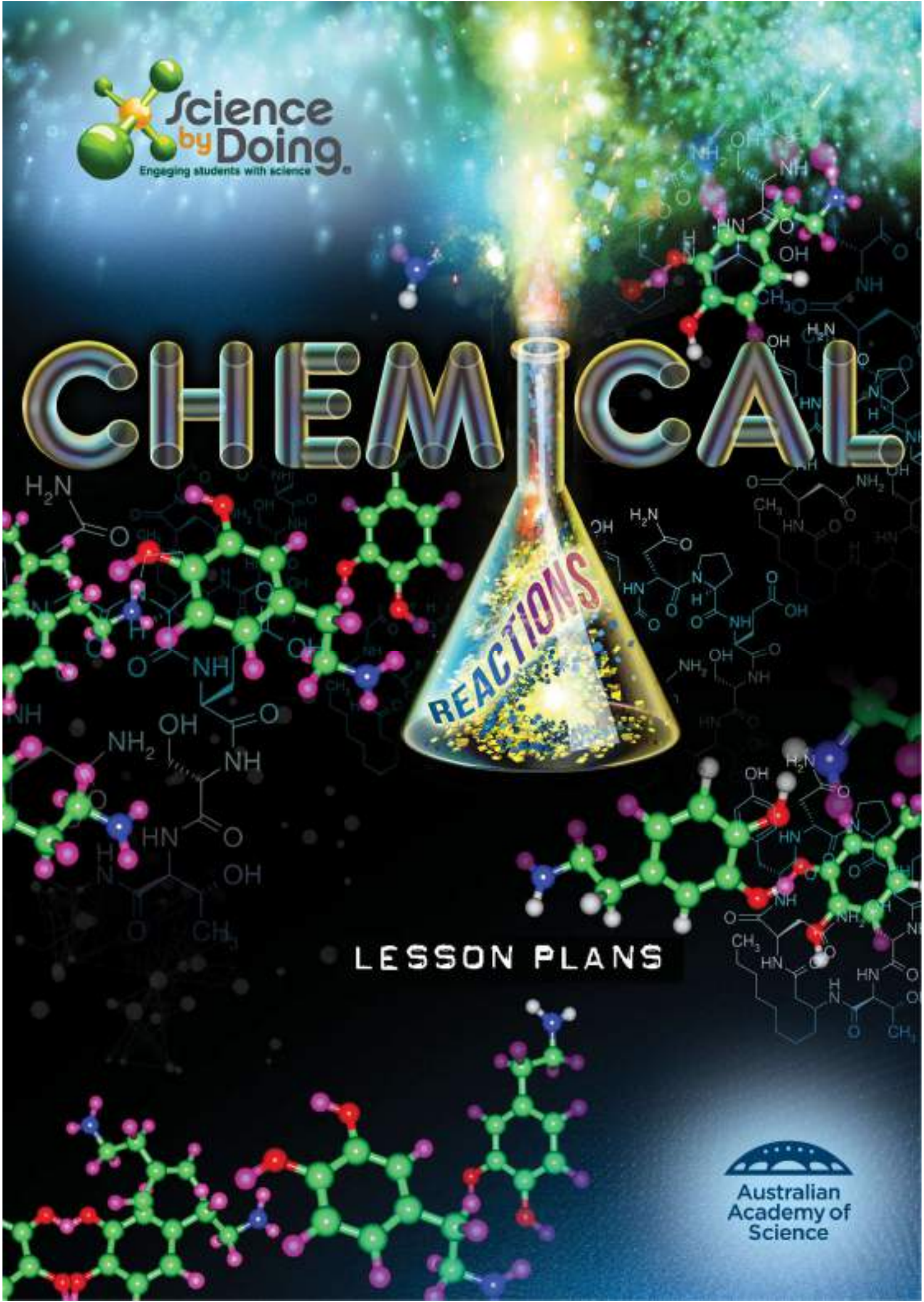
Science by Doing
Engaging students with science

CHEMICAL REACTIONS

LESSON PLANS



Australian Academy of Science

Part 1 It's elementary

Activity No	Activity Name	Lesson type	Activity Description
1.1	What's the matter?	Engage & Explore Classroom & Digital Medium	Students will play a game to review their understanding of chemistry. They will explore the issue of what matter is and that matter comprises elements. They also attempt a review quiz.
1.2	Atoms matter	Engage, Explore & Explain Classroom & Digital Medium	Students will compare the atomic models of the Greek philosopher Democritus and John Dalton. They will use a digital interactive to investigate the contributions of scientists since Dalton to develop our understanding of atomic structure.
1.3	Atomic structure	Explore, Explain & Elaborate Classroom & Digital Medium	Students will use models and digital interactive simulations to study atomic structure, including the electron configuration of atoms and ions.
1.4	What makes chemicals different?	Explore, Explain, Elaborate & Evaluate Hands-on, Classroom & Digital Long	Students will learn about the organisation of the periodic table and explore the relationships between properties of elements and their positions in the table using both hands-on and digital interactive activities.
1.5	Isotopes	Explain & Elaborate Classroom Short	Students will use models to learn how isotopes of an element differ from one another.

Optional

1.1 What's the matter

Lesson outcomes

At the end of this activity students will be able to:

- recall that all matter is composed of atoms and has mass
- describe elements as the basic unit from which all substances are made.

What ideas might your students already have?

Students should have a basic background in chemistry and the properties of matter from Stage 4 Science.

Key vocabulary:

Matter, element, property, classify.

Equipment list

The CLASS will require:

- set of *Celebrity Chemistry Hats*.

Each GROUP will require:

- *Science by Doing* **Student Digital**.

Each STUDENT will require:

- copy of Pre-topic test.

Things to consider:

It is important to generate enthusiasm and ensure students refresh their memories of basic chemistry to build on throughout this unit. The game *Celebrity Chemistry Hats* should motivate students and refresh their memories about chemistry apparatus and terms. Make cards with words in large letters (and pictures e.g. of apparatus, elements or chemical terms) that will easily slot into paper headbands.

Suggestions for words are:

Apparatus: test tube, measuring cylinder, tripod stand, Bunsen burner, beaker, filter funnel, retort stand, tongs, test tube, watch glass. Elements/compounds: gold, oxygen, lead, nitrogen, iron, hydrogen, sodium chloride (salt), hydrochloric acid, water, mercury.

Chemical terms: atom, molecule, proton, electron, neutron, compound, element, precipitate, solution, evaporation, solid, liquid, gas.

Students play the game in groups of 8-10, wearing hats with different words or pictures. They must discover what they represent by asking questions of the class. Only yes or no answers are permitted.

Teacher content information:

Lesson plan

Step 1: Play Celebrity Chemistry Hats as a class (see **Hint**).

Step 2: Use the hat words to stimulate a discussion of the classification and properties of matter, to help remember and understand scientific information.

Step 3: Students can then complete the revision glossary worksheet to consolidate on the meaning of terms. (This could be a homework activity.)

Step 4: Introduce and explain *Science by Doing* **Student Digital**, then brainstorm types of matter in the Sydney Harbour scene.

Step 5: Students form groups of three or four to complete ***Notebook*** activities.

Step 6: Individual completion of **Pre-topic Quiz** (see assessment documents), followed by discussion of any problems.

Step 7: Class review: What new things about chemistry have I learnt?

Suggested questions:

1. What are some words we use to describe matter?
2. What is a property? Give examples.
3. Why do we classify things?
4. What properties did you use to try and guess what was on your hat?
5. Do artists and scientists look at matter differently?

1.2 Atoms matter

Lesson outcomes

At the end of this activity students will be able to:

- outline historical developments in atomic theory
- identify that models and theories are challenged and refined as new scientific evidence emerges
- describe the structure of an atom in terms of the nucleus, protons, neutrons and electrons.

What ideas might your students already have?

Students may have a basic understanding that atoms are composed of protons, neutrons and electrons.

Key vocabulary:

Philosopher, nucleus, proton, neutron, electron, orbit, energy level.

Equipment list

Each GROUP will require:

- *Science by Doing* **Student Digital**.

Each STUDENT will require:

- a sheet of A4 paper.

Things to consider:

Review **Teacher content information** to stimulate a discussion of why educated people in earlier times were often simultaneously philosophers, scientists, mathematicians and teachers.

The students will draw a time line placing discoveries in historical perspective. Allocate different scientists to each pair of students so that the class can cover a range of discoveries and share their results. ***Notebook*** and have them briefly report back to the class, so all appreciate the contributions made.

History of atomic model timeline: This interactive helps students gain an idea of time and quickly summarises each scientist's contribution. Videos can be shown to the class or groups.

Thomson's Plum Pudding Model (2'17"): A cherry pie is used as a model of Thomson's atom. Cherries represent electrons that can be pulled out of the positively charged pie.

Cathode Rays lead to Thomson's Model of the Atom (3'12"): A demonstration of an experiment done in the mid-1800s to pass an electric current through a vacuum. This gives a glow caused by a stream of electrons and led to Thomson's discovery.

Teacher content information:

Democritus (460-370 BCE) was a scientific philosopher who believed everything was the result of natural laws. He belonged to a group called the atomists and is regarded as the father of modern science as he always asked for a logical (mechanical) explanation. He was also a pioneer of mathematics, particularly geometry.

Democritus held egalitarian philosophical and political views, believing 'Equality is everywhere noble' and the powerful should help the less fortunate.

Aristotle (384-322 BCE) belonged with Plato and Socrates to a group which subscribed to the earth, air, fire, water theory of matter. He had a much greater influence over a longer period of time than Democritus. This meant atomic theory was not seriously revisited for about 2000 years, until Dalton's time.

For Aristotle, 'all science (dianoia) is either practical, poetical or theoretical'. By practical science, he meant ethics and politics; by poetical science, he meant the study of poetry and the other fine arts; by theoretical science, he meant physics, mathematics and metaphysics.

Aristotle had scientific blind spots. However, as he was perhaps the philosopher most respected by European thinkers during and after the Renaissance, these thinkers often accepted his erroneous positions, which held back science in this period. However, despite his scientific shortcomings, his great advances in many scientific fields should not be forgotten.

John Dalton (1776-1884) came from a poor family (his father was a weaver) and had little formal education. Despite this, he began teaching at the age of 14, becoming a highly regarded teacher of mathematics and philosophy and publishing a book on meteorology early in his career.

His scientific research was thorough, methodical and characterised by quantitative experimental evidence. He presented his first significant papers on gas volume and pressure at the Manchester Literacy and Philosophy Society, which led to his law of partial pressures. He then calculated atomic weights of elements and formulated his atomic theory of matter.

Explaining amount of space in an atom:

1. Have a student hold a bat or stick up in the middle or the room. Students have eyes closed and try to hit the bat with their ping-pong ball. This leads into discussion of Rutherford's gold foil experiment.
2. Students draw a small circle in the middle of a page. Then with eyes closed draw twenty lines randomly across the page. How many hit it?

Lesson plan

Step 1: Introduce the Democritus atom with the paper tearing activity, *How small is small?* done individually.

Step 2: Lead a class discussion using the images and questions in *Science by Doing* **Student Guide p6**.

Step 3: Students work in groups to read about and discuss the Dalton atom, using the information, images and questions on page 7 of the *Science by Doing* **Student Guide**, and compare it to the Democritus atom. Students could attempt the questions in the in the 'Is there anything smaller' ***Notebook***.

Step 4: Referring to the *Science by Doing* **Student Digital**, students draw their own timeline and research the contributions of scientists involved (***Notebook*** 'More discoveries') Brief reports can be shared with the class.

Step 5: The ***Notebook*** videos can be shown to the class with discussion or viewed individually as students complete the ***Notebook*** questions.

Suggested question/s:

1. Why do you think educated people in earlier times were involved in so many areas of learning? What is philosophy?
2. Why did most people not believe Democritus' atomic theory?
3. What made them support Dalton's ideas?
4. Why do scientists still investigate atomic structure?

1.3 Atomic structure

Lesson outcomes

At the end of this activity students will be able to:

- visualise how small an atom is
- construct atomic models to represent elements 1-20 in the periodic table
- explain how the relative number of protons and electrons in an atom affects the charge it carries.

What ideas might your students already have?

Students should know an atom is composed of protons, neutrons and electrons.

Key vocabulary:

Electron shell, ion, mass number, atomic number

Equipment list

The CLASS will require:

- cathode ray tube (Maltese cross or alternative) for teacher demonstration

Each GROUP will require:

- coloured counters or smarties (10 each of three colours)
- *Science by Doing* **Student Digital**.

Things to consider:

Hands-on atomic models: Many students find it helpful to make atomic models with counters or smarties to illustrate the structure of the first 10 elements in the periodic table.

Cathode ray tubes run on high voltages and produce X-rays. If you are not familiar with their use and related risks your friendly physics teacher may be happy to run the demonstration for you.

Digital interactive resources

- **Cathode ray tube simulation:** this can substitute for or reinforce the teacher demonstration. It has clear explanations and shows a magnet deflecting the cathode ray.
- **Build an atom:** students build atom to discover nuclear structure and electron configuration, as well as the formation of ions and their charges.
- **How small is an atom? (5'):** an animation with analogies to help students visualise how tiny an atom and its nucleus are. This could be used at the start or end of the lesson.
- **Atomic structure tutorial (5'):** explains atomic structure, electron shells (energy levels) and configurations. There is an introductory link to the organisation of the period table.
- **Atomic models and hula hoops/Atomic Rant: (3'):** The video Atomic Rant considers today's most common atomic model (the Rutherford/Bohr model) and concludes it is no longer relevant. It suggests the electron cloud model, supported by the quantum theory, should replace it.

Teacher content information:

Teacher demonstration - cathode ray tube: Replicates Sir Joseph John Thomson's experiment, in which he demonstrated electrons could be separated from atoms and were negatively charged.

Schools usually have one of two versions, the original Crookes' tube, in which the beam of electrons shows up as a green glow at the end of the evacuated tube, or a Maltese cross tube, which shows electron beams travel in a straight line and do not pass through metal. The charge on the electrons can be readily demonstrated by showing the deflection that occurs when a magnet is placed close to the beam.

An on-line simulation is available in the *Science by Doing* **Student Digital Activity 1.3**.

Maltese cross evacuated tube (note that the green glow is a region where X rays are being produced due to the collision of the high energy electrons with the glass).

Lesson plan

Step 1: Teacher demonstration of cathode ray tube, with discussion linked to Thomson's atomic model.

Step 2: Discussion of Rutherford/Bohr atomic model. An on-line tutorial can be used to supplement information in the *Science by Doing* **Student Guide**.

Step 3: Students build atomic models with coloured counters or Smarties.

Step 4: The Build an atom interactive can now be used. Students explore the structure of atoms and ions.

Step 5: Students complete ***Notebook*** questions to consolidate their understanding of atomic structure.

Step 6: How small is an atom? Students watch the animation, then try to make their own analogy (See ***Notebook*** Question 5). Perhaps a prize can be given for the best analogy.

Suggested question/s:

1. What is the green glow at the end of the tube?
2. Describe the beam. What does this tell us about atoms?
3. What will be the charge on an atom if there are more protons than electrons?
4. What would cause the atom to become negatively charged?

Follow up:

Understanding of atomic structure is extended in Activities 1.4 and 1.5, as well as in Part 5, where radiation is explored.

1.4 What makes chemicals different?

Lesson outcomes

At the end of this activity students will be able to:

- describe the organisation of elements in the periodic table using atomic numbers
- relate properties of elements, including crystal structure, to their position in the table
- use the table to predict the properties of some elements
- carry out a risk assessment when planning an experiment.

What ideas might your students already have?

Students should have had a basic introduction to the periodic table and atomic structure.

Key vocabulary:

Group, period, metalloid.

Equipment list

The CLASS will require:

- Set of reagents, for **What's on the shelf?**: bottles with names, formulae worksheet and risk assessment Materials Safety Data Sheet (MSDS) or Safety Data Sheet (SDS).

Suggested reagents: copper sulphate, sodium chloride, calcium carbonate, hydrochloric acid, sodium hydroxide (pellets), granulated zinc, copper turnings, sulfur (powder), sulfuric acid, iodine crystals, ethanol, aluminium, copper oxide. The mystery chemical could be an everyday item such as sugar (sucrose $C_{12}H_{22}O_{11}$).

Each GROUP will require:

- *Science by Doing* **Student Digital**.

Each PAIR will require:

- copy of periodic table
- ***Notebook***

Things to consider:

In the activity **What's on the shelf?** distribute each chemical and its SDS so students can easily circulate about the room, from different starting points.

This activity familiarises students with chemicals and the elements they contain, as well as reinforcing the concept of classification based on properties.

Afterwards, you may show students your department's chemical storage areas, pointing out special storage conditions e.g. chemicals kept in the fridge, requirements for acids, bases etc.

Teacher demonstration - sublimation of iodine: a good demonstration to show gaseous elements form crystals when they solidify. Simple apparatus can be seen on the Royal Society of Chemistry (RCA) clip: http://www.youtube.com/watch?v=Mrc6Id0VaYI

Note that iodine vapours are toxic, so ensure you look at the SDS and carry out this demonstration safely, with students at an appropriate distance.

Digital interactive resources

- **interactive periodic table**: RCA periodic table with easy access to information about structure and properties, as well as other information about elements
- **periodic table revision quiz/game**: revision of elements 1-20
- **What is the rarest precious metal?** (7'): enrichment for interested students - a fun look at experiments with vanadium, sulphur, gold, osmium and platinum
- **Freezing liquid metal mercury** (2'50"): Enrichment - mercury solidified with dry ice (CO_2), then remelted.

Lesson plan

Step 1: Brainstorm what students remember about the periodic table, using p12 *Science by Doing* **Student Guide** as a stimulus.

Step 2: Review the laboratory safety rules and procedures involved in risk assessment (p10 **Student Guide**) **Step 3: Class practical – What's on the shelf?** Follow with a discussion of the properties of the substances found and risk assessment..

Step 3: Class discussion of periodic table focusing on property differences of metals, metalloids and non-metals. See p13 in *Science by Doing* **Student Guide**. Include Iodine sublimation demonstration here.

Step 4: Introduce digital activities with the roll-over revision of the first 20 elements, before exploring the periodic table interactive and completing ***Notebook*** Questions 1-4.

Step 5: All students are given a different element to research and produce an information poster on, for a class display (see ***Notebook*** Question 5).

Step 6: The class discusses and arranges the posters according to the different criteria suggested, discussing the relationships found. (Question 6)

Step 7: Interested students can explore the **Find out more** activities.

Suggested question/s:

1. How would the structure of the atoms change as you moved across the periodic table?
2. How would they differ as you moved down a group?
3. What do these substances have in common?
4. Can you see any differences between the substances?

Follow up:

Understanding of the periodic patterns will be extended in **Part 2: Reactions happen**, where bonding and formulae are introduced.

1.5 Isotopes

Lesson outcomes

At the end of this activity students will be able to:

- recall that isotopes are forms of elements differing only in the number of neutrons
- construct atomic models to represent the isotopes of an element.

What ideas might your students already have?

This lesson assumes students understand basic atomic structure.

Key vocabulary:

Isotope, deuterium, tritium.

Equipment list

The CLASS will require:

- *Science by Doing* **Student Digital**

Each GROUP will require:

- coloured counters or Smarties (see **Activity 1.2**).

Each STUDENT will require:

Digital interactive resources

- **What are atoms and isotopes?** (3'): explains a simple model of atomic structure and introduces isotopes.

Lesson plan

Step 1: Use the questions in *Science by Doing* **Student Guide** to introduce the concept of isotopes, looking at examples and symbols used to distinguish them.

Step 2: Students make models of isotopes using counters, draw them and write symbols for each.

Step 3: **The Build an atom** interactive can be used to consolidate learning.

Step 4: Watch and discuss **Find out more** video, before students choose and carry out their activity for the ***Notebook*** question.

Step 5: Students display their presentations.

Suggested question/s:

1. How can you distinguish the atoms of different elements?
2. Does the number of neutrons make this a different element?

Follow up:

An understanding of isotopes is needed for **Part 5: Energy from the nucleus**.