation that passed through each material. The results of her experiment are shown in the table below.

Results of radioactivity experiment

Material	Effect on Geiger counter readings
Paper	No effect on readings
Plastic	Readings fell by two-thirds
Lead	Large fall in readings

What type of nuclear radiation does this radioisotope emit? Explain your answer.

THINK

8 About 0.01 per cent of the potassium in your body is the radioisotope ${}^{40}_{19}K$.
   (a) How many protons and neutrons are in each atom of this radioisotope?
   (b) The stable nuclei of potassium atoms have one less neutron than the nuclei of potassium's unstable radioisotope. Write down the complete symbol for the stable isotope of potassium.

9 Are the atoms ${}^{230}_{93}X$ and ${}^{239}_{94}Y$ isotopes of the same element? Explain.

10 An atom of uranium-238 (${}^{238}_{92}U$) decays by emitting a single radioactive particle. The atom formed as a result of the decay is thorium-234 (${}^{234}_{90}Th$). What type of radioactive particle is emitted? Explain how you got your answer.

11 The half-life of an isotope of tritium is 4500 days. How many days will it take an amount of tritium to fall to a quarter of its initial mass?

INVESTIGATE

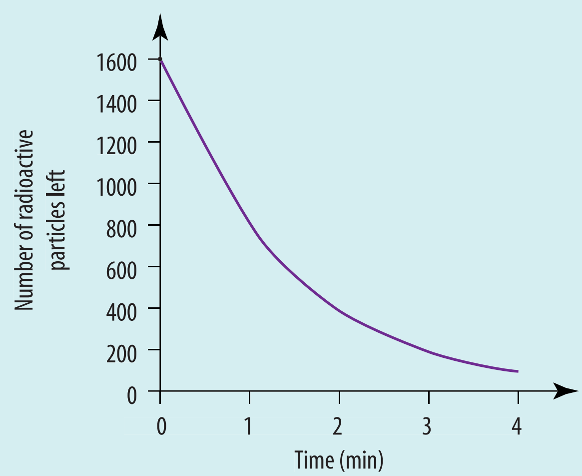
12 Find out which radioactive gas in the atmosphere is responsible for most of the background radiation we are exposed to on Earth.

13 Use the **Radioactive half-life** interactivity in your eBookPLUS to choose a radioactive element and the mass, and then watch the graph of its half-life. Use the data to answer questions on the accompanying worksheet. **int-1652**

eBook*plus*

ANALYSE AND EVALUATE

14 The graph below shows the decay of a radioisotope over four minutes.



Graph of radioactive decay of an isotope

   (a) What is the half-life of this isotope?
   (b) How many radioactive particles would be left after five minutes?
   (c) When the decay takes place in a sealed container, helium gas is collected. Name one type of radiation produced in the decay.

work sheet 6.3 Top ten elements

Using radioactivity

In 1903, Marie Curie, her husband Pierre, and Henri Becquerel were awarded the Nobel Prize in Physics for their discovery of radioactivity and their work on uranium. Little did they know that their discoveries and investigations would change the course of history.

They could not have imagined that their work would lead to the development of nuclear weapons capable of killing millions of people, nuclear power plants that generate electricity, and radioactive isotopes that can be used to treat cancers and detect life-threatening illnesses.

Radioisotopes are used in industry and research, and also have medical applications. They can be used as radioactive 'tracers' to follow the movement of substances through liquids (for example, sediment movement in rivers and the movement of substances in the blood). Radioactive isotopes are also used in smoke detectors, soil analysis, pollution testing, measuring the thickness of objects and criminology.

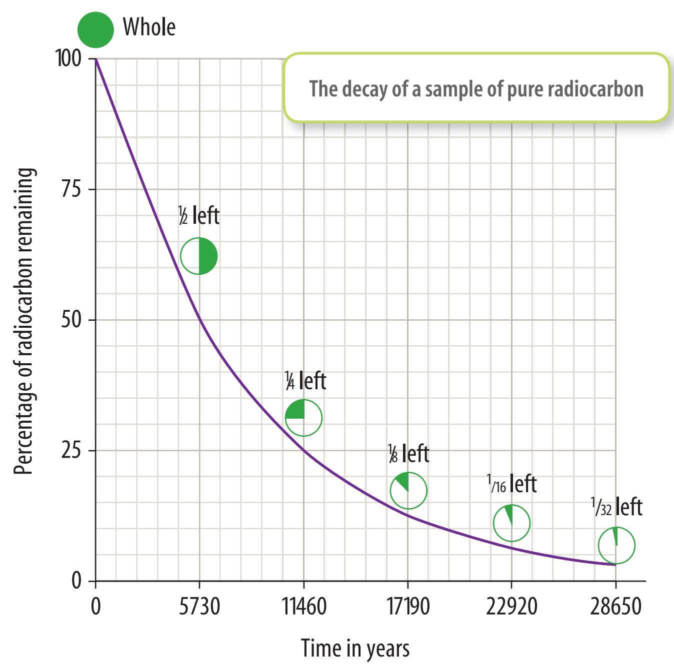
Radiometric dating

Naturally occurring radioisotopes can be used to calculate the age of samples from archaeological sites. Geologists make use of radioisotopes to determine the age of rocks and fossils. The technique is called **radiometric dating**.

The isotope carbon-14 has a half-life of 5700 years. Radiometric dating with carbon is called **radiocarbon dating**. All living things contain the element carbon. A small amount of the carbon is radiocarbon. As long as organisms are alive, carbon (along with radiocarbon) is being replaced. Plants take in carbon dioxide, animals eat plants, and micro-organisms consume plant and animal matter or each other. All living things, therefore, contain a small amount of radiocarbon.

When living things die, the decaying radiocarbon is no longer being replaced. Since all fossils were once living, their age can be determined by measuring the amount of radiocarbon remaining. After 5700 years, only half of the usual amount of radiocarbon will be left. A graph can be used to estimate the age of a fossil. After about 50 000 years, the amount of radiocarbon becomes too small to measure accurately.

All rocks contain small amounts of radioactive elements such as uranium and potassium. The age of older rocks, and the fossils within them, can be determined by using radioactive elements with longer half-lives.



Radioisotopes and nuclear power

The radioactive properties of uranium are used in the generation of electricity in **nuclear reactors**. Australia is one of several countries that have large high-grade deposits of uranium. Uranium is converted to uranium dioxide and then sealed in rods, called **fuel rods**. The uranium undergoes a **fission** reaction in the reactor when neutrons are fired at the radioactive uranium. This causes the uranium nuclei to split and form two new elements, releasing neutrons, radiation and heat in the process. This heat energy is used to heat water to produce steam, which is used to turn the turbines that generate the electricity.

A worker inspecting output at a nuclear power plant

FAST BREEDERS

In some countries fast breeder reactors use the artificial radioisotope plutonium-239 as a fuel. Plutonium-239 is made by bombarding uranium-238 with fast moving neutrons (that's why the term 'fast breeder' is used). The plutonium-239 produced is also used to produce nuclear weapons.

NUCLEAR WASTE

The used fuel rods in a nuclear reactor are radioactive and contain a mixture of radioisotopes. Some of the waste radioisotopes have half-lives of only minutes, while others have half-lives of thousands of years. These waste products are currently sealed in steel containers or glass blocks and stored in power stations or buried deep at sea or underground away from groundwater. There is, however, still no permanent solution to the problem of disposing of nuclear waste.

It has been suggested that nuclear waste should be sent by rocket to the sun or into outer space. However, the risk of a rocket carrying nuclear waste exploding before leaving the Earth's atmosphere makes that solution very risky.

WHAT DOES IT MEAN?

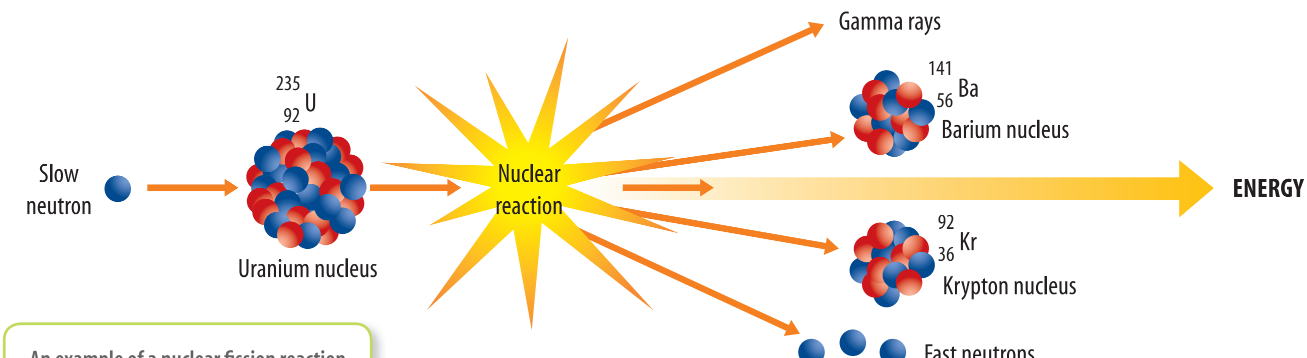
The word *fission* comes from the Latin word ***fissio***, meaning 'to split'.

Radiotherapy in the treatment of cancer

Radiotherapy is the use of radioisotopes, or other radiation such as X-rays, to kill cancer cells or prevent them from multiplying. It can be targeted at a small area so that surrounding tissue is not damaged. Radiotherapy is often used along with other treatments such as surgery or chemotherapy.

Radiation can be directed at the cancer by a machine like the one at right. This method is known as **external radiotherapy**. The other method, known as **internal radiotherapy** or **brachytherapy**, involves placing radioisotopes inside the body at or near the site of the cancer. In some cases both methods are used. The type of treatment depends on the type of cancer, its size and its location as well as the general health of the patient.

Nuclear equation: $^{235}_{92}\text{U} + ^{1}_{0}\text{n} \longrightarrow ^{141}_{56}\text{Ba} + ^{92}_{36}\text{Kr} + 3\,^{1}_{0}\text{n}$



An example of a nuclear fission reaction eBook*plus* **eLesson**

Nuclear medicine

Meet Dale Bailey, who works with nuclear medicine, in an episode of *Catalyst* from ABC TV.

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Radioisotopes in the diagnosis of disease

Radioactive substances may be inserted into the body to detect or identify the cause of disease. The radiation produced by the substance while it is in the part of the body under investigation is measured to diagnose the problem.

Some radioisotopes can be used to obtain images of parts of the body. The gamma rays emitted by these radioisotopes are used to produce the images. PET (positron emission tomography) scans use cameras surrounding the patient to detect gamma rays coming from radioisotopes injected into the body.

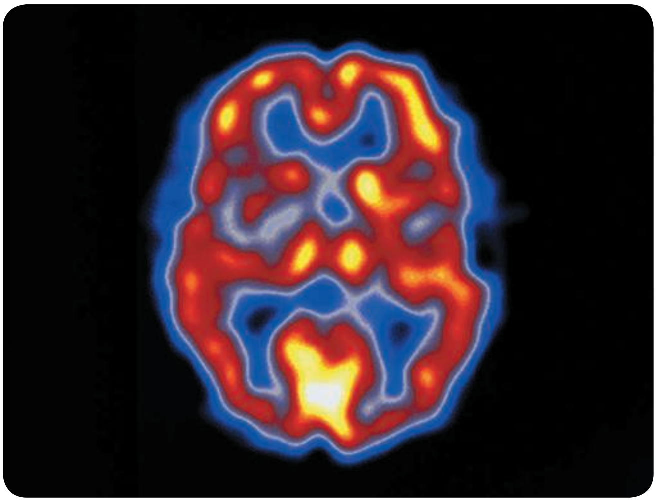
A patient undergoing a PET scan of her brain

Preserving food

If you've ever suffered from food poisoning you will understand why it is necessary to keep food from spoiling. Food in sealed containers can be preserved by exposing it to gamma radiation. The radiation kills the micro-organisms in the food and keeps it from spoiling. However, there has been much controversy about the safety of food that has been treated in this way.

HOW ABOUT THAT!

Cigarette smoke contains radioactive isotopes, including radium-226, polonium-210 and lead-210. When a smoker inhales, these radioactive isotopes are deposited in the lungs.



A PET image of the human brain

The dark side of radioactivity

Nuclear radiation can have a devastating effect on living things. Exposure to large doses of radiation can cause immediate effects such as nausea, headaches, vomiting and diarrhoea. Nuclear radiation damages living cells, and too much exposure can lead to diseases such as leukaemia and cancer. It can also damage the reproductive mechanisms in cells, including DNA, leading to birth defects in the offspring of exposed organisms. It is ironic that Marie Curie herself died of leukaemia at the age of 67. Her illness was almost certainly caused by her constant exposure to radioactivity.

Some of the radioisotopes used in the treatment and diagnosis of disease

Radioisotope	Use	Half-life
Phosphorus-32	Treatment of leukaemia	14.3 days
Cobalt-60	Used in radiotherapy for treating cancer	5 years
Barium-137	Diagnosis of digestive illnesses	2.6 minutes
Iodine-123	Monitoring of thyroid and adrenal glands, and assessment of damage caused by strokes	13 hours
Iodine-131	Diagnosis and treatment of thyroid problems	8 days
Iron-59	Measurement of blood flow and volume	46 days
Thallium-201	Detection of damaged heart muscles	3 days

INQUIRY: INVESTIGATION 6.1

Radioactive decay

KEY INQUIRY SKILL:

- processing and analysing data and information

Equipment:

graph paper

- The half-life of the radioisotope iodine-131 is 8 days. Calculate the amount of iodine-131 left after 8, 16, 24, 32, 40, 48, 56, 64, 72 and 80 days if 100 g is given to a patient to treat a thyroid problem. Present your information in a table.
- Draw a graph showing how the radioisotope decays. Make the horizontal axis represent time and the vertical axis represent the amount of radioisotope left.

DISCUSS AND EXPLAIN

1 What fraction of the iodine-131 is left after:
  (a) 8 days
  (b) 16 days
  (c) 24 days
  (d) 80 days?

2 Why is it difficult to store radioisotopes with short half-lives?

UNDERSTANDING AND INQUIRING

REMEMBER

1 What is the name of the nuclear reaction that takes place in nuclear power stations?

2 Describe three uses of radioactive elements.

3 What is radiotherapy and how does it prevent the spread of cancer through the body?

4 How is internal radiotherapy different from external radiotherapy?

5 How do radioisotopes used in food preservation stop food from spoiling?

THINK

6 Is iodine-131 a more stable radioisotope than barium-137? Explain.

7 The use of barium-137 in the diagnosis of digestive illnesses involves the patient drinking it in a syrup. What property of barium-137 makes its use quite safe?

IMAGINE

8 It was Marie Curie who invented the word 'radioactivity' to describe the disintegration of the nucleus. What would Marie Curie think if she were still alive today and could see both the good and bad effects of radioactivity? Would she be proud? Would she be disappointed? Would she be angry? Imagine that you are Curie and write an open letter explaining your feelings.

INVESTIGATE

9 What is radioactive fallout?

10 Research the topic 'nuclear reactors' and find out:
  (a) what they are built from
  (b) what fuel rods and control rods are
  (c) what type of nuclear reaction occurs in the reactor
  (d) how the reactor is kept cool
  (e) how electricity is generated
  (f) what kinds of safety features are used.

11 Radiotherapy is an effective method of treating cancer. However, it has a number of side effects. Find out what the side effects are.

12 Suppose you have been asked to write a report to discuss the following proposal: The use of radioactive elements should be banned in Australia. Give both sides of the argument, but present a conclusion for or against the proposal. For more information, click on the **Uranium Information Centre** weblink in your eBookPLUS. You should also search the internet using keywords such as uranium, radiation, mining, nuclear and waste to find other useful sites.

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ANALYSE AND EVALUATE

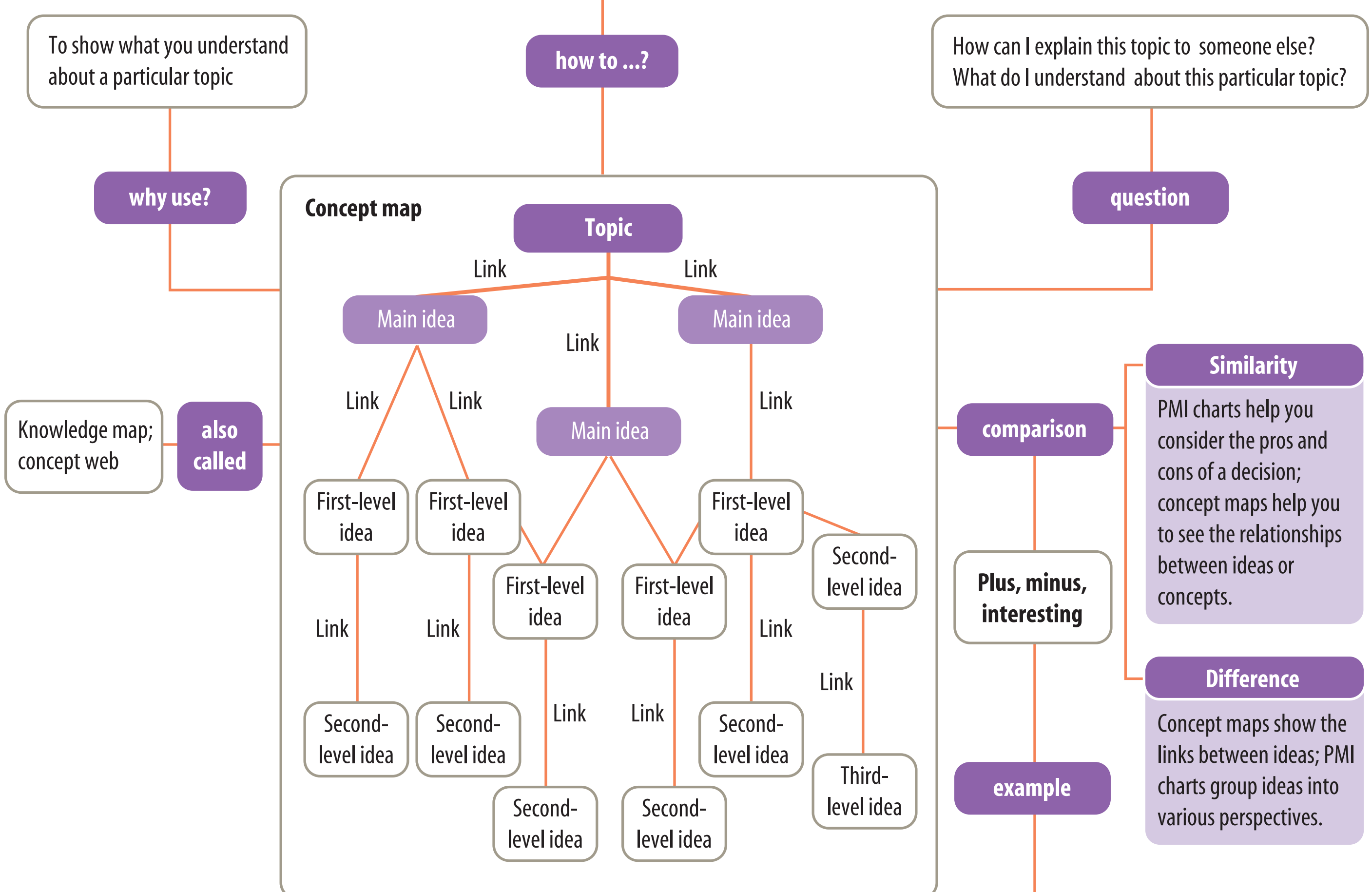
13 Use the graph at the beginning of section 6.3 to answer the following questions.
  (a) Parts of the skeleton of a large animal are found buried in sand dunes. The amount of radioactive carbon-14 in the bones is about one-eighth of that found in the skeletons of living animals. How long ago did the animal probably die (to the nearest thousand years)?
  (b) Approximately what percentage of the original amount of radioactive carbon-14 would you expect to find in:
    (i) an Aboriginal spear 11 000 years old
    (ii) a skull 23 000 years old, found in a cave?

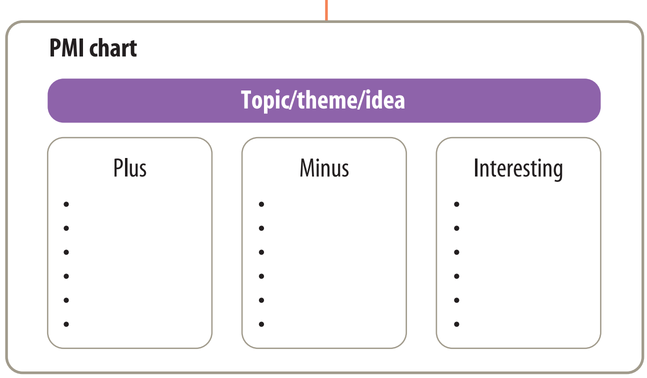
work sheet 6.4 Putting nuclear energy to use

6.4 THINKING TOOLS

Concept maps and plus, minus, interesting charts

1. On small pieces of paper, write down all the ideas you can think of about a particular topic.
2. Select the most important ideas and arrange them under your topic. Link these main ideas to your topic and write the relationship along the link.
3. Choose ideas related to your main ideas and arrange them in order of importance under your main ideas, adding links and relationships.
4. When you have placed all of your ideas, try to find links between the branches and write in the relationships.





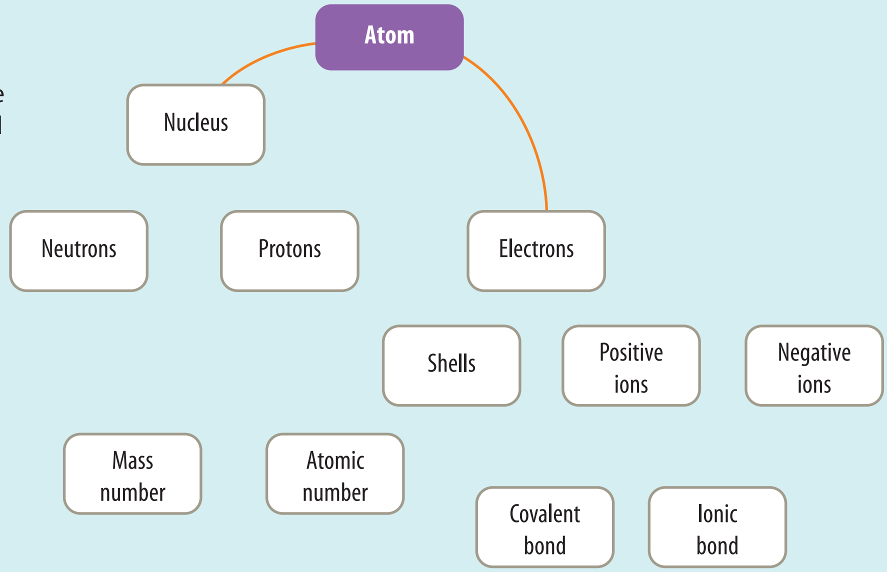
UNDERSTANDING AND INQUIRING

THINK AND CREATE

1 A concept map can be used to illustrate some of the important ideas associated with the atom and the links between the ideas.

(a) Copy the concept map on the right into your workbook and complete it by adding the links between the ideas.

(b) Construct your own concept map to show how ideas about what is inside substances are linked. Begin by working in a group to brainstorm the main ideas of the topic.



2 Construct a concept map of ideas associated with radioactivity.

3 Create a PMI chart on radioactivity, using the diagram below as a starting point.

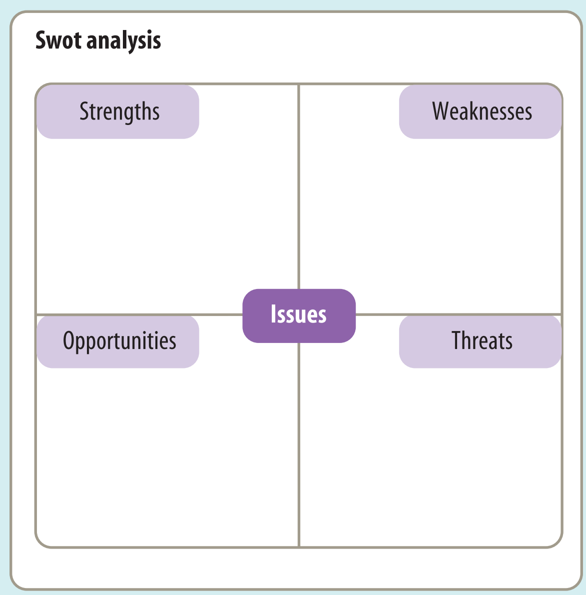
Radioactivity		
Plus	Minus	Interesting
• Can be used to treat cancer • • • • • •	• Radioactive isotopes can be used in nuclear weapons • • • •	• Radioactivity was discovered by accident • • • • •

Radioactive materials are classified as dangerous goods. The international symbol for radioactivity must be displayed wherever they are used.

4 A SWOT analysis, like a PMI chart, is a visual tool that helps you think about different viewpoints related to an issue or topic. Work in a small group to perform a SWOT analysis to represent the positive and negative aspects of one of the following issues.

(a) Nuclear power for Australia

(b) Exporting uranium to other countries



STUDY CHECKLIST

STRUCTURE OF THE ATOM

- describe the main features of the currently accepted model of the atom
- identify the nucleus, protons, neutrons and electrons in a simple illustration of an atom
- compare the mass and charge of protons, neutrons and electrons

RADIOACTIVITY

- associate different isotopes of elements with the number of neutrons in the nucleus
- explain why, in terms of the stability of the nucleus, some isotopes are radioactive while others are not
- represent isotopes correctly in both symbols and words
- describe the characteristics of alpha, beta and gamma radiation, including penetrating power
- identify the main sources of background radiation
- define the half-life of radioisotopes
- explain how the known half-life of some radioisotopes can be used to determine the age of rocks, fossils and ancient artifacts
- describe the use of nuclear fission reactions in nuclear reactors

SCIENCE AS A HUMAN ENDEAVOUR

- investigate the historical development of models of the structure of the atom
- investigate the contribution of scientists such as Henri Becquerel, Marie and Pierre Curie, and Lord Rutherford to development of the model of the structure of the atom and radioactivity
- describe the impact of the discovery of radioactivity and the subsequent development of nuclear technology on the course of history
- explain how radioisotopes are used in nuclear reactors, radiometric dating, the treatment of cancer, medical diagnosis and food preservation
- examine the risks associated with radioactivity

ICT

eBook*plus* Summary

eLESSONS

Nuclear medicine

Meet Dale Bailey who works with nuclear medicine. Watch this ABC *Catalyst* video about how lives are saved using this technology.

Searchlight ID: eles-1084

Smashing atoms in CERN

Watch an episode of *Catalyst* from ABC TV to find out more about the matter inside atoms.

Searchlight ID: eles-1085

INTERACTIVITY

Radioactivity half-life

In this interactivity, you can choose a radioactive element and the mass, and then watch the graph of its half life. Use the data to answer questions on the accompanying worksheet.

Searchlight ID: int-1652

INDIVIDUAL PATHWAYS

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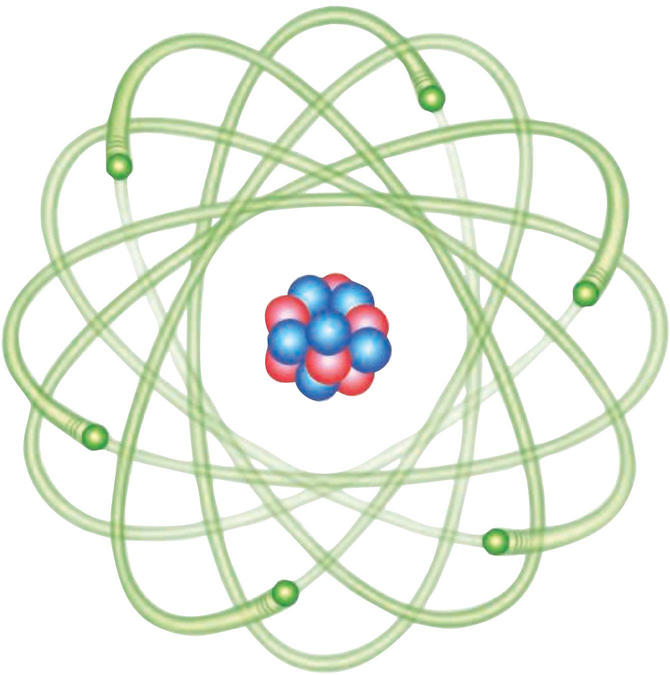
Activity 6.1	Activity 6.2	Activity 6.3
Revising the atom	Investigating the atom	Investigating the atom further

LOOKING BACK

1 The diagram below represents a model of a neutral atom.



(a) Which two types of particles make up the nucleus of the atom?
(b) Which particles are shown orbiting the nucleus in the atom?
(c) What features of atoms are not very well represented by this particular model?
(d) To which element does this atom belong?

2 Which of the particles in the neutral atom has:
(a) a negative electric charge
(b) a positive electric charge
(c) no electric charge
(d) the smallest mass?

3 Describe the contributions of the following scientists to our understanding of the structure of the atom.
(a) J. J. Thomson
(b) Lord Rutherford
(c) Niels Bohr

4 The hydrogen atom exists as three different isotopes.
(a) How are the atoms of each isotope different from the others?
(b) Identify two features of the hydrogen atom that are the same for each of the three isotopes.

5 Alpha particles are helium nuclei containing two protons and two neutrons.
(a) What is the electric charge of an alpha particle?
(b) How do the mass and size of an alpha particle compare with the mass and size of a beta particle?
(c) Suggest why alpha particles are easily stopped by human skin while beta particles are not.
(d) Which type of radiation from the nucleus is more penetrating than either alpha or beta particles?

6 Which type of nuclear radiation travels at the speed of light?

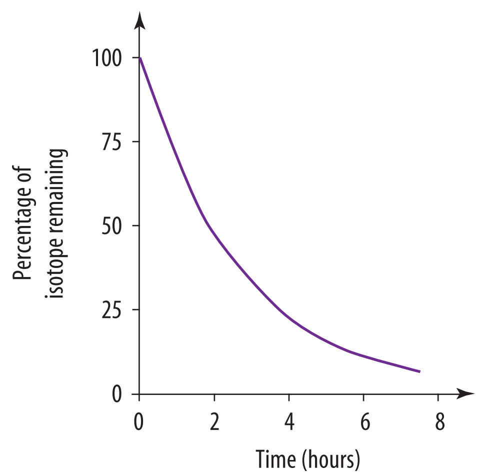
7 Where does most of the natural background radiation that we experience every day come from?

8 Radioisotopes have many uses.
(a) What property of radioisotopes makes them useful?
(b) Describe some of the beneficial uses of radioisotopes.
(c) Some radioisotopes are considered highly dangerous even after thousands of years. Why?

9 Two isotopes of the element carbon found naturally on Earth are carbon-12 and carbon-14.
(a) How is every atom of carbon-14 different from every atom of carbon-12?
(b) What features and properties do carbon-14 and carbon-12 have in common?
(c) Which of the two carbon isotopes is stable?

10 The half-life of strontium-90 is 28 years. If a 400 gram sample of strontium-90 was left to decay, how many grams of the sample would be left after:
(a) 28 years
(b) 56 years
(c) 84 years?

11 Estimate the half-life of the isotope whose decay is shown in the graph below.



12 Use the **Radioactive waste management** weblink in your eBookPLUS to investigate how and where waste is stored in Australia.

13 Explain how it is possible to use carbon-14 to estimate the age of the remains of a dead plant embedded in a rock.