Badger GCSE Science

Working Scientifically

Chemistry

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Badger LEARNING

Introduction

This is the second of a series of three books of Working Scientifically activities for GCSE science. They have been developed by teachers to give colleagues a range of resources to use in teaching science through the principles of Working Scientifically. These activities work well as an 'add on' to any of the KS4 schemes of work.

Working Scientifically is an essential part of the national curriculum for science. For many science teachers, this has meant getting to grips with a new approach to science teaching. The activities in this book have been designed to encourage structured discussion, improve knowledge and understanding of Working Scientifically, and to support learners to consider a range of viewpoints and make an informed decision.

The KS4 science national curriculum sets out the parameters for Working Scientifically, and the specifications for each of the GCSE examination boards have interpreted these in a variety of ways. These activities are suitable for use in all schools, whichever exam board they use.

We have found that learners do not necessarily have the required background knowledge about scientific issues such as nanotechnology. Without this information, it is hard for them to discuss the issue and form an opinion. The tasks we have created boost this background knowledge and help learners to consider evidence from a range of contexts and make a decision.

How to use these activities

The general approach is to introduce the learners to the task, then allow them to discuss it in pairs or groups of four. During this time, the teacher should circulate amongst the groups to encourage the discussions. Once the learners have had time to talk about their ideas and make decisions, the teacher can lead a class discussion to draw out the key points.

More specifically, the activities take a variety of forms that require slightly different management. **Data analysis, graph drawing and predicting activities** follow the general approach, but note that the discussion should focus on the *process* of analysing, data presentation and prediction rather than just what the answer is.

Card sorts also take different forms, but the general approach allows learners to sort statements physically into groups. Discussion should focus on the nature of evidence, or facts and opinions in the context of the content of the activity.

Timelines require more time and can be extended by allowing learners to add their own images and additional events. They are designed so that learners can identify how ideas change, and relate images to the text. Follow-up discussion should focus on how and why the ideas have changed and, perhaps, on imagining what may happen in the future.

A note about timing

We have identified the approximate time taken for the activities based on an average ability class. More able groups may need less time on the task but more time on the discussion, and lower ability learners may need support (particularly literacy) during the activities themselves. Most tasks have some differentiation suggestions.

Authors

Dr Andy Chandler-Grevatt trains teachers at the University of Sussex. Previously he was a science teacher and Advanced Skills Teacher, where he developed an interest in producing engaging resources. This publication is dedicated to his nephews, Toby and Olly.

Dr Deborah Shah-Smith is an experienced science teacher. She has a keen interest in developing resources using practice-based evidence. She would like to dedicate this publication to her husband, Paul, and daughter, Zaveri.

Acknowledgements

We would like to thank our colleagues who have helped us to develop these tasks. These include Ben Riley of Oriel High School, West Sussex and Ross Palmer of Cardinal Newman School, Brighton and Hove.

Contents and curriculum links

A. Atomic Structure and the Periodic Table

B. Structure, Bonding and Quantitative Chemistry

Title	NC WS	WS Programme of Study	Activity Type
11. Nanotechnology: benefits, drawbacks and risks	1c, 1d, 1e	The development of scientific thinking	Card sort and discussion
12. Chemical bonding timeline	1a	The development of scientific thinking	Card sort and discussion
13. Percentage yield	2d, 2g	Experimental skills and strategies	Calculations and discussion
14. Investigating changing mass	2c, 2d, 2g	Experimental skills and strategies	Discussion and writing improvement suggestions
15. Ionic or covalent bonding?	3e, 3f	Analysis and evaluation	Data analysis and discussion
16. Molecular diagrams	3b	Analysis and evaluation	Diagram drawing and discussion
17. Definitions: bonding	4a	Vocabulary, units, symbols and nomenclature	Card sort and discussion
18. Matching molecules	4a, 4b, 4c	Vocabulary, units, symbols and nomenclature	Card sort and discussion
19. Oxidation of magnesium	Experimental focus	Experimental skills and strategies	Planning and discussing an investigation, written task
20. Making molar solutions	Maths skills	Analysis and evaluation	Graph interpretation and discussion

C. Properties and Energy

Title	NC WS	WS Programme of Study	Activity Type
21. Metals discovery timeline	1a, 1b, 1c	The development of scientific thinking	Card sort and discussion
22. Allotropes of carbon	1a, 1c, 1d	The development of scientific thinking	Card sort and discussion
23. Investigation glossary	2b, 2d	Experimental skills and strategies	Card sort and discussion
24. Investigating properties of metals	2b, 2c, 2d	Experimental skills and strategies	Planning writing activity and discussion
25. Energy-changing chemical reactions	3c, 3g	Analysis and evaluation	Calculations and discussion
26. Metal, non-metal or metalloid?	3e, 3f	Analysis and evaluation	Evaluating evidence, written task and discussion
27. Definitions: energy and states of matter	4a	Vocabulary, units, symbols and nomenclature	Card sort and discussion
28. Size matters: energy values	4a, 4b, 4d	Vocabulary, units, symbols and nomenclature	Calculations and discussion
29. Endothermic reactions in the kitchen	Experimental focus	Experimental skills and strategies	Card sort and discussion
30. Cooling of naphthalene	Maths skills	Analysis and evaluation	Graph drawing and interpretation, and discussion

D. Chemical Changes and Rates of Change

Title	NC WS	WS Programme of Study	Activity Type
31. Use of catalysts timeline	1a	The development of scientific thinking	Card sort and discussion
32. Catalytic converters: benefits, drawbacks and risks	1e	The development of scientific thinking	Card sort and discussion
33. Collecting carbon dioxide	2c, 2f, 2g	Experimental skills and strategies	Evaluating sampling methods, written task and discussion
34. Fastest fizz	2c, 2f,	Experimental skills and strategies	Evaluating methods, written task and discussion
35. Analysing copper extraction	3a, 3b, 3c, 3e	Analysis and evaluation	Analysing and drawing conclusions, and discussion
36. Plotting a disappearing cross	3a, 3b, 3d, 3e	Analysis and evaluation	Graph drawing and interpretation, and discussion
37. Hazard symbols	4a	Vocabulary, units, symbols and nomenclature	Card sort and discussion
38. Definitions: chemical reactions	4a	Vocabulary, units, symbols and nomenclature	Card sort and discussion
39. The effect of a catalyst on the rate of a reaction	Experimental focus	Experimental skills and strategies	Planning written task and discussion
40. Making magnesium oxide	Maths skills	Analysis and evaluation	Calculations and discussion

E. Analytical and Industrial Chemistry

Title	NC WS	WS Programme of Study	Activity Type
41. Mobile metals: benefits, drawbacks and risks	1c, 1d, 1e	The development of scientific thinking	Card sort and discussion
42. Metals discovery timeline	1a	The development of scientific thinking	Card sort and discussion
43. Making biofuels	2c	Experimental skills and strategies	Card sort and discussion
44. Matching gas tests	2c	Experimental skills and strategies	Card sort and discussion
45. Why recycle?	3e	Analysis and evaluation	Analysis of a graph and discussion
46. Carbon chains and boiling points	3a	Analysis and evaluation	Graph drawing
47. Hydrocarbon prefixes	4a, 4c	Vocabulary, units, symbols and nomenclature	Card sort and discussion
48. Definitions: chemical analysis	4a	Vocabulary, units, symbols and nomenclature	Card sort and discussion
49. Distillation: alcohol boiling points	Experimental focus	Experimental skills and strategies	Planning an experiment and discussion
50. Calculating Rf values	Maths skills	Analysis and evaluation	Calculations and discussion

F. Earth and Atmosphere

Title	NC WS	WS Programme of Study	Activity Type
51. History of the Earth's atmosphere	1a	The development of scientific thinking	Card sort and discussion
52. Desalination of seawater in Australia: the issues	1d	The development of scientific thinking	Card sort and discussion
53. Making potable water in the kitchen	2b, 2c, 2d	Experimental skills and strategies	Planning an experiment and discussion
54. Will global warming affect plant growth?	2b, 2c, 2d	Experimental skills and strategies	Planning an experiment and discussion
55. Analysing global warming	3e	Analysis and evaluation	Graph analysis and interpretation, and discussion
56. Why did the oxidation catastrophe happen?	3e, 3f	Analysis and evaluation	Analysis and interpretation of evidence, and discussion
57. Definitions: Earth and atmosphere	4a	Vocabulary, units, symbols and nomenclature	Card sort and discussion
58. An atmospheric scale	4a, 4c, 4d	Vocabulary, units, symbols and nomenclature	Card sort and discussion
59. Does carbon dioxide trap heat energy?	Experimental focus	Experimental skills and strategies	Improving a plan and discussion
60. Does carbon dioxide cause global warming?	Maths skills	Analysis and evaluation	Plotting a graph and discussion

1 Atomic Structure and the Periodic Table
Mendeleev's predictions

KS4 National Curriculum WS link

1. *The development of scientific thinking*
   a. the ways in which scientific methods and theories develop over time
   b. using a variety of concepts and models to develop scientific explanations and understanding

Resources:
Task sheet 1: 1 each

Time:
Activity: 10 minutes
Discussion: 5 minutes

Notes

- **Suitable for:** Starter or Plenary
- Some literacy support may be required.
- **Key words/concepts:** making predictions, the Periodic Table, density, atomic mass

Suggested answers

'eka-silicon' is most likely to be:
Germanium – closest in properties.

Reasons:
Gallium – melting point too low and density of chloride too high.
Arsenic discovered in 1250! Also, chloride salt melting point too low.

Extension suggestion

What is the difference between atomic mass and atomic number?

Atomic Structure and the Periodic Table

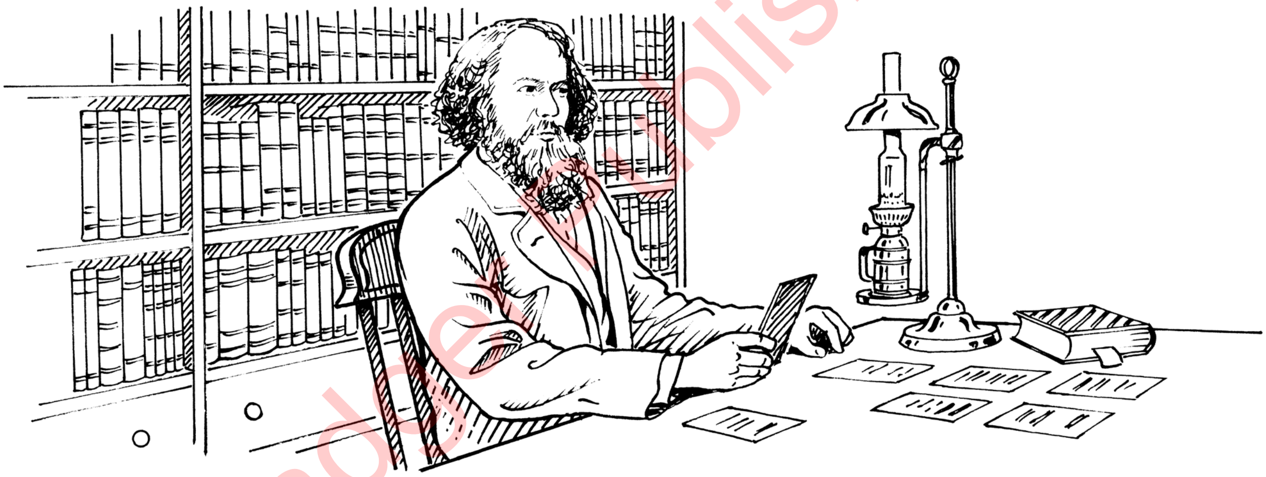
Mendeleev's predictions

1

The Periodic Table is the most valuable tool a chemist has to hand. It lists all the known elements in order of atomic number, while keeping elements with similar properties grouped together.

The Periodic Table that we use today was conceived by a Russian chemist called Dmitri Mendeleev (1822–1907). He made a card for each known element, listing all its properties. He then arranged the elements by their atomic mass and properties. What made Mendeleev's table different from other efforts to order the elements was that he left gaps in his table where elements were missing. He was able to accurately predict the properties of these missing elements. One such element he predicted was 'eka-silicon'.

Mendeleev predicted that 'eka-silicon' would have an atomic mass of 72, with a density of 5.5 g/cm^3 and a high melting point. He thought its colour would be grey; it would form a chloride salt with a density of 1.9 g/cm^3; and have a boiling point of less than 100°C.



Task

Read the text above. Using the information in the text, decide which element 'eka-silicon' is most likely to be. Give reasons for your answer.

Element name	Discovered	Atomic mass	Melting point (°C)	Density (g/cm^3)	Chloride salt density	Chloride salt boiling point (°C)	Colour
Gallium	1875	70	30	5.9	2.5	78	Grey
Germanium	1886	73	947	5.3	1.9	86	Grey
Arsenic	1250	75	613	5.7	2.2	–16	Grey

2

Atomic Structure and the Periodic Table

Structure of the atom timeline

KS4 National Curriculum WS link

1. *The development of scientific thinking*
   a. the ways in which scientific methods and theories develop over time
   b. using a variety of concepts and models to develop scientific explanations and understanding

Resources:
Task sheet 2: cut into cards, with instructions: 1 set each

Time:
Activity: 20–30 minutes
Discussion: 10 minutes

Notes

- **Suitable for:** Main or Homework activity
- **Key words/concepts:** how scientific ideas change

Suggested answers

C Around 442 BC, Democritus proposes an atomic theory of the universe, saying that all matter is made up of atoms which are eternal, invisible and so small they can't be divided.

B 1803, J. Dalton develops an 'atomic theory' in which atoms are tiny, indestructible, solid spheres.

F 1897, J.J. Thomson proposes the 'plum pudding' model to explain the structure of the atom. He also discovers the electron.

A 1903, Nagaoka proposes a model in which the atom resembles the planet Saturn, i.e. the electrons orbit a central nucleus in a single plane.

C 1911, E. Rutherford states that the mass of the atom is in a small, positively charged ball at the centre, surrounded by a cloud of electrons. Rutherford is also credited with discovering protons.

H 1914, H.G.J. Moseley says that the 'atomic number' of an element equals the number of protons in the nucleus. The Periodic Table is laid out in order of number rather than atomic mass.

E 1922, N. Bohr proposes that electrons are arranged in successively large orbits around the nucleus. This theory explains the regularities seen in the Periodic Table.

G 1932, Chadwick discovers the neutron, a neutrally charged particle with a mass similar to that of a proton.

Extension suggestion

Suggest why each of these discoveries happened in this order.

Atomic Structure and the Periodic Table

Structure of the atom timeline

2

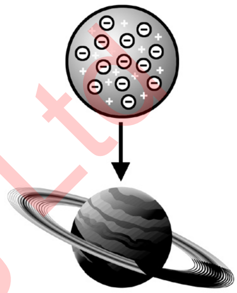
Task

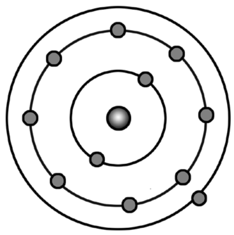
Cut out the timeline, statements and images. Read each statement carefully and place it on the timeline. Match the images to illustrate it.

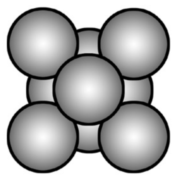
Timeline

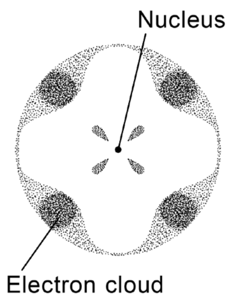
- 500 BC
- 1700 AD
- 1800 AD
- 1900 AD
- 2000 AD

A	Nagaoka (1903) proposes a model in which the atom resembles the planet Saturn, i.e. the electrons orbit a central nucleus in a single plane.
B	J. Dalton (1803) develops an 'atomic theory' in which atoms are tiny, indestructible, solid spheres.
C	In 1911, E. Rutherford states that the mass of the atom is in a small, positively charged ball at the centre, surrounded by a cloud of electrons. Rutherford is also credited with discovering protons.
D	Around 442 BC, Democritus, a Greek philosopher, proposes an atomic theory of the universe, saying that all matter is made up of atoms which are eternal, invisible and so small they can't be divided.
E	N. Bohr (1922) proposes that electrons are arranged in successively larger orbits around the nucleus. This theory explains the regularities seen in the Periodic Table.
F	In 1897, J. J. Thomson proposes the 'plum pudding' model to explain the structure of the atom. He also discovers the electron.
G	In 1932, Chadwick discovers the neutron, a neutrally charged particle with a mass similar to that of a proton.
H	H. G. J. Moseley says that the 'atomic number' of an element equals the number of protons in the nucleus. The Periodic Table is laid out in order of number rather than atomic mass (1914).









3

Atomic Structure and the Periodic Table

Is the jewellery pure gold?

KS4 National Curriculum WS link

2. *Experimental skills and strategies*
   b. planning experiments to make observations, test hypotheses or explore phenomena
   c. applying a knowledge to a range of techniques, apparatus, and materials to select those appropriate both for fieldwork and for experiments

Resources:
Task sheet 3: 1 between 2

Time:
Activity: 20 minutes
Discussion: 10 minutes

Notes

- **Suitable for:** extended Starter or Main activity, or Homework activity
- **Key words/concepts:** planning an investigation, how to calculate density, Eureka cans, density

Suggested answers

A Equipment that you plan to use and other apparatus you may need:

Eureka can
Glass beaker
Electronic balance
Measuring cylinder
Tap water
Tripod*
Gauze*

* The tripod and gauze may be needed so the measuring cylinder can be placed under the spout of the Eureka can.

The most important pieces of equipment needed are the pieces of jewellery.

B Bullet-point method for using the equipment. Include:

- Measure the mass of each object using the electronic balance. Record the results.
- Place one piece of jewellery into a full Eureka and collect the displaced water in the measuring cylinder. Record the volume of water displaced.
- Calculate the densities of the pieces of gold jewellery and compare with the density of pure gold (19.3 g/cm^3).

Extension suggestion

Draw a results table for your investigation.

Atomic Structure and the Periodic Table

Is the jewellery pure gold?

3

The density of a metal is calculated using the following equation:

$$\text{Density} = \frac{\text{Mass (g)}}{\text{Volume (cm}^3\text{)}}$$

The unit of density is g/cm^3

It is possible to tell if a piece of metal is pure by measuring its density, i.e. weighing the piece, measuring the volume and calculating the density using the equation above. This is easy if the metal is in a shape that can be measured accurately to find the volume. However, if the metal is an odd shape, one way to measure the volume is to use a Eureka can.

The Eureka can is filled with water. The metal is placed in the can. The volume of water that is displaced is the volume of the metal piece.

Task

Plan an investigation to find out which pieces of jewellery are made of pure gold. The density of pure gold is 19.3 g/cm^3.

A. Select the equipment that you plan to use from the list below, and include any other apparatus you may need.

Eureka can	Periodic Table	Glass rod
Glass beaker	Measuring cylinder	Tap water
Electronic balance	Ruler	Newton meter
Bunsen burner	Thermometer	Gauze
Hydrochloric acid	Tripod	Stopwatch

B. Write out a brief bullet-point method outlining how you are going to use the equipment.

4 Atomic Structure and the Periodic Table
Investigating elements

KS4 National Curriculum WS link

2. *Experimental skills and strategies*
   b. planning experiments to make observations, test hypotheses or explore phenomena
   d. carry out experiments appropriately, having due regard to the correct manipulation of apparatus, the accuracy of measurements and health and safety considerations
   g. evaluating methods and suggesting possible improvements and further investigations

Resources:
Task sheet 4: 1 between 2

Time:
Activity: 15 minutes
Discussion: 5 minutes

Notes

- **Suitable for:** Plenary, Main or Homework activity
- **Key words/concepts:** oxide, risk assessment

Suggested answers

A. Improvements to the method could include:
- Clean surface of metals with sandpaper before heating.
- Place the magnesium ribbon in a wrapper to avoid igniting the whole ribbon.
- Hold the metals using the tongs.
- Hold the metals over the heatproof mat during and after heating.

B. Risk assessment could include:
- Wear safety spectacles when heating the metals.
- Do not look directly at the magnesium when it is burning; the light intensity is strong enough to damage the retina.
- Wait until the metal oxides have cooled down before handling.
- The tongs will become hot when heating the metals, so care should be taken to only hold them by the handles to prevent burns.

Extension suggestion

Draw a results table for this investigation.

Atomic Structure and the Periodic Table

Investigating elements

4

Metals react with oxygen at different rates and some need to be heated in order for the reaction to happen. Copper and magnesium react very differently when they are heated in air in a Bunsen burner flame.

Task

Read the text below which outlines a simple method for reacting magnesium and copper with oxygen to form magnesium oxide and copper oxide, respectively.

A. Suggest how the method could be improved.
B. Write a risk assessment for the investigation.

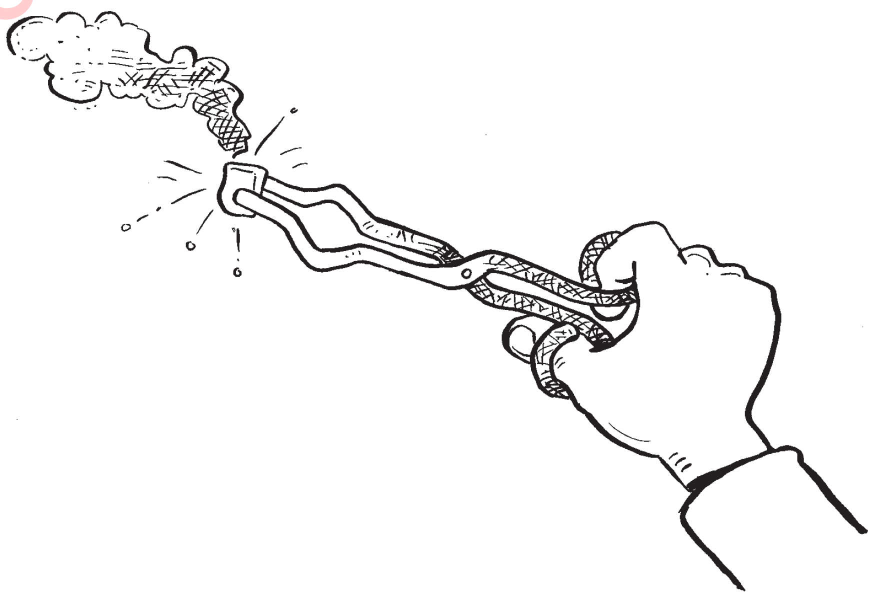
Reacting magnesium and copper with oxygen

Equipment:

Magnesium ribbon
Sandpaper
Bunsen burner
Piece of copper foil
Tongs
Heatproof mat

Method:

1. Cut a piece of magnesium ribbon.
2. Light the Bunsen burner and heat the magnesium ribbon until it bursts into flames.
3. Turn off the Bunsen burner.
4. The magnesium ribbon should have burned in oxygen to form a white powder – magnesium oxide.
5. Repeat steps 2 to 4, replacing the magnesium ribbon with a piece of copper foil.



5

Atomic Structure and the Periodic Table

The size of atoms

KS4 National Curriculum WS link

3. *Analysis and evaluation*
   a. presenting observations and other data using appropriate methods
   b. translating data from one form to another
   d. representing distributions of results and making estimations of uncertainty

Resources:
Task sheet 5: 1 each
Graph paper

Time:
Activity: 15 minutes
Discussion: 5 minutes

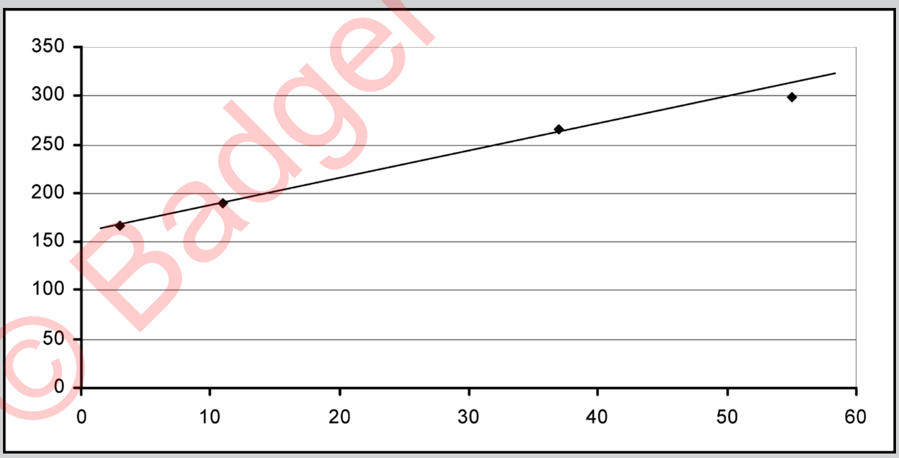
Notes

- **Suitable for:** Starter or Plenary
- **Keywords/concepts:** Periodic Table, Group 1 metals, using line graphs to make predictions

Suggested answers

A. Independent variable: atomic number. **Dependent variable:** atomic radius.

B/C. Graph should look something like this:



D. Using the graph, estimate the atomic radius for potassium:
243 is the value, but allow 233–246 from a good line of best fit.

Extension suggestion

How confident are you in your estimate?

Atomic Structure and the Periodic Table

The size of atoms

5

The radius of atoms can be calculated.

In Table 1 below, the atomic radii of the elements in Group 1 of the Periodic Table are listed. However, the atomic radius for potassium is missing.

Use your graph-drawing skills to estimate the atomic radius of potassium.

Table 1: The atomic radii of the Group 1 elements

Element	Atomic number	Atomic radius (picometres)
Lithium	3	167
Sodium	11	190
Potassium	19	?
Rubidium	37	265
Caesium	55	298

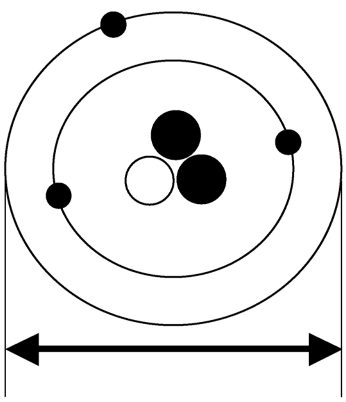
Task

A. Decide on the independent and dependent variables.

B. Plot a suitable line graph for this data.

C. Draw a line of best fit.

D. Using your graph, estimate the atomic radius for potassium.



Lithium atom
radius 167 pm