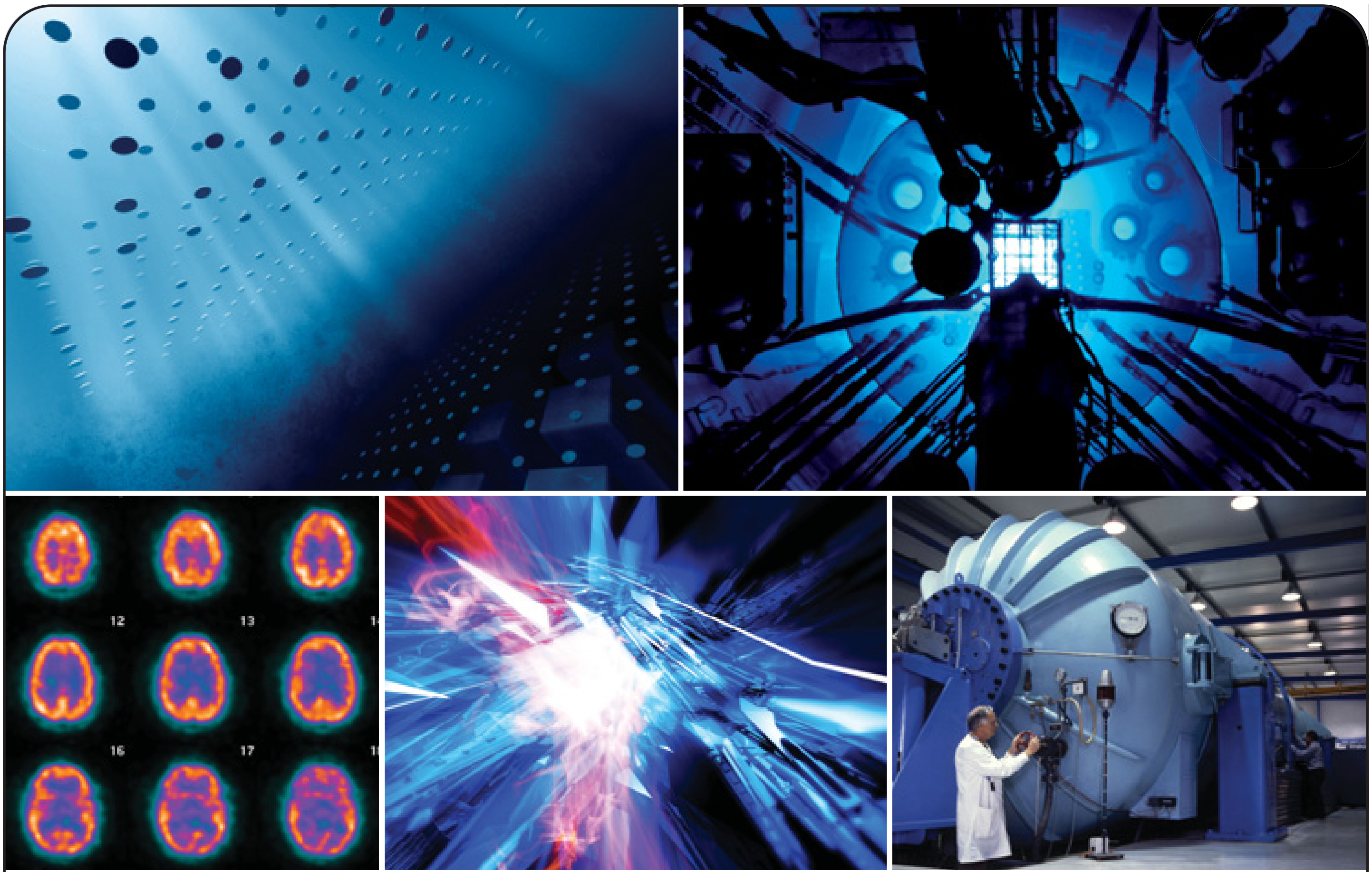


RADIATION: FROM THE INSIDE OUT

Science Lesson Plan for K-6 Teachers

Australian Government

ansto
Nuclear-based science benefiting all Australians

Contents

Unit Overview Radiation: From the Inside Out!

Lesson	Lesson Objective
Lesson 1 A Look at the Atom	To capture students interest and find out what they think they know about the atom.
Lesson 2 Atomic Detectives	To capture students interest and find out what they think they know about radioactivity.
Session 1 Energy from the Atom	
Session 2 Marie Curie Element Discoverer	
Lesson 3 Build an Unstable Nucleus	To provide hands-on, shared experiences of what makes an atom unstable.
Lesson 4 A Sweet Simulation of Half-Life	To provide hands-on, shared experiences of the halflife of an element.
Lesson 5 Energy Transformations	To support students to summarise, represent and explain their understanding of how nuclear energy can be harnessed.
Lesson 6 Modern Applications	To support students to summarise, represent and explain their understanding of the uses of radioactivity.
Lesson 7 The Dark Side of Nuclear Technology	To support students to understand the hazards of nuclear radiation.
Session 1 Nuclear Waste	
Session 2 Personal Radiation Dose	
Lesson 8 "Are Radioactive Isotopes too Dangerous to Use?"	To provide opportunities for students to reflect on their learning during this unit and prepare a debate that represents what they know about the benefits and problems associated with the use of radioactive isotopes.

Unit Description

This unit provides opportunity to identify and explore the different forms of radioactivity. These include alpha particles, beta particles and gamma radiation. Students will be able to explain how nuclear energy is transformed into heat, movement and electrical energy for people to use. The Sun is the primary source of energy for the Earth. Radioisotopes play a very significant role in our lives. Students will investigate both the benefits and the problems associated with the use of radioisotopes.

Outcomes and Indicators

Content Strands

A student:

Information and Communication (IC S3.2)

- selects websites and other reference material and checks their accuracy through identifying sources, currency of information, purpose and bias.

Physical Phenomena (PP S3.4)

- evaluates past models of the atom
- researches the different forms of radiation and applies findings to understanding the radioactive decay of specific isotopes
- develops and evaluates a model to represent an unstable atom
- demonstrates energy transfer between the Sun and the Earth
- identifies energy transformations that occur in a coal power station and in a nuclear reactor
- researches information on the uses and effects of radioisotopes in science, medicine and industry
- observes and predicts the hazards of nuclear radiation

Earth and its Surroundings (ES S3.6)

- researches information on the causes and effects of nuclear accidents
- devises an experiment to simulate the half-life of an element

Learning Processes

A student:

Investigating (INV S3.7)

- collects and records information on the factors that make an isotope radioactive
- devises an experiment to simulate the half-life of an element
- researches information on the uses and effects of radioisotopes in science, medicine and industry

Designing and Making (DM S3.8)

- works collaboratively to design and make a model to represent an unstable atom
- designs a presentation to support an argument about the safety or danger of the use of radioactive isotopes

Using Technology (UT S3.9)

- uses a digital or video camera to record students' findings
- uses email to communicate with ANSTO after researching about radioisotopes
- prepares arguments about the potential hazards of waste from a nuclear power station
- selects and uses a range of information sources to research the contribution of ANSTO to regional and global initiatives

Assessment

Listed below are selected examples of strategies that may be used in assessing this unit.

Diagnostic Assessment

Science and Technology workbook entries
'Observation record: Describing the atom' (Resource Sheet 1)

Formative Assessment

Science and Technology workbook entries
'Changing Energy' (Resource Sheet 5)

Summary

Email or letter sent to ANSTO

Summative Assessment

Science and Technology workbook entries
Students' comments during presentations
Class debate

Links with other Key Learning Areas

English	use vocabulary related to a particular topic
	engage in discussion to compare ideas and generate explanations
	demonstrate understanding
	record information in a table
	understand the purpose, structure and features of a factual recount
	develop skills in accessing factual information
	use oral, written and visual language to record and discuss investigation results
	use oral, written and visual language to research and summarise
	use oral and written language to write a brief report
	compare ideas and relate evidence from an investigation to explanations
	follow a procedural text to complete an investigation
	present a brief explanation or summary to peers
	compare explanations and engage in argument
	make contributions to a class summary
	represent ideas in a debate and present an argument to an audience
Mathematics	count and estimate
	calculate an average annual personal radiation dose
	draw a graph
HSIE	explain the significance of Marie Curie's discovery of radioactivity
	describe patterns of human involvement in environmental areas of Australia
	examine how natural factors can influence peoples interactions with the environment
	describe the effects of increasing greenhouse gases and climate change on the Earth
	demonstrate an understanding of the connectedness between Australia and global economies

	explain how beliefs and practices influence the ways in which people interact with, change and value their environment
	research how ANSTO disposes of nuclear waste
	clarify and reflect on various perspectives about environmental use, including negative aspects
	identify warning signs and appropriate survival techniques
	clarify and discuss the responsibility of all Australians towards the conservation of environments
	explain the effect of natural changes on the environment and how people respond to these changes
PDHPE	describe roles and responsibilities in developing and maintaining positive relationships

Suggested Excursion

An ANSTO excursion can be planned for during the Unit or as a final activity. The timing of the email or letter writing activity could be adjusted to allow the students the opportunity to also thank ANSTO for the site visit.

Primary school tours are of 2 to 21/2 hours duration. Tours are engaging, fun and free! For further information contact ANSTO on (02) 9717 3934, or enquiries@ansto.gov.au.

Links with *National Statements of Learning for Science*

Year 5 Professional Elaborations – Opportunities to Learn for Science

Year 5 Science as a human endeavour

Students have the opportunity to:

- describe how people in a wide range of occupations and cultures use science in their work and leisure.

Year 5 Science as a way to know

Students have the opportunity to:

- collect and record data, checking and repeating observations or measurements as appropriate
- present data in different ways including graphing, and reflecting on how useful these were.

Year 5 Science as a body of knowledge

Students have the opportunity to:

- investigate how some different forms of energy (eg *heat, sound, light, electricity*) are transferred and used in their community and research the sources of these forms of energy.
- investigate different types of changes materials can undergo.

Materials and equipment

Every lesson each student will need to use, or refer to, their Science and Technology workbook. The whole class will need to have access to the bulletin board, that will be progressively added to throughout the unit. The following table highlights the materials and equipment specific to each lesson in the unit.

Lesson	For the class	Each group
1	diagrams of past models of the atom (eg. Thomson, Rutherford and Bohr models) enlarged copy of 'Observation record: Describing the Atom' (Resource Sheet 1) DVD "ANSTO Stories: Isotopes" DVD player	small piece of fruit cake per student 'Observation record: Describing the Atom' (Resource Sheet 1) for each student
2	photograph or DVD of a nuclear bomb blast	'Marie Sklodowska Curie: Element Discoverer' (Resource Sheet 2) for each student
3	large, flat area (eg. the school hall) enlarged copy of 'What happens when an atom is too large?' (Resource Sheet 3) **optional:** digital camera to record students' findings	'What happens when an atom is too large?' (Resource Sheet 3) for each student wooden building blocks (eg. Jenga®) marble or small ball
4	enlarged copy of 'A Sweet Simulation of Half-Life' (Resource Sheet 4) roll of paper towel	'A Sweet Simulation of Half-Life' (Resource Sheet 4) for each student approximately 80 small pieces of candy marked on one side (eg. Skittles®), paper towel, paper cup
5	samples of crude oil and kerosene enlarged copy of 'Changing Energy' (Resource Sheet 5) diagram showing how a coal power station works, diagram showing how a nuclear reactor works	'Changing Energy' (Resource Sheet 5) for each student sheet of A3 paper
6	example of a bone X-ray overhead projector and screen DVD resources from ANSTO DVD player	selection of ANSTO pamphlets access to ANSTO website, www.ansto.gov.au
7	overhead transparency of 'The Nuclear Waste Cube' (Resource Sheet 6) overhead transparency of 'Personal Radiation Dose' (Resource Sheet 7) overhead projector and screen DVD showing testing of nuclear weapons after World War II DVD "ANSTO Stories: Waste" DVD player	'The Nuclear Waste Cube' (Resource Sheet 6) for each student paper scissors, glue 'Personal Radiation Dose' (Resource Sheet 7) for each student
8		resources identified by the group (eg. information communication technology equipment, paper or cardboard, etc.)

Resources from ANSTO include:

CD ROM: "Nuclear Science in Society"

Resource Kit: "A Nuclear Source"

DVD: "ANSTO Stories"

"OPAL Launch April 2007"

on ANSTO and nuclear science.

All are available on request.

Teaching strategies

1 *Cooperative learning*
2 *Reflecting*
3 *Evaluating resources*
4 *Student's negotiated learning*
6 *Fostering curiosity*
7 *Observing to explore and discover*
8 *Researching to explore and discover*
10 *Proposing explanations*
11 *Predicting outcomes*
12 *Clarifying an investigation*
13 *Trialling and testing ideas and concepts*
15 *Explaining understanding*
16 *Applying understanding*
19 *Exploring ideas*
20 *Representing ideas by modelling*
28 *Learning safety procedures*
32 *Audio-visual technologies*
41 *Computer graphics*

Lesson 1 A LOOK AT THE ATOM

To capture students interest and find out what they think they know about the atom.

Students

- describe the structure of the atom
- describe atoms in terms of mass number and atomic number.

Targeted Lesson Outcomes

Students will be able to

- represent what they think they know about the atom as a diagram [TS 6]
- identify an element from the atomic number [TS 1]
- describe atoms in terms of mass number and atomic number [TS 4].

Teacher background information

Elements are made up of very small particles called atoms. Each element has its own, unique type of atom. Atoms are the smallest particle of an element that can exist and still keep the element's chemical properties.

Scientists make models of what they think an atom looks like. As scientists learn new facts about atoms, they change the model. The model currently used is therefore likely to change as scientists continue with their research.

According to the **electron cloud model**, atoms are made of three smaller particles: **protons**, **neutrons**, and **electrons**. Protons, which are positively charged, and neutrons are located in the centre of the atom. This central core is called the **nucleus**. The nucleus is surrounded by a cloud of negatively charged electrons.

Atoms are mostly empty space. The protons and neutrons give an atom most of its mass. Yet these particles take up very little space in the atom. Only a tiny part of an atom's mass lies in the electron cloud. Yet the electron cloud makes up almost all of the atom's volume. Imagine the nucleus of a hydrogen atom as big as a marble. The edge of the electron cloud would be more than three football fields away!

Each element has a different number of protons, ranging from hydrogen, the simplest element, which has one proton, to uranium which is used as nuclear fuel , which has 92 protons. This is called the elements **atomic number**. The mass number is given by the total number of protons and neutrons. For example, carbon-14 has a mass number of 14. This means that it must have 6 protons, because it is carbon, and 8 neutrons. The carbon-14 isotope can also be represented as ${}^{14}_{6}C$.

Lesson steps

1. Give each student a small piece of fruit cake and explain to students that this is how Thomson described the atom in 1898. Show students the different diagrams of past models of the atom. Ask students if they have seen diagrams like them before. Ask them to share where they have seen them.
2. Lead a discussion to elicit students' prior knowledge about the atom and its structure, without providing any formal definitions or answers about the current model at this stage.

   Record students responses on cards or paper strips. Commence a bulletin board.
3. Draw students' attention to the similarities and differences between each successive model of the atom. Use questioning and discussion to support students in sharing their ideas about the need for changing the model, with questions such as:

   What similarities do you notice about each model?

   What differences do you notice about successive models?

   Why do you think the model had to be changed?

   NOTE: Avoid using the term 'electron cloud' during this phase because the following activity could be used for diagnostic assessment.

   Ask students to record their ideas in their Science and Technology workbook.
4. Explain that students will be summarising their findings in a table. Show an enlarged copy of the 'Observation record: Describing the atom' (Resource Sheet 1), and discuss the purpose and the features of a table to record information.
5. When students have completed their 'Observation record: Describing the atom' (Resource Sheet 1), discuss their findings. Focus attention on the differences between the Thomson model and the Rutherford and Bohr models.
6. Explain that each element has a unique number of protons. The number of protons is given a special name called the atomic number. Explain that for a neutral atom, the number of protons (positives) equals the number of electrons (negatives). Use the DVD"ANSTO Stories: Isotopes" to consolidate students' learning.
7. Draw students' attention to the unique combination of atomic number and mass number of any particular isotope. Give students practice in calculating the number of protons, neutrons and electrons given the mass number and atomic number of an isotope. Isotopes that could be used include carbon-12, carbon-14; oxygen-16, oxygen-18; chlorine-35, chlorine-37; as well as potassium-40 and iodine-131.
8. Ask students to suggest questions they can investigate about the current model of the atom. Record their questions in the students workbook. For example, students might ask:

   How small is the nucleus?

   How much empty space is in an atom?

   Are all atoms of each element the same?

Observation Record: Describing the Atom

Name:__________________________________ Date: ________________

Name of Model	Diagram of Model	What is the same?	What has changed?
Thomson Model			
Rutherford Model			
Bohr Model			
Current Model			

Resource Sheet 1

Lesson 2 ATOMIC DETECTIVES

To capture students interest and find out what they think they know about radioactivity.

Session 1 Energy from the Atom

Students

- distinguish between stable and radioactive isotopes
- share and discuss information about radioactivity.

Session 2 Marie Curie - Element Discoverer

Students

- read and discuss a factual recount about Marie Sklodowska Curie
- discuss the discovery of polonium and radium.

Targeted Lesson Outcomes

Students will be able to

- explain that there are different forms of radiation [TS 7]
- describe Marie Curie's contribution to the study of radioactivity [TS 15].

Teacher background information

There is a large amount of energy locked inside a tiny atom. The energy is stored in the nucleus and so is called nuclear energy. If the mass of all the particles formed by the decay of an unstable nucleus were added, the amount would be slightly less than the mass of the original nucleus. The missing mass was converted to energy. Every time a nucleus breaks apart a massive amount of energy is released according to Einstein's equation, $E = mc^2$. E is energy, m is mass (kg) and c is the speed of light (300 000 000 ms^{-1}).

Isotopes may be stable or radioactive. For example, carbon-12 is stable while carbon-14 is radioactive. When carbon-14 decays it forms a nucleus that is more stable than it was before. A radioactive element may go through several stages of decay before finally becoming a stable element. An example of such an isotope is uranium-238.

The main reasons why isotopes are radioactive is due to an imbalance in the number of neutrons to protons in the nucleus, or the nucleus is too large.

When the nucleus of a radioactive element breaks down it can emit different types of radioactivity. **Alpha particles** (α) are made up of two protons and two neutrons. This is the nucleus of a helium atom. They are fast moving but can be stopped by a sheet of paper and will not travel through air. **Beta particles** (β) are fast moving electrons. They are more difficult to stop than alpha particles, but can be stopped by a thin sheet of metal. **Gamma rays** (γ) are not particles; they are a form of electromagnetic radiation. A thick sheet of lead is needed to block gamma rays.

Alpha particles contain two protons and two neutrons. In writing nuclear reactions, an alpha particle is written as $^{4}_{2}He$. When an atom loses an alpha particle, the atomic number of the product atom is lower by two and its mass number is lower by four.

Beta particles are fast moving electrons formed by the decomposition of a neutron of an atom. In writing nuclear reactions, a beta particle is written as $^{0}_{-1}\mathbf{e}$. When an atom loses a beta particle, the atomic number increases by one and the mass number stays the same.

Session 1 Energy from the Atom

Lesson Steps

1. Review the previous lesson, referring to the bulletin board.
2. Show the students the photograph or DVD of a nuclear bomb blast. Ask them whether they have ever wondered where the energy came from.
3. Lead a discussion to explain to students the reasons why some atoms are stable and some are radioactive. Use questioning and discussion to support students in sharing their ideas about the reasons why some specific examples of isotopes are radioactive (for example carbon-14, potassium-40 and uranium-235).
4. Introduce the different types of radioactivity. Explain that students will be summarising their findings in a table in their Science and Technology workbook.
5. **Optional:** Introduce students to nuclear reactions by constructing some examples as a group activity. Discuss with students the steps that need to be considered. Give students practice in writing nuclear reactions given the parent radioisotope and the daughter nucleus (for example, ${}^{14}_{6}C \rightarrow {}^{14}_{7}N + {}^{0}_{-1}e$ and ${}^{235}_{92}U \rightarrow {}^{231}_{90}Th + {}^{4}_{2}He$)

Session 2 Marie Curie - Element Discoverer

Preparation

Read 'Marie Sklodowska Curie: Element Discoverer' (Resource Sheet 2) and decide how you will use it with your class. It may be used as an independent reading task or in guided reading groups.

Lesson Steps

1. Explain that the students are going to read a factual recount about a person who was the first woman to receive a Nobel Prize. Discuss the purpose and features of a factual recount.
2. Arrange for students to read 'Marie Sklodowska Curie: Element Discoverer' (Resource Sheet 2) individually or in guided reading groups.
3. After students have read the text, ask them to brainstorm the key points and record them in their Science and Technology workbook.
4. Ask students the name of the phenomena and the names of the elements that Marie Curie discovered. Write the words 'radioactivity', 'radium' and 'polonium' on the board , and ask students to identify parts of the words. For example, explain that polonium is named after Poland, where Marie Curie came from.
5. Ask students to recall facts about Marie Curie. Discuss what the word 'radioactivity' means and create a class definition for the word.
6. Explain to students that in this unit they are going to be learning about radioactivity and how it can be used to generate energy and isotopes that are used in industry and medicine.
7. Direct students' attention to the bulletin board and add any new vocabulary.
8. Ask students to reflect on what they have learned, including the information about radioactivity and Marie Curie.
9. Ask students to form into groups. Ask students to share with their group something new they learnt and something they found interesting so far in the unit. Ask students to write a short reflection in their Science and Technology workbook.

Marie Sklodowska Curie: Element Discoverer

Name:______________________________ Date: ________________

Marie Sklodowska Curie (1867 – 1934) was born in Warsaw on November 7, 1867. She had to overcome many obstacles before she was able to pursue the science that she loved.

Her parents were both teachers, so the family valued education. When Marie was eleven years old, however, her mother died which was a financial blow as well as a heartache.

Marie was born at a time when Poland was controlled by Russia. Girls were not taught Latin and Greek even though these languages were needed to apply to Russian universities. Marie knew she would have to study on her own and eventually leave her country to get a university degree.

She graduated from high school with a gold medal for excellence and for a time secretly went to an illegal university where subjects were taught in Polish, against Russian law.

Eventually she worked as a tutor for eight hours a day to earn money for university studies abroad. After work, she taught Polish children for five hours a day at an illegal school and then studied physics and mathematics late into the night.

When she finally reached Paris, Marie was self-taught in many subjects. Marie was a hard worker, and in 1893 graduated first in her class with a Master's degree in Physics. She was also the only woman in her class. The next year she returned on a scholarship and earned a Master's degree in Mathematics. She also met Pierre Curie, a gifted and talented scientist. They were married on July 26, 1895, and began to support each other in their work.

At this time, Henri Becquerel discovered that uranium gave out radiation in the form of invisible particles. Marie and Pierre investigated Becquerel's rays by separating uranium from pitchblende. Marie realised that there was something else in the pitchblende giving off even stronger radiation than uranium. She invented the word 'radioactive' to describe materials that behaved like this.

In 1898 Marie and her husband Pierre, discovered two new elements, which she called radium and polonium. In 1903 Marie and Pierre Curie shared the Nobel Prize in Physics with Henri Becquerel.

Find out more at this website:

http://en.wikipedia.org/wiki/Marie_Curie

Resource Sheet 2

Lesson 3 BUILD AN UNSTABLE NUCLEUS

To provide hands-on, shared experiences of what makes an atom unstable.

Students

- review what they know about the stability of an isotope of an element
- work in groups to model the behaviour of stable and unstable atoms.

Targeted Lesson Outcomes

Students will be able to

- follow directions to investigate how being too large can make an atom unstable [TS 13]
- observe, record and interpret the results of their investigation [TS 7]
- identify the features that made their investigation a fair test [TS 12]
- design and make a model to represent an unstable atom [TS 20].

Teacher background information

Ernest Rutherford (1871 - 1937), a famous scientist from New Zealand, was given a large supply of expensive radium. He discovered that something very strange and miraculous happened to the radium. He proved that the radium changed into a new element!

Rutherford explained his discovery by stating that the radiation was bits of the radium atom being thrown out from the nucleus. Most scientists thought his ideas were preposterous. Rutherford's ideas were not popular, but he was right!

Today, **isotopes** are classified as stable isotopes and others are classified as **unstable**, or **radioactive**, isotopes. Stable isotopes maintain constant concentration on Earth over time. Unstable isotopes are atoms that disintegrate at predictable and measurable rates to make a new atom of a different element by the emission of either a nuclear electron (**beta** particle) or a helium nucleus (**alpha** particle) and **radiation**.

These isotopes continue to decay until they reach stability. As a rule, the heavier an isotope is than the most common isotope of a particular element, the more unstable it is and the faster it will decay. All the isotopes beyond bismuth (atomic number 83) are unstable.

Some of the unstable isotopes are only moderately unstable and can therefore persist in nature today. The isotope uranium-238 is a good example. It is radioactive but it's **half-life** is 4.43 billion years.

Preparation

Clear the tables in the classroom, or book the school hall, to allow for adequate space for each group.

Lesson steps

1. Review Lessons 1 and 2, and invite students to make further contributions to the bulletin board.
2. Review students' understanding of the current model of the atom and the types of radioactivity. Ask students to read their ideas written in their Science and Technology workbook.
3. Explain that students will undertake an investigation to discover what happens when an atom is too large. Read through an enlarged copy of 'What happens when an atom is too large?' (Resource Sheet 3). Discuss the purpose and features of procedural texts.
4. Introduce the idea of a fair test and the need for a control. Draw students' attention to the fact that they are using the *same* size wooden blocks, the *same* marble or small ball and the ball rolled at the same speed. Discuss why this is important to ensure a fair test.
5. Form groups and allocate roles. Ask one group member to collect the equipment.
6. After groups have set up their investigations, set a timer for 20 minutes. The students should write their predictions in their Science and Technology workbook, and then perform their investigation.
7. After 20 minutes, ask students to record their observations and discuss their findings with the rest of the class.
8. Provide time for students to design and make a better model to represent an unstable atom in their groups. Students should have access to a variety of everyday materials to build the model. Each group should demonstrate their model and other groups can evaluate their design.
9. Update the bulletin board.

What happens when an atom is too large?

Name:______________________________________ Date: ___________________

Aim

To demonstrate how being too large can make an atom unstable using wooden blocks.

Equipment

- Science and Technology workbook
- a marble or small ball
- wooden blocks (eg. Jenga®)

Activity Steps

1 Pile a few blocks up into a tower.

2 Roll the marble gently at the tower.

3 Add a few more wooden blocks to the tower and roll the marble at the same speed at the tower.

4 Repeat step 3 until you have built the highest tower that you can, or until the tower collapses, whichever comes first.

5 Repeat the investigation at least two more times.

6 Record your observations.

Questions to answer

1 When the tower was short, did the marble knock it over?

2 As the tower got taller and taller, what happened to the stability of the tower?

3 Did the tower get high enough for it to start collapsing by itself?

Resource Sheet 3

Lesson 4 A SWEET SIMULATION OF HALF-LIFE

To provide hands-on, shared experiences of the half-life of an element.

Students

- review what they think they know about the half-life of an element
- read and discuss a procedural text
- record and discuss observations in groups.

Targeted Lesson Outcomes

Students will be able to

- plan an investigation, with teacher support, that simulates the half-life of an element [TS 8]
- predict, observe, record and interpret the results of their investigation [TS 10]
- understand that the half-life of an unstable isotope can be measured [TS 15]
- identify the features that made their investigation a fair test [TS 2].

Teacher background information

> Everytime a living being dies a stopwatch starts ticking.
> Death starts the stopwatch. Science can read it.
>
> *Source Unknown*

The rate of **radioactive decay** is described by the term **half-life**. Half-life refers to the time required for half of the nuclei in a sample of a radioactive isotope to decay. The half-life of carbon-14 is 5 730 years. This means that a 10g sample of carbon-14 will become a 5g sample in 5 730 years. After a further 5 730 years there will be 2.5g of carbon-14, and so on.

Because the rates of radioactive decay are measurable, unstable isotopes are useful tools in determining age. Through this technique, carbon-14 is used to date the remains of once living things. This process is called **carbon dating**.

Preparation

Clear the tables in the classroom, or book the school hall, to allow for adequate space for each group.

Count out approximately 80 small pieces of candy for each group of students. This can be done quickly by measuring the mass of 80 candies and then weighing this same mass for each group.

Lesson steps

1. Review Lesson 3. Remind students' why some isotopes are unstable. Ask students to reflect on what they think is emitted during radioactive decay. Focus students' attention on how many nuclei they think would be left after one half-life, after the second half-life, and so on. Record their understandings in their Science and Technology workbook.
2. Discuss students' suggestions for an investigation to determine the time it takes for unstable nuclei to decay. Encourage students to think about a simulation with a large number of 'particles' that represent the nucleus of an unstable isotope. Discuss how they will make this a fair test (by changing one variable and keeping all other variables the same).
3. Read through an enlarged copy of 'A Sweet Simulation of Half-Life' (Resource Sheet 4), and review the purpose and features of procedural texts.
4. Form groups and allocate roles. Ask one group member to collect equipment.
5. Ask groups to follow the procedure outlined in 'A Sweet Simulation of Half-Life' (Resource Sheet 4).
6. Combine the class data in a table which the students should copy from the board. Using this data draw a graph by plotting the number of radioactive nuclei on the vertical axis and the number of tosses (half-lives) on the horizontal axis.

   Optional: This could be done using a spreadsheet program.
7. Discuss students' initial predictions and observations as well as their answers to the questions from 'A Sweet Simulation of Half-Life' (Resource Sheet 4).
8. Update the bulletin board.

A Sweet Simulation of Half-Life

Name:____ Date: _________________

Aim

To investigate and measure the half-life of a 'radioactive isotope'.

Equipment

- Science and Technology workbook
- approximately 80 small pieces of candy marked on one side (for example, Skittles®)
- paper towel
- 1 paper cup

Activity Steps

1 Count the nuclei that you have been given. Record the number in the data table under the heading Number of Radioactive Nuclei. In the column marked Prediction for Next Toss write the number of nuclei you think will be left after the first toss (half-life). The nuclei that have not decayed are the candies with the marked side up.

2 Place all the nuclei into the paper cup; cover and shake the cup. Pour the nuclei onto the paper towel. Separate the nuclei into two piles, one with the marked side up and the other with the marked side down. Under the heading Number of Radioactive Nuclei record the number of candies with the marked side up. Discard the nuclei that have decayed already, with the marked side down, the best way you can think of!

3 Return only the radioactive nuclei (candies with the marked side up) to the paper cup.

4 Repeat this process until there are no radioactive nuclei left, filling in the columns of the following table as you go.

Toss (Half-Life)	Number of Radioactive Nuclei	Prediction for Next Toss
0		
1		
2		
3		
4		
5		
6		
7		
8		

Combine the class data by adding the number of radioactive nuclei of all the class groups together for each toss in a different table.

Toss (Half-Life)	Number of Radioactive Nuclei
Before the first toss	
1	
2	
3	
4	
5	
6	
7	
8	

6 Using the combined data prepare a graph by plotting the number of radioactive nuclei on the vertical axis and the number of tosses (half-lives) on the horizontal axis.

Questions to answer

1 How good is the assumption that half the radioactive nuclei decay in each half-life? Why did we combine the class data?

2 If you started with 200 radioactive nuclei, how many would remain undecayed after three half-lives?

3 Can you predict when a particular piece of candy will decay? What does this imply in terms of radioactive nuclei?

4 What is meant by the term 'half-life'?

5 **Optional:** What determines how long an isotopes half life is?

Resource Sheet 4

adapted from http://www.sciencenetlinks.com/lessons.cfm?BenchmarkID=4&DocID=178

Lesson 5 ENERGY TRANSFORMATIONS

To support students to summarise, represent and explain their understanding of how nuclear energy can be harnessed.

Students

- distinguish between chemical and nuclear energy
- compare the relative amount of each type of energy from the same quantity of fuel
- work in groups to generate a flow chart that represents the energy relationship between the Sun and the Earth
- discuss the need for alternative energy sources in the future.

Targeted Lesson Outcomes

Students will be able to

- distinguish between chemical and nuclear energy [TS 1]
- understand the energy relationship between the Sun and the Earth [TS 15]
- use a flow diagram to show the steps in energy pathways from the Sun to the Earth [TS 4]
- demonstrate energy transfer [TS 19]
- describe the changes in energy in a coal power station and in a nuclear reactor [TS 16].

Teacher background information

All living things need energy to live and grow. Most machines are powered by **chemical energy** that comes from burning coal, oil or natural gas. Coal, oil and gas are known as **fossil fuels**.

Burning fossil fuels causes air pollution. This is harmful to people and damages the environment. The excessive burning of fossil fuels is thought to be the major cause of the Greenhouse Effect—the increased temperature of the Earth's atmosphere due to more heat being absorbed in the troposphere.

Scientists have predicted that fossil fuels will run out soon. This depends on whether or not new sources of energy are found, and how carefully we conserve what is left, particularly in the production of plastics from petrochemicals. We cannot rely on fossil fuels as a source of energy. Alternate sources of safe, clean, **renewable** energy to power the machines we depend on are required.

Energy from the Sun is called **solar energy**. Plants use solar energy to convert carbon dioxide and water into food and oxygen. This is called **photosynthesis**. Animals and people get their energy from food which plants have made. The Sun's energy is passed along the food chain giving energy to all living things.

When a nucleus of uranium-235 is hit be a slow moving neutron, the nucleus can absorb the neutron and become so unstable that it splits apart. More neutrons are released along with a burst of energy. This is called **nuclear fission**. When the neutrons from one nucleus collide and split the nuclei of atoms nearby, it is the beginning of a **chain reaction.**

Energy stored inside the nucleus of atoms is called **nuclear energy**. Nuclear energy is the most powerful source of energy there is. 1 kg of uranium produces the same amount of energy as 25 tonnes of coal or 100 barrels of oil.

Nuclear energy is a **non-renewable** source of energy, but large amounts of energy can be extracted from very small amounts of fuel. Nuclear energy does not cause pollution and is more efficient than fossil fuels. However, it does have other problems to do with safety.

Lesson steps

1. Review the previous lessons.
2. Obtain a sample of crude oil from a petroleum company. Compare this sample to kerosene, a refined product of petroleum. **Safety:** Keep the oil and kerosene in closed jars. Both crude oil and kerosene are flammable; keep them away from anything that might ignite them.
3. Discuss which energy resource is used to heat the students' homes. If electricity is the answer, probe for the resource used to produce the electricity, such as coal, oil, natural gas, or hydroelectric.
4. Explain that coal, oil, natural gas and wood are chemical forms of energy. Ask students if they know of any other forms of energy that supply us with electricity. With teacher support, students should list solar, tidal, wind and geothermal which are renewable, and nuclear which is non-renewable.
5. Form groups, allocate roles, and ask students to research the differences between chemical energy and nuclear energy. They should construct a table, in their science and technology workbooks, in which they consider the benefits and problems of both types of energy.
6. Invite students to share their findings with the rest of the class. Point out to students that energy is one of the fundamental concepts of science. Describe how energy can affect matter by making it move, change state, change shape and so on.
7. Review with the class the following suggested Energy Pathways. Ask students to think of some ways in which solar energy is 'captured' naturally on Earth.

   Energy Pathways

   Sun → Grass → Cattle → Steak Dinner → Athlete

   Sun → Ancient Sea Life → Oil Deposit → Refinery Plant → School Bus

   Sun → Earth heated → Winds → Wind Generator → Light Bulb
8. Read through the enlarged copy of 'Changing Energy' (Resource Sheet 5). Ask students to complete the activity to show their understanding of the dependence of the Earth on the Sun.
9. Divide the class in half, with each half having an equal number of groups. One half of the class is to research the energy pathway for a coal power station. The other half of the class is to research the energy pathway in a nuclear power station. Display the diagrams of the coal power station and the nuclear reactor to give students some ideas.
10. Discuss the purpose and features of a summary.
11. Provide time for students to develop a summary of their findings in their Science and Technology workbook and on a sheet of A3 paper.
12. When students have completed their written summaries, bring the class together. Invite students to share their summaries while displaying the sheet of A3 paper for support.

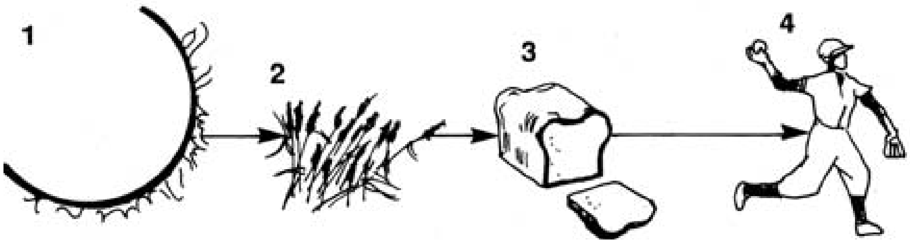
    Encourage other students to agree or disagree with the contributions.
13. Reform groups and ask students to share with their group something new they have learnt and something they found interesting. Ask students to consider how our lives would be different if we did not know how to produce energy in power stations. Ask students to record a short reflection in their Science and Technology workbook.
14. Bring the class together again. Share reflections about the unit so far.

Changing Energy

Name:____ Date: ______________

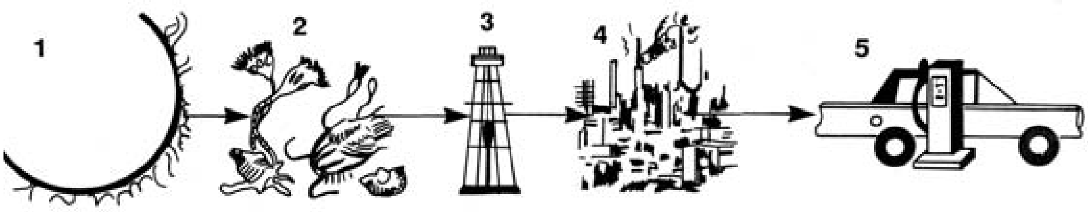
Look at the energy pathways below. They show how the energy for throwing a ball or moving a car can be traced back to the Sun. Write a caption for each numbered step. The captions should describe how energy flows in each drawing.

Energy for Throwing a Ball



1. ____
2. ____
3. ____
4. ____

Energy to Move a Car



1. ____
2. ____
3. ____
4. ____
5. ____

Resource Sheet 5

Lesson 6 MODERN APPLICATIONS

To support students to summarise, represent and explain their understanding of the uses of radioactivity.

Students

- review what they know about radioactive decay products
- describe how commercial radioisotopes are produced
- work in groups to investigate ways in which radioisotopes from ANSTO are used either in science, medicine or industry
- share their understandings and discuss the importance of ANSTO.

Targeted Lesson Outcomes

Students will be able to

- describe how commercial radioisotopes are produced [TS 6]
- explain how radioisotopes are used in science, medicine and industry [TS 8]
- explain the importance of ANSTO to Australia and other countries in the Asia-Pacific region [TS 3].

Teacher background information

Nuclear energy does invaluable work. There are many ways that nuclear energy can help us in our everyday lives — even save lives!

There are two different types of radioactive isotopes. **Neutron-rich** radioisotopes (more neutrons than protons) are produced in a nuclear reactor, such as **OPAL** at ANSTO. **Neutron-poor** radioisotopes (more protons than neutrons) are made in a cyclotron, such as the **National Medical Cyclotron** at the Royal Prince Alfred Hospital.

Radiation in Science

Scientists can label important molecules, called **tracers**, that pass through living things to allow them to understand the steps that occur in important processes, such as **photosynthesis**. They can also study paths that different types of air and water **pollution** take through the environment.

Radiation is used to measure the age of ancient objects by a process called **carbon dating**.

Carbon is found in all living things, and a small percentage of this carbon is **carbon-14**. When a plant or animal dies, it no longer takes in new carbon and the carbon-14 continues the process of radioactive decay. After many years the percentage of radioactivity in the old object is less than when the object was living.

Radiation in Medicine

Doctors administer slightly radioactive substances to patients which are attracted to certain internal organs such as the pancreas, kidney, thyroid, liver, or brain. A computer can change a **non-invasive** scan of the targeted organ or system into pictures on a computer screen or film.

This can be used by the doctor to **diagnose** what is wrong with the patient.

Radiation is also used for the **treatment** of serious illnesses, such as **cancer**. Treating patients with radiation is called **radiotherapy**. A beam of radiation can pass through the skin and kill harmful cancer cells without the patient having an operation.

Five hundred thousand patients are treated annually by **radiopharmaceuticals** made at ANSTO.

An example of a radioisotope made by ANSTO is technetium-99m which emits gamma radiation.

Radiation in Industry

Medical equipment such as bandages, syringes and surgical instruments can be placed in sealed bags and **sterilised** by radiation. Since the radiation passes through the bags, they can remain sealed until the contents are needed.

Engineers use radioisotopes to **gauge** the **thickness** of materials and to find **defects** in many types of metals and machines which would be difficult to detect otherwise. They can be used to check the flow of liquids in machinery and the way various materials wear out.

An example is americium-241 which is used inside smoke **detectors**.

ANSTO's Major Scientific Facilities, Instruments and Technologies

OPAL, which stands for Open Pool Australian Light-water reactor, is a small, but very sophisticated nuclear reactor. It is not a nuclear power plant, so it does not produce electricity.

Instead OPAL is helping Australia maintain its advanced position at the frontiers of international scientific research. It provides greatly increased capacity for irradiation of radioisotopes for nuclear medicine and industry, and the performance of its neutron beam instruments for scientific research will rank it as one of the top three research reactors in the world.

The **National Medical Cyclotron**, an accelerator facility adjacent to the Royal Prince Alfred Hospital, produces radiopharmaceuticals used to diagnose heart conditions, neurodegenerative and thyroid diseases, and cancer. A cyclotron is an electrically powered machine that accelerates charged particles to high speeds and beams them at a suitable target, producing a nuclear reaction that creates a radioisotope.

ANTARES, the Australian National Tandem Accelerator for Applied Research, and **STAR**, the Small Tandem for Applied Research, are particle accelerators. They provide ultra-sensitive radioisotope analysis for environmental studies, atmospheric research, oceanography, archaeology, bio-medicine and nuclear safeguards. They are also used to develop new materials technology and understand the characteristics of materials.

Preparation

It would be beneficial if students could look at the ANSTO website, www.ansto.gov.au, *before* this lesson to maximise interest and involvement. If students print out any information, ask them to bring it to the lesson.

Lesson steps

1. Review the previous lessons.
2. Discuss with students that a wide variety of uses have been found for radioisotopes since radiation was first discovered. Show them the bone x-ray using an overhead projector.

   Discuss with students how the x-ray helped the doctor treat the patient.
3. Ask students if any of them have, or know someone who has, taken a medical radioisotope. Explain that the radioisotope would probably have come from ANSTO.

   Show students a variety of pamphlets from ANSTO by passing them around the class.
4. Explain that radioisotopes can be either neutron-rich and made in a nuclear reactor, or neutron-poor and made in a cyclotron. Discuss ANSTO's major scientific facilities, instruments and technologies.
5. Form groups and allocate roles. Ask one group member to collect the ANSTO pamphlets. Tell students that they are going to use pamphlets from ANSTO and the ANSTO website www.ansto.gov.au to research and summarise information about radioisotopes produced by ANSTO and what they are used for.
6. Provide time for students to record their findings in their Science and Technology workbook.
7. Bring the class together. After writing the headings Science, Medicine and Industry on the board ask students to contribute radioisotopes and what they are used for under each heading. Make sure each group contributes at least two radioisotopes.
8. Reform groups. Ask students to make a general list of the ways that radioisotopes are used. Ask students to record a short reflection in their Science and Technology workbook.
9. Bring the class together. Ask students to go home and ask their families whether they have heard of ANSTO.
10. **Optional:** Provide time for students to send an email to Silvia from Education and Tours at silvia.kostas@ansto.gov.au, or write a letter to ANSTO, c/- Silvia Kostas, PMB 1 Menai NSW 2234 to share what they have learnt about the role of ANSTO and the importance of the work that the scientists are doing at ANSTO. The students can be prompted with questions such as "One thing we have learned about was ...", and "It was interesting to hear about ...".

Lesson 7 THE DARK SIDE OF NUCLEAR TECHNOLOGY

To support students to understand the hazards of nuclear radiation.

Session 1 Nuclear Waste

Students

- construct a cube that represents the amount of nuclear waste for one person
- discuss the methods used to dispose of the waste from a nuclear reactor
- describe the common sources of nuclear waste
- explain why the waste must be treated carefully.

Session 2 Personal Radiation Dose

Students

- describe the most common sources of radiation
- calculate and record their total annual radiation dose
- discuss the effects of a large radiation dosage.

Targeted Lesson Outcomes

Students will be able to

- describe the handling and disposal of radioactive waste generated by nuclear reactors [TS 10]
- distinguish between high- and low-level radioactive waste [TS 28]
- describe the sources of background radiation [TS 1]
- calculate and record their total annual radiation dose [TS 11].

Teacher Background Information

High doses of radiation destroy life. All biological damage effects begin when radiation interacts with atoms forming the cells in the human body. Radiation causes **ionisation** of atoms that will affect molecules that may affect **cells** that may affect **tissues** that may affect **organs** that may affect the whole body. Low doses of radiation cause people to feel **nauseous**. Higher doses cause ulcers and burns on the skin, and damage the bone marrow where red blood cells are made.

Breathing in radiation damages the lungs. Over a number of years, nuclear radiation can cause **cancers**. It can even harm children who have not yet been born.

The first use of nuclear energy was the **atomic bomb** dropped on Hiroshima in August, 1945.

The radiation that was spread over this city, as well as the bomb dropped on Nagasaki, continues to affect people even today. Nuclear **leaks** and dumped **waste** from past decades continue to affect us today and will also affect future generations. Other sources of radiation include cosmic radiation, the earth, the materials in our home, the food we eat, aeroplane travel and, the most significant, medical procedures. Radiation workers are exposed according to their occupations and to the sources with which they work.

Nuclear power stations produce enough **waste** to fill a truck each year and the waste is dangerously radioactive for thousands of years. The air inside nuclear reactors is constantly monitored so that any leaks are detected immediately.

Nuclear waste, from any source, is divided into three groups depending on how radioactive it is.

Low-level waste, the least radioactive, includes workers' clothing, air filters and old equipment.

Intermediate-level waste includes used fuel cans and chemicals from waste-treatment processes.
High-level waste is the most dangerous and usually comes from spent fuel.

Each type of radioactive waste is handled and stored differently. Most low and intermediate-level waste is sealed in containers and stored above ground at special sites. High-level waste is often set in bricks before being buried deep underground. ANSTO has developed **SYNROC** (synthetic rock) that binds the nuclear waste inside artificial rock. Currently, nuclear waste burial sites are all on land.

Session 1 Nuclear Waste

Lesson steps

1. Review the previous lessons. Ask students what their families had been able to tell them about ANSTO.
2. Ask students 'What is waste?' Provide time for students to discuss and write a definition of waste, and to estimate the volume of waste that their families generate every week.

   Ask them to imagine how much rubbish results from one visit to a fast food restaurant, such as McDonalds®.
3. Discuss that all industries produce garbage. The volume of waste generated every week by one city is enormous. Ask students why they have recycle bins at home.
4. Explain that the problem with nuclear power plants and research reactors, like OPAL, is not the *amount* of waste they make, which is small in comparison. The problem is that the waste is dangerously *radioactive*. Ask students to think about and list other producers of radioactive waste. All producers of radioactive waste must take care in the disposal of these materials to protect workers, the public and the environment. Provide students with prompts such as:

   Would a small leak of radioactive waste from ANSTO be detected?

   How would immediate detection of even a very small leak of radioactive waste differ from leak detection of other types of toxic industrial wastes?

   Why are there special sites for disposal of waste in Australia?

   Why is there a controversy over the selection of a high-level nuclear waste disposal site in Australia?

   Are special containers built to protect the radioactive contents or keep the contents from getting in contact with the environment? What are they made of and how are they tested?
5. Form groups and allocate roles. Ask one group member to collect equipment. Show students the overhead transparency of 'The Nuclear Waste Cube' (Resource Sheet 6).

   Explain this is the size of one person's share of high-level waste from nuclear power plants for a period of 20 years. This is the amount left over after all stable materials have been recycled.
6. Provide time for students to assemble 'The Nuclear Waste Cube' (Resource Sheet 6).

   Some students may also have the time to decorate their cube.
7. Ask students to research how low-, intermediate- and high-level radioactive waste are disposed of at ANSTO. Students could be shown the DVD "ANSTO Stories: Waste".
8. Bring the class together. Discuss their findings and update the bulletin board.

Session 2 Personal Radiation Dose

Lesson steps

1. Review the different levels of nuclear waste.
2. Show students the DVD depicting the testing of nuclear weapons that occurred after World War II. Ask students to consider if the scientists understood the impact of what they were doing on the Earth. Explain that the effects of these tests are still being monitored today.
3. Ask students if they have heard of any major accidents that have occurred in nuclear power reactors. Some may have heard of Chernobyl in Russia (1986) and Three-Mile Island in the USA (1979).
4. Form groups and allocate roles. Ask one group member to collect the ‘Personal Radiation Dose’ (Resource Sheet 7). Show students the overhead transparency of ‘Personal Radiation Dose’ (Resource Sheet 7). Go through the list of materials that contribute to the radiation dose that we all experience.
5. Provide time for students to fill in the activity sheet and to discuss their own personal radiation dose quantities with the other students in their group.
6. Bring the class together. Update the bulletin board. Share reflections about the unit so far and record in the Science and Technology workbook.

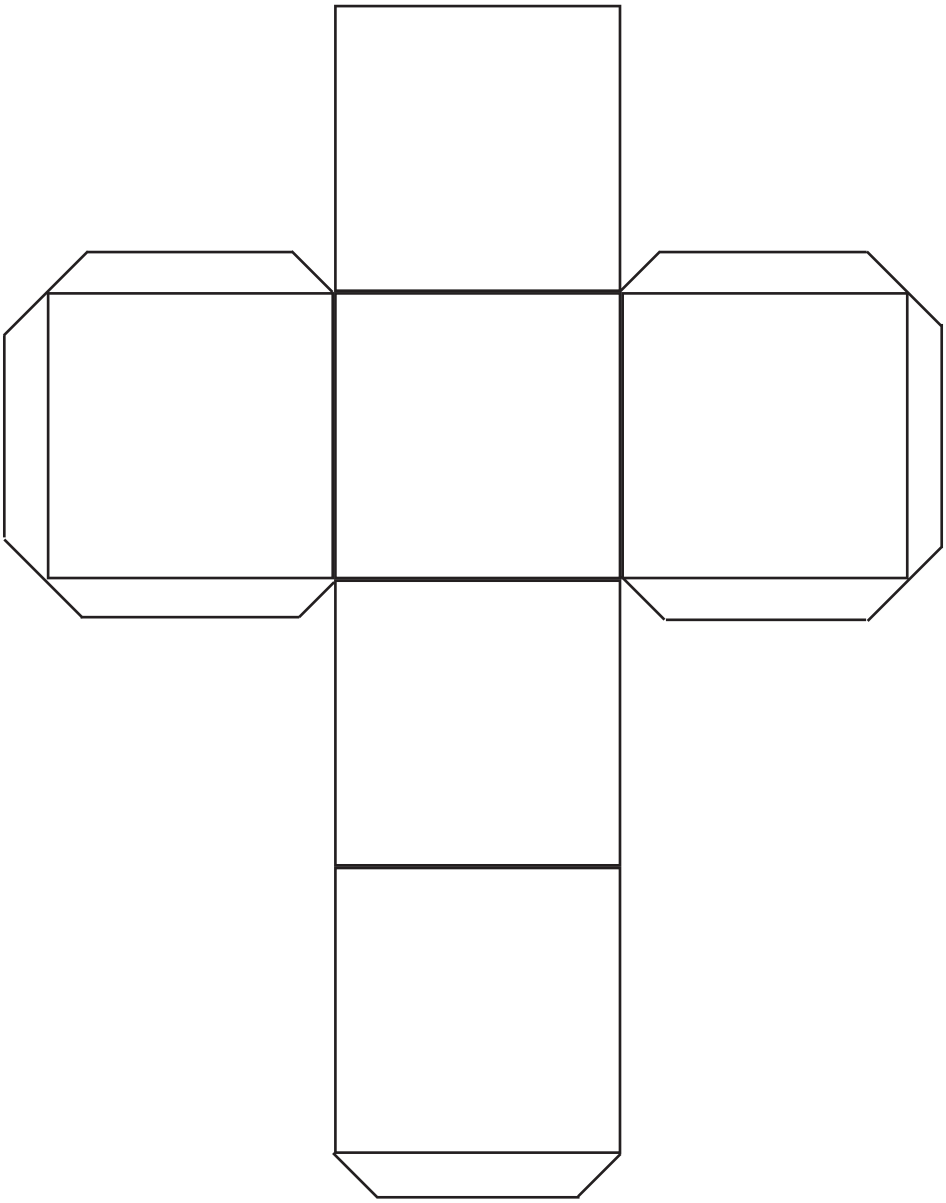
The Nuclear Waste Cube

Name:____ Date: ______________

This cube is the size of one person's share of high-level radioactive waste from nuclear power plants for a period of 20 years. This is the amount of waste left over after all stable materials have been recycled.

Directions:

Using the diagram as a guide, cut out and fold the pattern to make a cube.



Resource Sheet 6

adapted from http://www.nrc.gov/reading-rm/basic-ref/teachers/waste-cube.html

Personal Radiation Dose

Name:______________________________ Date: ______________

(microsieverts) **μSv**

Where you live

1. Cosmic radiation at sea level (from outer space) **270**
2. Select the number of microsieverts for your elevation (in metres)

   up to 300 m = **20** 300-600 m = **50**

   600-900 m = **90** 900-1200 m = **90**

   1200-1500 m = **210** 1500-1800 m = **290**

   1800-2100 m = **400**

   Elevation of some Australian cities (in metres): Sydney, 40; Lucas Heights, 140; Melbourne, 113; Canberra, 578; Tidbinbilla, 700; Thredbo, 1957; Brisbane, 4; Toowoomba, 641; Perth, 25; Adelaide, 48; Mt Lofty, 730; Hobart, 51; Mt Wellington, 1261; Darwin, 30.

   add this number . . . . ______
3. Terrestrial (from the ground) **280**
4. House construction

   If you live in a stone, brick, or concrete building, add 70 . . . . ______

What you eat and drink

5. Internal radiation (in your body)

   From food and water **400**

   From air (radon) **2000**

Other sources

6. Weapons test fallout (less than **10**) **10**
7. Jet plane travel

   For each 1500 kilometres you travel, add **10** . . . . ______
8. If you have porcelain crowns or false teeth, add **1** . . . . ______
9. If you use gas lantern mantles when camping, add **1** . . . . ______
10. If you wear a luminous wristwatch (LCD), add **1** . . . . ______
11. If you use luggage inspection at airports (using typical X-ray machine), add **1** . . . . . . ______
12. If you watch colour television, add **10** . . . . ______
13. If you use a video display terminal, add **10** . . . . ______
14. If you have a smoke detector, add **1** . . . . ______
15. If you have had medical procedures, add **530** . . . . ______
16. If you live within 50 kilometres of the ANSTO research reactor add **1** . . . . ______
17. If you live within 50 kilometres of a coal-fired electrical power plant, add **1** . . . . ______

My total annual radiation dose = **μSv** ______

Resource Sheet 7

Lesson 8

"ARE RADIOACTIVE ISOTOPES TOO DANGEROUS TO USE?"

To provide opportunities for students to reflect on their learning during this unit and prepare a debate that represents what they know about the benefits and problems associated with the use of radioactive isotopes.

Students

- work in groups to prepare an argument on the safety or danger of radioactive isotopes in their lives
- make presentations to an audience.

Key Lesson Outcomes

Students will be able to

- summarise, represent and explain their understanding of how nuclear energy can be harnessed [TS 10]
- summarise, represent and explain their understanding of the benefits of radioactivity [TS 2]
- explain the hazards of nuclear waste [TS 15]
- prepare a debate that represents what they know about the benefits and problems associated with the use of radioactive isotopes [TS 16].

Lesson steps

1. Explain that students are going to work in two main groups to develop presentations that will be part of a debate. The question students are debating is 'Are Radioactive Isotopes too Dangerous to Use?'
2. Assign one group the position of advocating the use of radioisotopes. Have the other group advocate prohibiting the use of radioactive isotopes. Within each group, smaller teams will be asked to find reasons to back up their positions. Remind students to use the bulletin board and their Science and Technology workbook for background information.

   They may also like to do further research or interview parents and friends.
3. Brainstorm presentation ideas.
4. Have each team within a group consolidate their reasons into a summary of arguments to be presented to the class.
5. Explain the information that you will be looking for to assess students' presentations:
   well organised information

   evidence of research into the topic

   evidence of knowledge of the topic

   clear oral communication

   evidence of group work

   creative presentation.
6. Form groups and allocate roles. Ask one group member to collect whatever equipment they need.
7. Provide groups with time to plan, prepare and practise their presentations.
8. Invite an audience (for example, another class, parents) to view presentations in the debate.
9. Conduct a class debate in which students present their findings and evaluate the various arguments. Encourage students to come to their own conclusions.

Resource List

Books - Juvenile Literature

Books - Juvenile Literature	ISBN
Nuclear Energy (2005) Discovery Channel	8179912345
Holland, G. (1996) Nuclear Energy, New York, Benchmark Books.	0761400478
Gibson, D. (2004) Nuclear Power, Black Rabbit Books.	1583406530
Stoyles, P., Pentland, P & Demant, D. (2003) Nuclear Energy, Black Rabbit Books.	1583403280
Kelly, D.D. (2006) Radioactive Waste: Hidden Dangers, Rosen Publishing Group.	1404207457
Daley, M. J. (1997) Nuclear Power: Promise or Peril?, Twenty-First Century Books.	0822526115
Andryszewski, T. (1995) What to do about nuclear waste, Brookfield, Millbrook Press.	1562945777
Giacobello, J. (2003) Nuclear Power of the Future: New Ways of Turning Atoms into Energy,Rosen Publishing Group.	0823936619
Pettigrew, M. (2004) Radiation, Stargazer Books.	1932799214
Graham, I. (2005) Curie and the Science of Radioactivity, Salariya Publishers.	1904642543
Graham, I. (1998) Energy Forever? Nuclear Power, London, Wayland Publishers.	0750222360
Moe, B. (2003) The Revolution in Medical Imaging, Rosen Publishing Group.	0823936724
Bryan, N. (2004) Chernobyl: Nuclear Disaster, Gareth Stevens.	0836855116
Miller, R. (2006) The Elements: What You Really Want to Know, Twenty-First Century Books.	0761327940
McLeish, E. (2007) The Pros and Cons of Nuclear Power, Rosen Publishing Group.	1404237402
Anderson, D. (2004) The Atom Bomb Project, Gareth Stevens.	0836854136
Landau, E. (2006) The History of Energy, Minneapolis, Twenty-First Century Books.	0822538067
Silverstein, A. (2006) Heart Disease, Twenty-First Century Books.	0761334203
Asimov, I. (2000) Worlds Within Worlds: The Story of Nuclear Energy, Washington, University Press of the Pacific.	0898750016
Richards, J. (2007) Future Energy, South Yarra, Macmillan Education Australia P/L.	9781420261035
Snedden, R. (2001) Nuclear Energy, Oxford, Reed Educational and Professional Publishing Ltd.	0431117616
Richardson, H. (1999) How to Split the Atom, Oxford University Press.	0199105928

General Books

General Books	ISBN
Hodgson, P.E. (1999) Nuclear Power, Energy and the Environment, Imperial College Press.	186094101X
Ogilvie, M. B. (2004) Marie Curie: A Biography, Greenwood Press.	0313325294
Silverstein, A. (2005) Cancer, Twenty-First Century Books.	0761328335

New Scientist Magazine Articles

19 January 2008	Best supporting role (p. 5)
	Push to nuclear (p. 6)
	The great coal hole (p. 38)
12 January 2008	Nuclear battles (p. 4)
	Life’s a beach on planet Earth (p. 8)

15 December 2007	Medical crisis (p. 5)
01 December 2007	Nuclear security in Russia 'disturbing' (p. 18)
13 October 2007	Nuclear reactions (p. 4)
06 October 2007	Windscale fallout blew right across Europe (p. 11)
22 September 2007	Safety warning at nuclear bomb plant (p. 8)
11 November 2006	Altered half-life (p. 26)
21 October 2006	Half-life heresy: Accelerating radioactive decay (p. 36)
10 June 2006	Who will pay for a nuclear future? (p. 8)
23 August 2003	How to create and destroy elements in a flash of light (p. 12)
15 March 2003	Bones tell where victims lived and when they died (p. 7)
17 November 2001	Should we worry (p. 18)
14 October 2000	The heat is on (p. 4)
	Tainted wilderness (p. 10)
18 March 2000	Radiation and risk: Inside Science 129 (middle insert)

Websites

http://www.ansto.gov.au

http://www.nrc.gov/reading-rm/basic-ref/students.html

http://www.nrc.gov/reading-rm/basic-ref/teachers.html

http://nuclearinfo.net/Nuclearpower

http://www.skwirk.com.au/p-c_s-4_u-191_t-528_c-1970/nsw/science

http://wps.pearsoned.com.au/qs1/0,9190,1393306-,00.html

http://nobelprize.org/nobel_prizes/physics/laureates/1903

http://www.terrace.qld.edu.au/academic/lote/french/yr5curie.htm

http://www.darvill.clara.net/altenerg.htm

http://www.energyquest.ca.gov/story/chapter13.html

http://www.outreach.psu.edu/news/magazine/vol_3.2/nuclear.html

http://www.sciencenetlinks.com/lessons

http://www.uic.com.au/nip26.htm

http://www.geog.ucsb.edu/~williams/Isotopes.htm

http://www.soest.hawaii.edu/GG/ASK/isotopes.html

http://hypertextbook.com/physics/modern/half-life

Posters

Mentone Educational Centre (www.mentone-educational.com.au)

- The Atom (Safari)
- Nuclear Fusion
- Nuclear Fission
- The Atom
- Radioactivity
- Nuclear Power Reactors

Southern Cross Educational (www.pcet.co.uk) Phone: (03) 9572 4277 Fax: (03) 9572 4299

Radioactivity (A Teaching Guide is supplied free with every title)

Audio-Visual

Audio Tape: "Voices of Science"

Video: "Beyond 2000 Medical Breakthroughs and Prevention"

DVD: "Radioisotopes at Work" Classroom Video www.classroomvideo.com.au

DVD: "Nuclear Physics" Classroom Video

DVD: "Atoms and Their Electrons" Classroom Video

DVD: "Trinity and Beyond: The atomic bomb movie" and "Atomic Filmmakers: Behind the scenes" Magna Pacific www.magnapacific.com.au

"The Atoms Kit" by E GLO Pty Ltd

www.epatch.com.au

References

Board of Studies (1993) *Science and Technology: Syllabus and Support Document*, Sydney, Board of Studies.

Curriculum Corporation (2006) *Statements of Learning for Science*, Carlton, Curriculum Corporation.

Holland, G. (1996) *Nuclear Energy*, New York, Benchmark Books.

Richards, J. (2007) *Future Energy*, South Yarra, Macmillan Education Australia P/L.

Richardson, H. (1999) *How to Split the Atom*, Oxford University Press.

http://www.boardofstudies.nsw.edu.au

http://www.science.org.au/primaryconnections

http://www.nrc.gov/reading-rm/basic-ref/teachers.html

http://www.sciencenetlinks.com/lessons

http://hypertextbook.com/physics/modern/half-life