11 Metals and non-metals

Planning page

Getting started

11.1 The periodic table page 262
- Animation: Chemical bonds

11.2 Chemical families page 266
- Investigate 21: Metal properties
- Investigate 22: Alkaline earth metals with water
- Investigate 23: Flame colours

11.3 Extracting metals page 273
- Investigate 24: Froth flotation
- Activity page 276
- Investigate 25: Copper metal from copper ore
- Assessment task 11: Metals

Main ideas
- Chapter 11 crossword

Review
- Chapter 11 test

Essential Learnings for Chapter 11

Essential Learnings	References		
	Student book (page number)	**Workbook (page number)**	**Teacher Edition CD (Assessment task)**
Knowledge and understanding *Natural and processed materials* Matter can be classified according to its structure	pp. 262–272		Assessment task 11 Metals
Chemical reactions can be described using word and balanced equations	pp. 270, 274–278		Assessment task 11 Metals
Science as a human endeavour People from different cultures contribute to and shape the development of science	Mendeleev p. 262		
Ways of working Select and use scientific equipment and technologies to enhance the reliability and accuracy of data collected in investigations	Investigate 25 pp. 277–278		
Research and analyse data, information and evidence		p. 91	
Draw conclusions that summarise and explain patterns, and that are consistent with the data and respond to the question		pp. 87–89	

QSA Science Essential Learnings by the end of Year 9

Vocabulary

allotropes
bauxite
bromine
charcoal
conductivity
diamond
displacement
electrolysis
graphite
halogens
helium
lithium
malleable
metallic lustre
metalloids
monatomic
neon
nickel
noble gases
periodic table
smelting
titanium

Focus for learning

Interpret a data table on the properties of metals (page 259).

Equipment and chemicals (per group)

Investigate 21 page 267	small samples of various metals (eg aluminium, copper, iron, magnesium, lead, tin, silver, zinc), steel wool or emery paper, dilute hydrochloric acid (1 M) in a dropper bottle, test tubes (in test tube rack), zinc sulfate solution (saturated), copper sulfate solution (saturated), ammeter or multimeter, 4 connecting wires, power pack, switch
Investigate 22 page 268	2 test tubes, test tube holder and rack, Bunsen burner and heatproof mat, 5 cm strip of magnesium, small sample of calcium, phenolphthalein, steel wool or emery paper
Investigate 23 page 269	petri dish, piece of nichrome wire (about 10 cm long), wooden peg or test tube holder, Bunsen burner, saturated solutions of chlorides or carbonates of barium, calcium, copper, potassium, sodium and strontium
Investigate 24 page 274	fine sand, kerosene, spatula, liquid detergent, watch glass, large test tube with stopper, powdered chalcopyrite, galena or haematite
Activity page 276	test tube and rack, silver nitrate solution (0.2 M), 15–20 cm copper wire
Investigate 25 pages 277–278	copper ore (made by mixing copper sulfate, sand and plaster of Paris, adding water and allowing to set), balance, mortar and pestle, 2 beakers or conical flasks, filter funnel and stand, filter paper, burner, tripod and gauze, watch glass, hand lens, spatula, sodium chloride, stirring rod, power pack, strips of lead and copper, 2 connecting wires, steel wool

Special preparations

Investigate 23 page 269	If you set up six different 'stations' around the laboratory you will need one of the solutions plus the equipment per station.

11 Metals and non-metals

Getting Started

Use the table below to answer these questions about the physical properties of metals.

1 Which is the strongest metal?
2 Which is more dense—iron or copper?
3 Which are the two rarest metals listed in the table?
4 Which metals do not melt until the temperature is above 1000°C?
5 Is there a relationship between percentage abundance and cost? Explain your answer.
6 Suggest why bridges are made from steel (iron) rather than aluminium.
7 Which would be the best metal to make a spacecraft to explore the surface of Venus, where the temperature varies from 450°C to 1000°C?

Metal	Symbol	Percentage abundance in Earth's crust	Approximate cost ($/kg)	Density (g/cm^3)	Melting point (°C)	Strength ($\times 10^6$ N/m^2)
aluminium	Al	8.1	3	2.7	660	80
copper	Cu	0.007	10	8.9	1083	150
gold	Au	0.000 000 5	27 000	19.3	1063	120
iron	Fe	5.0	0.6	7.9	1535	300
lead	Pb	0.002	1	11.3	327	15
silver	Ag	0.000 004	500	10.5	961	150
tin	Sn	0.000 4	11	7.3	232	30
titanium	Ti	0.6	16	4.5	1668	620
zinc	Zn	0.013	5	7.1	420	150

Starting point

1 Ask students to skim through this chapter and jot down some *what* and *why* questions. Allow them to use the section headings to help generate their questions. At the completion of the chapter, they can see how many of these questions they can answer. They will probably be pleased to discover they know most of the answers.

2 Before students complete the Getting Started questions, they could perform some practical investigations of some properties of metals. At workstations around the classroom, have a selection of different metal strips or cubes, preferably of the same dimensions. In a chart, students could record observations about the metal's appearance, hardness, malleability, conductivity (remind students how to safely test this) and density (if using cubes). Ask students if they are investigating the physical or chemical properties of the metals.

3 Students could write their own set of questions about the information in the table on this page, and then give them to another student to answer. Some suggested questions are:

- Why are these elements metals?
- What makes each of the metals different?
- How is density measured?
- How do you think strength is measured?
- Oxygen, nitrogen and sulfur are non-metals. How are these elements different from the metals listed?

Hints and tips

From the previous chapter, and from *ScienceWorld 2*, students should recall how to correctly write element symbols. When students were studying *ScienceWorld 2* (Chapter 4, page 72), they may have learned the names and symbols of the elements in the given table. See how many they can recall.

Periodic table of the elements

Key

6 — atomic number
C — symbol
Carbon — name of element

The colour of the name for each element indicates its state at room temperature:
black—solid
blue—liquid
pink—gas
red—synthetic

I	II							
1 H Hydrogen								
3 Li Lithium	4 Be Beryllium							
11 Na Sodium	12 Mg Magnesium							
19 K Potassium	20 Ca Calcium	21 Sc Scandium	22 Ti Titanium	23 V Vanadium	24 Cr Chromium	25 Mn Manganese	26 Fe Iron	27 Co Cobalt
37 Rb Rubidium	38 Sr Strontium	39 Y Yttrium	40 Zr Zirconium	41 Nb Niobium	42 Mo Molybdenum	43 Tc Technetium	44 Ru Ruthenium	45 Rh Rhodium
55 Cs Caesium	56 Ba Barium		72 Hf Hafnium	73 Ta Tantalum	74 W Tungsten	75 Re Rhenium	76 Os Osmium	77 Ir Iridium
87 Fr Francium	88 Ra Radium		104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium

57 La Lanthanum	58 Ce Cerium	59 Pr Praseodymium	60 Nd Neodymium	61 Pm Promethium	62 Sm Samarium
89 Ac Actinium	90 Th Thorium	91 Pa Protactinium	92 U Uranium	93 Np Neptunium	94 Pu Plutonium

Learning experience

A great activity is to construct a giant periodic table. If there is more than one class at the same year level studying the same topic you could do this as a joint exercise.

Allocate each student a different element. Using coloured A4 paper, each student makes their own element block (portrait orientation). Students should use the periodic table of elements on this page as a colour guide and select an appropriately coloured A4 sheet for their element. When all the blocks are completed, construct a giant periodic table by laying out each block in atomic number and group order. Make sure one of the science labs has a free wall to pin the table up.

As an extension activity, students could research their element and add the information they find to their element block. For example, element blocks could include:

- element symbol
- element name
- atomic number
- mass number
- state of matter at room temperature
- chemical family (group, and if it is a metal, non-metal or metalloid)
- some physical/chemical properties and interesting facts
- abundance
- whether it is naturally occurring or synthetic
- who discovered it
- when and how it was discovered
- some of its uses.

Award marks for creativity, readability and accuracy.

WEBwatch

For a lighthearted look at the periodic table go to www.scienceworld.net.au and follow the links to The elements.

Chemical families

- Alkali metals
- Alkaline earth metals
- Transition metals
- Rare earth metals
- Other metals
- Metalloids
- Other non-metals
- Halogens
- Noble gases

			III	IV	V	VI	VII	VIII
								2 He Helium
			5 B Boron	6 C Carbon	7 N Nitrogen	8 O Oxygen	9 F Fluorine	10 Ne Neon
			13 Al Aluminium	14 Si Silicon	15 P Phosphorus	16 S Sulfur	17 Cl Chlorine	18 Ar Argon
28 Ni Nickel	29 Cu Copper	30 Zn Zinc	31 Ga Gallium	32 Ge Germanium	33 As Arsenic	34 Se Selenium	35 Br Bromine	36 Kr Krypton
46 Pd Palladium	47 Ag Silver	48 Cd Cadmium	49 In Indium	50 Sn Tin	51 Sb Antimony	52 Te Tellurium	53 I Iodine	54 Xe Xenon
78 Pt Platinum	79 Au Gold	80 Hg Mercury	81 Tl Thallium	82 Pb Lead	83 Bi Bismuth	84 Po Polonium	85 At Astatine	86 Rn Radon
110 Ds Darmstadtium	111 Rg Roentgenium							

63 Eu Europium	64 Gd Gadolinium	65 Tb Terbium	66 Dy Dysprosium	67 Ho Holmium	68 Er Erbium	69 Tm Thulium	70 Yb Ytterbium	71 Lu Lutetium
95 Am Americium	96 Cm Curium	97 Bk Berkelium	98 Cf Californium	99 Es Einsteinium	100 Fm Fermium	101 Md Mendelevium	102 No Nobelium	103 Lr Lawrencium

Hints and tips

- Reinforce the difference between atomic number and mass number, especially if students are using an alternative periodic table. Students often confuse these. Mass number is the number of nucleons (protons plus neutrons).
- It is important for students to recognise the names and symbols of some commonly known elements, especially the first 20 in the periodic table. You could test the students at the beginning of each lesson by randomly choosing about 10 elements to test at a time. Award the students certificates if they are able to remember all 20 elements in a single quiz (name and symbol).

Learning experience

A fun and visual activity is to decorate the science room with labels identifying different elements. For example, glass is mostly silicon and oxygen, so label it Si and O; stainless steel (sink) is iron, chromium and nickel; sodium stearate (soap) is sodium, carbon, hydrogen and oxygen; plastic is mainly carbon and hydrogen; electrical leads are pure copper and solder is tin and lead; argon is in light bulbs; tap water contains hydrogen, oxygen, and traces of fluorine and chlorine; air is a mixture of mostly nitrogen and oxygen. Students will soon see that everything is made up of elements. Sticky Post-it notes are good to use as labels because they can easily be removed.

Learning experience

Do the Webwatch if you have access to computers in class, or give it as a homework exercise.

11.1 The periodic table

Imagine searching through piles of unsorted CDs looking for the latest album of your favourite artist. Such a task could take days. Fortunately music shops arrange their CDs in separate sections. They then divide each of these groups into smaller groups according to the type of music, eg rock, popular, jazz and classical. Artists within each group are then arranged alphabetically.

Scientists have a similar problem to the music store owner. There are over 100 different elements, each with different physical and chemical properties. However, some of these elements have similar properties. For example, fluorine, chlorine, bromine and iodine all react very easily with metals. Groups of elements with similar properties are called *families*. Fluorine, chlorine, bromine and iodine are all in the same family.

Mendeleev's table

Over the years chemists have tried many different ways of classifying the elements. In 1869 Dmitri Mendeleev (MEN-del-LAY-if), a Russian chemist, devised a classification system that, with some changes, is still used today. He made a card for each element, with its name, atomic mass and properties. He placed the cards in a row in order of increasing atomic mass. Hydrogen has the lightest atoms, so it was first. He then took from the row of cards those elements whose properties were similar to others before them in the row and placed these cards in columns under the ones they were similar to. In this way he built up a table like a calendar. On a calendar the days of the month are in order, but the dates for the same day of the week are in the same vertical column. For example, on the calendar below, April 4, 11, 18 and 25 are all Mondays. In Mendeleev's table, elements in the same family were in the same column.

APRIL						
S	M	T	W	T	F	S
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

Look at the left-hand blue column in the table on page 260. This column contains lithium, sodium and potassium, which all have similar properties. The number above each element is its **atomic number**—the number of protons in the nucleus, or the number of electrons surrounding the nucleus. If you begin with lithium Li (atomic number 3) and count eight elements to the right you come back to sodium Na (atomic number 11). Count another eight elements and you come to potassium K. Mendeleev's chart is called the **periodic table** because it shows a periodic (occurring at regular intervals) pattern in the elements.

Mendeleev was so convinced of the periodic properties of the elements that he left a few empty spaces in his table. He felt that none of the elements known at that time had the right properties to belong in those spaces. Instead he predicted the existence of new elements with the correct properties to fit the empty spaces. Years later his predictions were found to be correct when these new elements were discovered.

Research

Ask students to research Dmitri Mendeleev in more detail and find out more about his contributions to science. How did his contribution help with the understanding of chemistry? Did he publish his scientific findings and, if so, when? Did he work alone or with colleagues to develop his table? What other interesting information can students discover? Have students present their information as a profile of Mendeleev.

To avoid students plagiarising information from unknown sources, it may be appropriate to print off sets of information sheets about Mendeleev for them to use. This way, they will know that you will be able to check easily for copying. Also insist that students write a bibliography (in the correct format). Another way to avoid plagiarism is to allow students to present their work in a more creative way. Consider getting them to write or perform an interview with Mendeleev titled 'This is your life' for a science program or TV show. They could also write an article for a science or history textbook, write a quiz with answers about the chemist, and so on. Encourage gifted and talented students to choose two presentation methods and combine them creatively for their final assessment piece.

Learning experience

In pairs or groups of three, students could write a mnemonic for the first 20 elements of the periodic table. Alternatively, they could come up with a song or a rhyme using all 20 elements in order. Encourage them to list the elements in order so they can more easily recall the element's atomic number. The mnemonics, songs or rhymes could be written on poster paper and displayed around the room, read or sung to the class, or recorded as audio files and played or given to students so they can listen to them on MP3 or MP4 players. Listening to the audio files would be an excellent homework revision exercise. Consider starting the students with a mnemonic like '**H**appy **He**idi **Li**kes **Be**rries **B**ut **C**an **N**ot **O**ften **F**ind **Ne**ctar …' for the first 10 elements.

Learning experience

Element Memory

ScienceWorld 2 Teacher Edition (Chapter 4, page 72) suggests that students create a game of Element Memory, using the elements listed in the table. Have students make a similar game for the first 20 elements of the periodic table. Make two sets of cards—one set with the element names on them and the other set with their symbols. In pairs, the students can play a game of memory. They lay the shuffled cards out on the table, face down, and take turns to flip up two cards at a time. If they flip up the name and matching symbol, they win that pair, and so on.

Element Snap

The same cards can be used to play Element Snap. This is also played in pairs. One student should have the set of cards with the symbols, while the other student has the set of names. Each student shuffles their pack of cards. The first person to say 'Snap!' or 'Element!' wins the pair if the cards match. More advanced students could extend their packs of cards to include more elements.

The modern periodic table

Elements that have similar properties appear in the same part of the periodic table. Families of elements are in the same vertical column, called a *group*. For example, lithium, sodium and potassium belong to Group I. The horizontal rows are called *periods*. The bottom two rows are so long that elements 57 to 71 and 89 to 103 are normally taken out and placed at the bottom so that the table fits on one page.

The elements fall into two main groups—metals and non-metals. Towards the right of the periodic table you will see a red zig-zag line. The elements above and to the right of this line are non-metals. The rest of the elements (about 80% of them) are metals.

The metals on the left become more reactive as you go down a group, and less reactive as you go from left to right across the periods. So the most reactive metal of all is francium (Fr) in the bottom left-hand corner of the table. The non-metals become less reactive as you go down a group, and more reactive as you go from left to right across the periods, except for the noble gases in Group VIII. So the most reactive non-metal is fluorine (F) in Group VII.

Elements next to the zig-zag line are neither metals nor non-metals. They are called *metalloids* or *semiconductors*, because they are neither good conductors of electricity nor good insulators. Examples are boron, silicon, germanium and arsenic, which are used to make diodes, transistors and microchips for the electronics industry.

You will notice that hydrogen is shown by itself. This is because it behaves like a Group I metal in some situations and like a Group VII non-metal in other situations.

Electron shells

The electrons moving around the nucleus of an atom are not all the same. They have different amounts of energy. The electrons nearest the nucleus have least energy, while those furthest away have most. Around the nucleus are several different *energy levels* or *electron shells*. The electrons can be anywhere on the surface of these spherical shells. In the smallest atoms, hydrogen and helium, there is just one small shell close to the nucleus. Hydrogen (below) has one electron and helium has two.

<WEBwatch>

Use the internet to search for *periodic table*. You will find many different periodic tables. With most of these you can click on a particular element to obtain information about it. For one suitable website go to www.scienceworld.net.au and follow the links to:

The Visual Elements Periodic Table

Choose an element and find information on it; for example—

- when and how it was discovered
- its physical and chemical properties
- what it is used for
- how it was named
- what chemical family it belongs to.

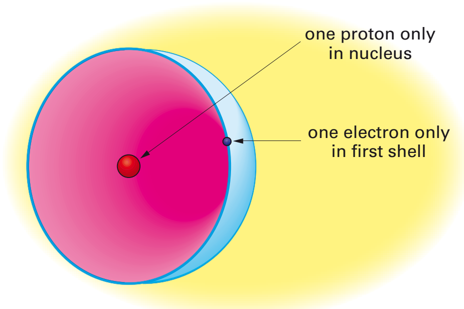


Fig 4 A cutaway view of a hydrogen atom (atomic number = 1), showing its nucleus and spherical electron shell

There is a limit to the number of electrons each shell can hold. In the inner shell there is room for only two, so if the atom has any more electrons they occupy a second shell, further from the nucleus. This second shell can hold up to eight electrons. The third shell can hold up to eighteen electrons.

Hints and tips

- If students have graphic or CAS calculators it is likely that they already have the periodic table of elements stored as an application. Be aware of this when setting chemistry tests/quizzes, especially for this topic.
- Reinforce the difference between periods and groups in the periodic table.
- Remind students that the electrons are moving around the nucleus, which contains neutrons and protons.

Learning experience

Students often like writing creative stories. Ask them to imagine they are the element they were assigned when they made their element block for the giant periodic table (see Learning experience, page 260). Using the information they gathered about their element, have them write a story titled ‘A day in the life of [element name]’. Stories need to be imaginative, yet descriptive and scientifically accurate. Students could present their work as a written response, role play or script, video, podcast or illustrated storybook.

Give a word limit of about 500 words. Students could include the following:

- a description of what they look like and how they behave at different temperatures (states of matter)
- where they are commonly found (eg in the sun, deep in the Earth, in humans, etc)
- how common they are (abundance)
- if they are considered ‘precious’
- if they are harmless or dangerous
- who some of their relatives are (same group)
- who some of their friends are (other metals, non-metals or metalloids)
- how big they are, compared to other atoms (atomic number)
- how smart they are (density)!
- what they are used for.

Learning experience

Another way to help students remember elements and their symbols or atomic numbers is to play a game of Elements Champs. Have students line up in pairs and ask each pair a question, such as:

- What is the symbol for [name of element]?
- Which element has the symbol [give a symbol]?
- Which element has an atomic number of [give a number]?
- What is the atomic number of [name an element]?

The student who gives the correct answer first wins, and lines up at the back of the row for another turn. The other student sits out of the game. This is a fun way to start or finish a lesson. Consider giving the ‘champ’ a small prize.

Homework

The Webwatch would be a good homework activity. Ask students to choose a different element from the one they wrote their story about.

The electrons in the outer shell of an atom are called the **valence electrons**. These electrons are the most easily removed, and they determine the chemical reactions of the element. Atoms like neon (below), with a full outer shell, are very stable and rarely react with other elements. This is because it takes a lot of energy to add an extra electron or take one away. They form Group VIII in the periodic table—the noble gases.

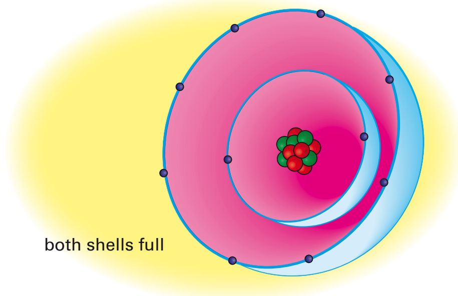


Fig 5 A neon atom (atomic number = 10)

Note that *the periodic table group number is the number of electrons in the outer shell*. For example, Group VIII elements have eight electrons in their outer shell, except for helium, which has two. Atoms like sodium (below), with one electron in their outer shell, are very reactive because this electron is easily removed, leaving the atom with a full outer shell. They form Group I—the alkali metals. All the metals in this group have a valency of 1+.

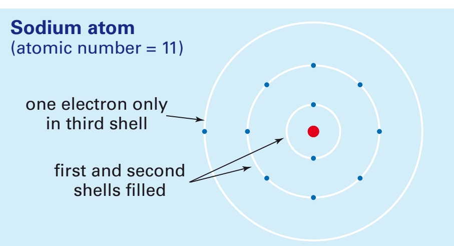


Fig 6 In chemical reactions a sodium atom tends to lose its outer electron to form a Na^+ ion. For simplicity the electron shells have been drawn in two dimensions.

Atoms like chlorine, which are one electron short of a full outer shell, are also very reactive because they readily accept another electron to fill their outer shell. They form Group VII—the halogens. All the non-metals have a valency of 1–.

When sodium reacts with chlorine to form sodium chloride, the sodium atoms lose an electron to form Na^+ ions, and the chlorine atoms gain an electron to form Cl^- ions. In this way both sodium and chlorine have full outer shells. The mutual attractive force between the positive and negative ions is an ionic bond.

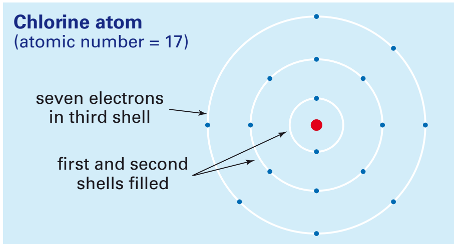


Fig 7 A chlorine atom tends to gain an electron to form a Cl^- ion with a full outer shell.

Carbon (below) has four electrons in its outer shell and therefore has a valency of 4. Rather than losing or gaining electrons to form ions, it *shares* electrons to form covalent bonds. When it reacts with hydrogen it can form four of these bonds, giving it a full outer shell of eight electrons. Hence the compound CH_4 (methane) is formed.

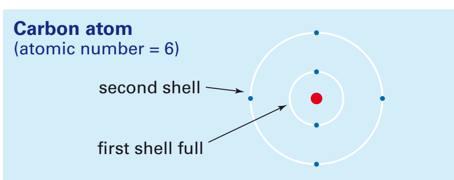


Fig 8 Carbon has 4 electrons in its outer shell and can therefore form 4 covalent bonds.

To see an animation of ionic and covalent bonds, open **Chemical bonds** on the CD. Working with technology

Hints and tips

Give the class a quick refresher lesson on how ions are formed, and ionic and covalent bonding. A quick quiz is one way to gauge areas that need further revision. The summary cards students developed in Chapter 10 (Learning experience, page 255) can be used for this chapter also. Encourage students to use and add to them.

Learning experience

Gifted and talented students could investigate how synthetic elements are made. Their explanations need to be simple and, where possible, include diagrams. A multimedia format such as PowerPoint would be a useful tool for their presentation.

Homework

An interesting task is to make a flip book showing how two atoms bond together. Students could choose to show ionic or covalent bonding. Medium-sized blocks of Post-it notes work well for this activity. A minimum of five diagrams needs to be drawn—the more diagrams drawn, the more effective the flip book will be. Those experiencing difficulties could view the Working with technology animation on the CD.

Learning experience

Information could be added to the Element Memory/Snap cards (see Learning experience, page 262). On the same side as the symbol, have students write the element's atomic number, group number and family, and electron shell configuration. These cards can then be used as a revision tool or learning aid to explain ionic and covalent bonding.

Learning experience

Dot diagrams like the ones on this page are a good way to show the electron shell configurations of atoms. Choose 5–10 elements for students to draw their own dot diagrams. They will find the task easier if they use a pair of compasses or Mathomat to draw concentric circles. For each diagram, get students to list the valency of the atom, if it is likely to lose or gain electrons, and how many electrons it needs to lose/gain/share to have a complete outer shell.

Learning experience

Gifted and talented students might like to further investigate electron shell configurations. Electrons are found in shells or energy levels numbered 1, 2, 3 and 4, and labelled K, L, M and N. How many electrons can go into each level? Why do potassium and calcium have electron shell configurations of 2, 8, 8, 1 and 2, 8, 8, 2 respectively? Is there a rule used to determine the number of electrons per shell? Have students present their findings as a poster, PowerPoint presentation or bookmark.

Check!

For most of these exercises you will need to refer to the periodic table on pages 260 and 261.

1 What does the atomic number of an element tell you?

2 What is the atomic number of these elements?
 a hydrogen c copper
 b carbon d uranium

3 Roughly sketch the periodic table. On it show where you would find:
 a metals and non-metals
 b the noble gases, the alkali metals, the halogens and the transition metals.

4 Which of the following elements are metals?

carbon	helium	radium	silicon
sodium	sulfur	titanium	tungsten

5 Use the periodic table to find at least three elements named after countries and at least three named after scientists.

6 Find calcium (atomic number 20) in the periodic table. Name three elements that are in the same family as calcium.

7 At room temperature, which of the non-metals are gases? Which are solids and which are liquids?

8 List the elements from Group IV in order of atomic number, and state whether each is a metal, non-metal or metalloid.

9 Use the periodic table to decide which three of the following elements have similar properties: aluminium, barium, calcium, chlorine, iron, magnesium, xenon.

10 Explain the difference between a period and a group in the periodic table.

11 What are valence electrons? How can they explain the different chemical properties of the elements?

challenge

1 Which would be more reactive:
 a magnesium or barium? c carbon or oxygen?
 b sodium or magnesium? d fluorine or chlorine?

2 Write a paragraph explaining how the periodic table is useful to scientists.

3 In 1996 scientists in Germany made a new element with atomic number 112. Predict which elements it is similar to.

4 Imagine that you have to learn the names of the first 10 or 20 elements. Design a jingle to help you remember. (A jingle is a sentence, sentences or rhyme to help you remember facts: for example My Very Educated Mother Just Served Us Nachos for the eight planets in the solar system.)

5 Copy and complete the table on the right for the first 20 elements in the periodic table, showing how the electrons are arranged. For each atom draw the electron shells as on page 264.

Elements	Atomic number	Number of electrons... first shell	second shell	third shell	fourth shell
hydrogen	1	1			
helium	2	2			
lithium	3	2	1		

 a Which of the first 20 elements have one electron only in their outer shell? Which group is this in the periodic table?
 b Which elements need only one electron to fill their outer shell? Which group is this? What is their valency?
 c Which elements have full outer shells? Which group do they belong to?
 d How many hydrogen atoms does oxygen need to react with to give it a full outer shell? Write the formula for the compound formed.
 e When nitrogen reacts with hydrogen, predict the formula of the compound formed.
 f Which two elements have properties similar to beryllium? How do you know?
 g Magnesium reacts with chlorine to form magnesium chloride. What is the formula for this compound?

Challenge solutions

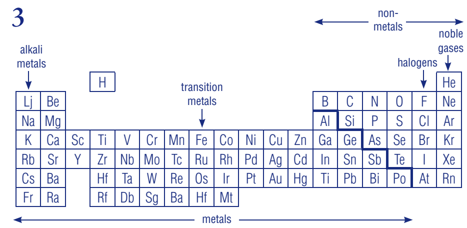
See page 332.

Check! solutions

1 The atomic number of an element tells you how many protons there are in the nucleus and how many electrons there are in each atom. It also tells you where it fits into the periodic table.

2 a The atomic number of hydrogen is 1.
 b The atomic number of carbon is 6.
 c The atomic number of copper is 29.
 d The atomic number of uranium is 92.

3



4 The following elements are metals: sodium, titanium and tungsten.

5 Elements that are named after countries include polonium, scandium, americium, francium, europium and germanium. Elements that are named after scientists include rutherfordium, curium, einsteinium and mendelevium.

6 Three elements that are in the same family as calcium are beryllium, magnesium and strontium (also barium and radium).

7 At room temperature the non-metals that are gases are nitrogen, oxygen, fluorine, chlorine, helium, neon, argon, krypton, xenon and radon. At room temperature the non-metals that are solids are carbon, phosphorus, sulfur and selenium. At room temperature the non-metal that is a liquid is bromine.

8 The Group IV elements are:

Carbon	6	non-metal
Silicon	14	metalloid
Germanium	32	metalloid
Tin	50	metal
Lead	82	metal

9 Generally, it is true that elements in the same group will show greater similarities. Magnesium, calcium and barium are all in Group II and will show similar properties.

10 A period is shown by a horizontal row on the periodic table, which means that the elements in this row have the same number of electron shells. A group is a vertical column on the periodic table, which means that the elements have the same number of electrons in the outer shell.

11 Valence electrons are those in the outer shell of the atom of an element. These electrons are gained, lost or shared in chemical reactions and this will determine how the element reacts with atoms of other elements (ie its chemical properties).

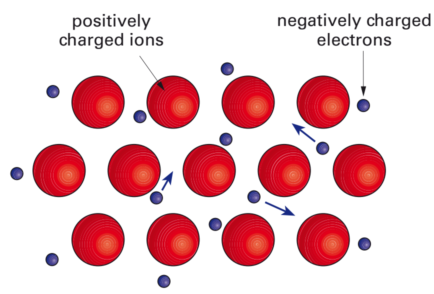
11.2 Chemical families

Metals

Metals have many properties in common. They are all good conductors of heat and electricity. They are *malleable*, meaning they can be pressed or bent into different shapes. For example, silver bars can be hammered into jewellery. Most metals also have what is called a *metallic lustre* or shine. These properties of metals can be explained in terms of their structure.

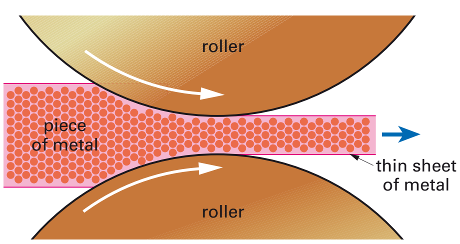
Metals conduct heat and electricity

The atoms in a metal are packed in a regular three-dimensional pattern called a *lattice*. The electrons are not firmly bound to the nuclei and can move freely in the spaces between the atoms. This is why metals conduct heat and electricity.



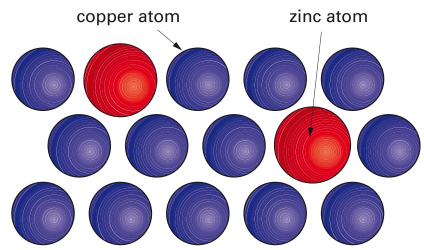
Metals are malleable

Metals can be rolled into thin sheets. This is because the layers of atoms can slide over each other and the free electrons can easily move into new positions.

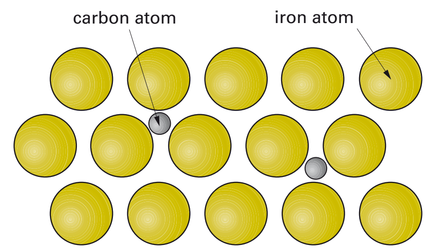


Alloys

An alloy is a mixture of two or more different metals made by mixing the molten metals together then allowing them to cool and solidify. For example, 'silver' coins are made from an alloy containing 75% copper and 25% nickel. Brass is an alloy of copper (70%) and zinc (30%). Because the zinc atoms are similar in size to the copper atoms they can take the place of copper atoms in the lattice.



In some alloys the atoms are different sizes. For example, steel is an alloy of iron and traces of carbon. In this case the carbon atoms are much smaller than the iron atoms and they fit into the gaps in the lattice.



Because gold is a soft metal, other metals such as silver and copper are added to it to make it harder; and the addition of copper produces a more orange colour (rose gold). The proportion of gold is expressed in terms of carats. Most rings and bracelets are 18 carat or 9 carat gold.

carats	24	22	18	14	9
percentage gold	100	91.7	75	58.5	37.5

Hints and tips

- Explain the difference between physical and chemical properties. Some physical properties include colour, malleability, ductility, hardness, conductivity, melting point, boiling point, solubility and density. Chemical properties include valency, and reactions with acids and bases, water and oxygen.

Learning experience

Mercury is a metal. Why is it so interesting? Get students to prepare a fact sheet about mercury. Students should include information about its physical and chemical properties, if it is toxic, how it should be handled, and so on. See if students can find out the origin of the saying 'As mad as a hatter' and how it relates to mercury. Their final presentation could be in the form of a pamphlet to accompany a mercury thermometer, or a fishing guide explaining the hazards of mercury (see Issues below).

Issues

Omega 3 fatty acids are very good for our health, and are found in foods such as oily fish. We have been encouraged to eat plenty of this type of fish because of its high omega 3 content. However, many fish contain traces of mercury, which is extremely harmful. Why is mercury so toxic to the human body? Do the benefits of eating fish outweigh the risks? Is taking an omega 3 capsule just as effective as eating fish? Is mercury harmful only to humans? In groups, get the students to discuss the issues surrounding these questions and present their ideas to the class. An issues map could be a useful tool for the students to begin their discussion.

Homework

Some cars have 'alloy' wheels. Does this name have anything to do with chemistry, or is it just a fancy name? Ask students to find out more about alloy wheels and present their findings as a leaflet for car dealerships.

Homework

At one time, lead was used in cosmetics. Ask students to find out when it was used, who used it and what the consequences were. They could present their information as a page in a book about the history of cosmetics. What other poisonous metals were used in cosmetics? Are any still being used today?

Learning experience

Draw a table listing the physical and chemical properties of metals. Students could complete the table after they have done Investigate 21. Do all metals share the same properties? Ask students to explain. What do they think *malleable* and *ductile* mean? Can students explain each property? Results from the practical investigation in Starting point, page 259, can be used to help fill in the section of the table on physical properties.

Investigate

21 METAL PROPERTIES

Aim

To test the chemical properties of metals and arrange them in the order of their chemical activity.

Materials

- small samples of various metals, eg
  aluminium, magnesium, lead, copper, tin, zinc, iron, silver
- steel wool or emery paper
- dilute **hydrochloric acid** (1M) in a dropper bottle — Corrosive
- test tubes (in test tube rack)
- **zinc sulfate** solution (saturated)
- **copper sulfate** solution (saturated) — Toxic
- ammeter or multimeter
- 4 connecting wires
- power pack
- switch

Planning and Safety Check

- Do a risk assessment for this investigation. What safety precautions will be necessary?
- Prepare a data table to record all your observations.

Method

Wear safety glasses.

Part A: Reactions with acid

1 Observe each of the metal samples. Which are tarnished (not shiny)?

2 Clean each sample with steel wool. Then put the samples in labelled test tubes.

3 Add 5 drops of dilute hydrochloric acid to each metal.

Record the rate at which bubbles of gas are formed: for example *fast*, *medium*, *slow* or *no reaction*.

4 Clean out the test tubes and wash the remaining metal samples in water. Keep them for Part C.

Part B: Reactions with metal solutions

1 Put about 5 mL of zinc sulfate in each tube.

2 Add a metal sample to each and leave for 3–5 minutes.

Record any reactions that occur. A reaction may be indicated by a dark deposit on the metal. If the metal remains shiny you can infer there has been no reaction.

3 Wash and clean the metal samples. Then repeat Steps 1 and 2 using *copper sulfate*.

Again record your results.

Discussion

1 What usually happens when you add dilute hydrochloric acid to a metal?

2 Which metals reacted with:

a all three test solutions (hydrochloric acid, zinc sulfate and copper sulfate)?

b two solutions only?

c one solution only?

d none of the solutions?

3 Put the metals in order from the most reactive to the least reactive.

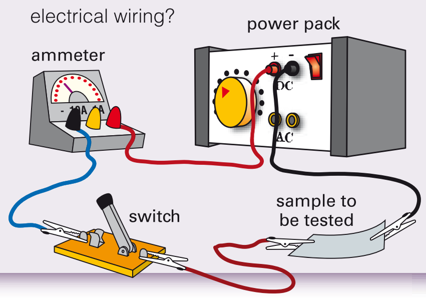
4 Suppose you wanted to make a metal tank to hold copper sulfate soultion. Which would be the best metal to use? Why?

Part C: Conductivity

1 To test the electrical conductivity of the samples, set up the electrical circuit shown. Set the power pack on 6 volts DC.

2 For each sample, record the electric current that flows.

Which metal would be best to use in electrical wiring?



Hints and tips

- Remember to monitor ESL students and check that they understand the meanings of new words and terms. Suggest they translate new words or terms into their native language.
- If students made a glossary of terms in Chapter 10 (see Learning experience, page 236), have them add to it using words from this chapter.

Lab notes

- Keep small samples of metals in labelled containers. Clear food storage containers (500 mL) are ideal.

Parts A and B

- Always use a bench mat.
- Make sure all liquids are cleaned up after each section is completed.
- Make sure the waste solids do not go down the sink.
- It is a good idea for students to wear disposable gloves when handling the solutions.

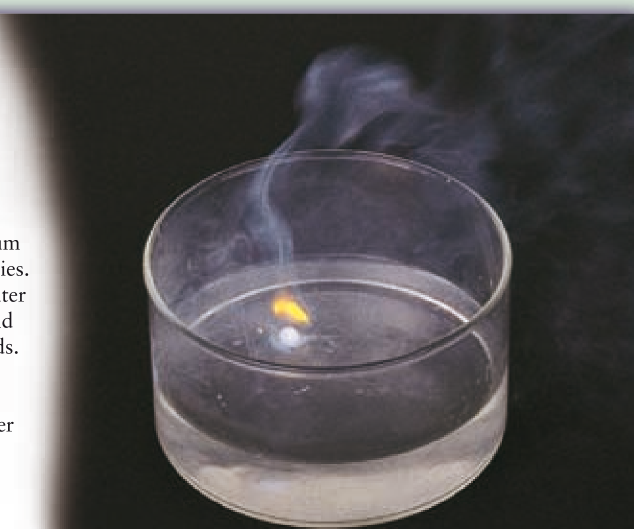
Part C

- Remind students to connect leads to the DC terminals, and to set the power pack only to 6 volts.
- Make sure switches are used in the circuit.

Reactive metals

The elements in Group I of the periodic table (lithium, sodium, potassium, rubidium, caesium and francium) are metals with similar properties. Because they have a single electron in their outer shell they are very reactive and are never found in nature as elements, only as ionic compounds. They are called **alkali metals** because they react with water to form alkaline solutions. For example, sodium reacts violently with water to form sodium hydroxide and hydrogen.

The **alkaline earth metals** in Group II have two electrons in their outer shell. They are reactive, but not as reactive as the alkali metals. They contain two of the most biologically important metals: magnesium is found in chlorophyll, and calcium is found in bones and teeth.



sodium + water → sodium hydroxide + hydrogen

$$2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$$

Fig 14 Sodium reacts violently with water. Your teacher may demonstrate this.

Investigate 22 ALKALINE EARTH METALS WITH WATER

Aim

To investigate the reactions of magnesium and calcium with water.

Materials

- 2 test tubes, test tube holder and rack
- Bunsen burner and heatproof mat
- 5 cm strip of magnesium
- small sample of calcium
- phenolphthalein
- steel wool or emery paper

Planning and Safety Check

- Do a risk assessment for this investigation. What safety precautions will be necessary?

Method

1 Clean the magnesium strip with steel wool and coil it around a pen.

2 Put the coil in a test tube and cover it with water.

3 Watch carefully over the next 5 minutes for any sign of a chemical reaction. If nothing happens, heat the tube gently over a small flame.

4 What happens when you add a drop of phenolphthalein to the test tube?

5 Add a small piece of calcium to the second test tube and cover it with water. Test the gas given off with a lit match. Add a drop of phenolphthalein.

Record your observations.

Discussion

1 Which is more reactive? Magnesium or calcium?

2 What was the gas produced when magnesium and calcium reacted with water?

3 Why did the phenolphthalein change colour?

4 Write balanced equations for the reactions of magnesium and calcium with water. See the sodium reaction above.

Learning experience

Do a teacher demonstration showing how reactive alkali metals are. You will need a fume cabinet, and very small pieces of lithium, sodium and potassium—about the size of a rice grain. The metal should be kept in paraffin oil until it is used.

Fill a pneumatic trough with water and add a few drops of phenolphthalein. Explain why the phenolphthalein was added. Using a scalpel or metal tongs, and wearing safety glasses, carefully place the lithium into the centre of the pneumatic trough. Do not get the scalpel wet. Using fresh water, repeat for sodium and then potassium.

What can students conclude from this? Which alkali metal is more reactive? What gas was given off during the reaction? Why do they think the metals have to be stored in paraffin oil? Are alkali metals likely to be found in nature as elements, or compounds? Ask them to explain.

Lab notes

- It is helpful to students if you explain the theory behind this investigation and demonstrate the purpose of phenolphthalein.
- The best way to gently heat the test tube is for students to use their fingers rather than a peg.

Learning experience

After students have watched the teacher demonstration and performed Investigate 22, ask them to write a summary listing the elements in order from least reactive to most reactive. They could construct a chart comparing and contrasting metals and non-metals. The chart could be further divided into sections for physical properties and chemical properties. Students can add to the chart as they progress through the chapter. The example here can be used as a guide.

Metals	Non-metals
Physical properties Lustre—shiny Malleable—can be beaten into thin sheets Ductile—can be stretched into wire Opaque as a thin sheet Solid at room temperature (except Hg) High melting points High density Good conduction of heat and electricity	*Physical properties*
Chemical properties Usually have 1–3 electrons in their outer shell Positive valencies—lose their valence electrons easily Form oxides that are basic	*Chemical properties*

Transition metals

The metals in the middle of the periodic table are called **transition metals**. They are hard and have high melting points. The properties of transition metals that are close together in the periodic table are often very similar. This is why they can be mixed to form alloys. Iron, cobalt and nickel, which are in the same period, have similar properties. For example, they are all magnetic. Copper, silver and gold, which are in the same group, also have similar properties. Metals near the top of the table (eg aluminium and zinc) are generally more reactive than those towards the bottom of the table (eg silver, gold and lead).

Many of the compounds that transition metals form with non-metals are coloured. For example, copper sulfate is blue and iron(II) chloride is green. This is why these compounds are used to colour glass. Copper ions give a blue colour, iron gives a green colour and gold gives a red colour. Hair colour is also determined by the presence of minute amounts of transition metal compounds. Blond hair contains titanium compounds, red hair contains iron compounds, and dark hair contains a mixture of iron, copper and cobalt compounds.

Metals give a characteristic colour to a flame, as you can see in Investigate 23.

Investigate 23 FLAME COLOURS

Aim

To observe the characteristic flame colours produced by metal salts.

Materials

- petri dish
- piece of nichrome wire, about 10 cm long
- wooden peg or test tube holder
- Bunsen burner
- saturated solutions of chlorides or carbonates of the following metals: barium, calcium, copper, potassium, sodium, strontium

Toxic

Planning and Safety Check

- Read the investigation carefully and do a risk assessment. Because the metal solutions are toxic you should wash your hands thoroughly after doing the investigation.
- Your teacher may set up six different 'stations' around the laboratory with the above materials and a different metal salt at each station.
- If the solutions are available in atomiser bottles you simply spray them into the flame.
- For Step 6 you will need an *unknown* metal salt to test.

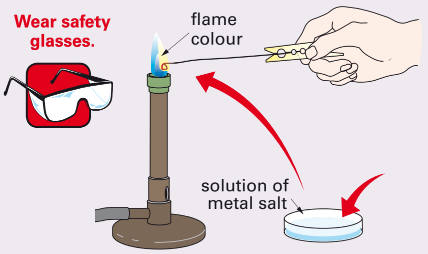
Method

1 Bend the end of the nichrome wire to form a small loop. Hold the other end with a peg.

2 Light the burner and adjust to a hot flame.

3 Dip the wire into the solution of the metal salt in a petri dish.

4 Place the wire in the edge of the flame and observe the colour.



5 Move to a new 'station' and repeat the procedure with a different metal salt.

Record the flame colours for the different metals in a data table.

6 Now that you know the colour each metal produces in a flame, your teacher will give you an unknown metal salt. Test it and infer which metal it contains.

Hints and tips

Noble metals are metals found in their elemental state (natural state) because they are unreactive. This means they do not corrode easily and are therefore often used for jewellery or for objects used in areas where corrosion is a problem. Transition metals are the ones we are familiar with. They are used for many industrial purposes and in numerous items around the home. Alkali metals and alkaline metals are usually found in compounds because of their high reactivity with non-metals.

Research

When heated, certain elements produce characteristic coloured light. The spectacular colours of fireworks come from the light emitted by excited electrons in metallic elements descending back to their normal state. Excited atoms are unstable and will give out the energy they absorbed as they return to their stable state. They release this energy as light, not as heat. Each element emits a unique colour spectrum, which can therefore be used to identify the element.

Ask students to research the chemistry of fireworks, and write an information booklet for pyrotechnics. Students should present their work in an electronic medium if possible, as the topic lends itself to the insertion of graphics, and the presentations can be visually stimulating.

Lab notes

- Copper sulfate and barium chloride are toxic and need to be handled with care.
- Safety glasses are essential, and students should wear protective gloves.
- Have the room slightly darkened so that the flame colours can be properly observed.
- If you use the wire loop for different solutions, clean it with concentrated hydrochloric acid between tests, then distilled water.
- Check that the jet of the burner is clean at the start and does not become contaminated.
- Instead of solutions, students could use powdered samples of the metallic salts. Use wooden pegs to hold a toothpick or piece of looped wire, dip it in a powder and carefully bring it close to the flame (not close enough to burn). To make the powder adhere to the toothpick or looped wire, dip the end into some hydrochloric acid (2 M) before dipping it into the powder. Repeat the process with new (clean) toothpicks or looped wire for each metallic salt.
- Remind the students not to contaminate the hydrochloric acid. (Set up a different metallic salt at each workstation with wire already looped to help minimise contamination.)

Metallic salt	Colour
Barium	Apple green
Calcium	Yellow/red
Copper	Green/blue
Lithium	Red
Potassium	Lilac (purple/pink)
Sodium	Yellow/orange
Strontium	Crimson

Fig 16 The colours of fireworks are due to transition metal compounds.

Non-metals

The non-metals are on the right of the periodic table. Many are gases at room temperature. The elements in Group VII (fluorine, chlorine, bromine, iodine and astatine) are called the **halogens**. Because they have a vacancy of one in their outer shell they have a valency of 1–. They are very reactive and form salts when they combine with metals. (The word 'halogen' means 'salt former'.) For example, chlorine reacts with sodium metal to form sodium chloride.

sodium + chlorine → sodium chloride

$$2Na(s) + Cl_2(g) \rightarrow 2NaCl(s)$$

The elements in Group VIII have a full outer electron shell. They are called the *inert gases* or **noble gases** because they do not react with other 'common' elements. Helium is used to fill balloons and as a mixture with oxygen for divers. Neon is used in neon signs and lasers because it gives a coloured light. Argon is used in light bulbs and in welding to provide an unreactive environment.

The noble gases are so unreactive that they do not even react with themselves. They are said to be *monatomic* because they consist of single atoms. The other non-metal gases form *diatomic* molecules, each consisting of a pair of atoms linked by a covalent bond; for example hydrogen H_2, nitrogen N_2, oxygen O_2, chlorine Cl_2 and fluorine F_2.

Fig 17 The red tubes in this sign contain the noble gas neon. The green, yellow and blue tubes contain argon.

Hints and tips

- As the students enter the room, hand them a card containing a word or phrase relating to the chapter (eg *periodic table*, *valence electrons*, *ionic bonding*, *covalent bonding*, *conductivity*, *alloy*, etc). When seated, randomly ask some students to read out the word/phrase on their card. In one minute, they have to define the word/term, give an example or application for it, and share any other useful information they know about it.
- Non-metals generally form molecules. Some form lattices (eg the carbon in diamond).
- The words and meanings for *monatomic* and *diatomic* can be added to student glossaries.
- Spend a few minutes revising the previous section and work from Chapter 10. Conduct a quick quiz on this earlier material, making sure to include a few open-ended thinking questions. Go through the answers immediately after the quiz so that the students have instant feedback.

Homework

Ask students to add to the compare and contrast chart they started on page 268. They may need to do further research to find out the physical and chemical properties of non-metals.

Learning experience

Colourful posters are always a good way to represent information simply. Get the class to make posters about noble gases to display around the room. Students could either make a poster about one gas or all gases. They should include information about the properties and uses of the gas(es). This activity may be further extended to include posters about all non-metals. Alternatively, a *Noble Gases* book could be made and displayed at the front of the room. Make sure it is colourful yet conveys the required information. Electronic versions could be produced.

Learning experience

A great way of engaging the students is by getting them to generate a list of questions about non-metals. For example:

- Argon gas is used in welding. Why is having an unreactive environment important when welding?
- Helium is a light gas. Are all noble gases as light as helium?
- Fluorine and chlorine are often put in drinking water. Do they form any salts in the water? Why are they added?
- Why is helium mixed in with oxygen for divers? Can too much of it be harmful?
- What advantages and disadvantages are there in the use of noble gases?
- Are all non-metals gases at room temperature?
- Which non-metal is a liquid at room temperature, and what are some of its uses?

If a question can be explored by doing a practical activity, ask them to use the 'prediction–observation–explanation–application' method. Alternatively, in small groups students could approach questions as a Round Table activity.

As you move to the left in the periodic table, the non-metals tend to form a greater number of covalent bonds. For example, molecules of white phosphorus (P_4) consist of four phosphorus atoms at the corners of a tetrahedron; and sulfur molecules (S_8) consist of eight atoms in a chair-shaped ring.

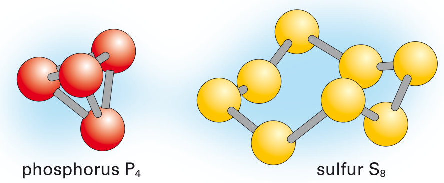
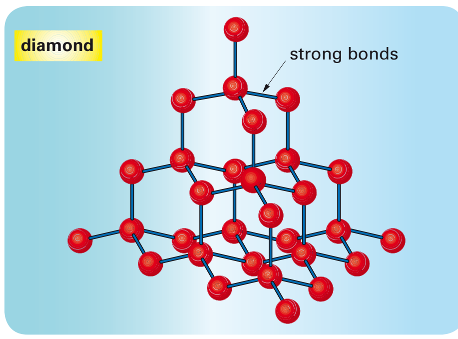


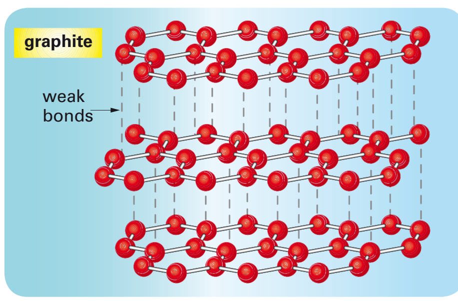
Fig 18 As you move to the left in the periodic table, the non-metals form a greater number of covalent bonds.

Some non-metals exist in different forms called **allotropes**. For example, oxygen can exist as O_2 or as O_3 (ozone), whose properties are quite different from those of O_2. Similarly, carbon can exist as diamond, graphite or charcoal (soot). Diamond is the world's hardest substance—tough, brilliantly clear and sparkling, and unaffected by heat below 700°C. On the other hand, graphite is a soft, grey, flaky material with a greasy feel. It is used as the 'lead' in pencils. Diamond and graphite are both made of carbon atoms, but their structures are different.

Fig 19 Diamond's unique properties are due to its structure of tetrahedrally bonded carbon atoms (top right).

There are no individual molecules in diamond or graphite. Instead they both consist of atoms covalently bonded to each other in a network lattice. In the diamond network each atom is linked to four others in an infinitely interlocking tetrahedral structure. It is this tight structure that makes diamond so hard.





Note: these diagrams show only part of the structure of diamond and graphite.

In graphite, however, the atoms are arranged in layers, like sheets of hexagonal tiles. Each atom links with only three other atoms, not four as in diamond, and there are therefore electrons left over. These unattached electrons drift freely between the layers like the free electrons in a metal. This is why graphite is a conductor of electricity and tends to look metallic.

Hints and tips

Students might have heard of the word *isotope*, for example, in Chapter 6. Do not confuse isotope with allotrope.

Research

'Diamonds are a girl's best friend' … but why isn't graphite, since they are both made of carbon? Before doing the theory in this section, ask students to investigate what makes diamonds and graphite different, what everyday applications each has, and if there are other forms of carbon. They might like to work in small groups and start their research with a graffiti wall to record words, terms and questions. They could present their work as an advertisement about the properties of diamonds and graphite. They should use simple explanations and neatly labelled diagrams so that a non-scientist can understand it. Encourage students to work creatively. Visual learners could draw cartoons, and those whose preferred learning style is auditory could make an audio recording.

Learning experience

A fun way to show the difference between diamond and graphite is to make a giant model structure of each. Organise the students so that some students make the graphite layers while others make the diamond lattice. Appoint one student to direct other class members on how to join the atoms together. Polystyrene balls and skewers could be used.

Hints and tips

Take a few minutes to revise and reinforce past work in this chapter before moving onto the next section. The students could write down a paragraph or jot down a series of dot points about what they have learned so far, then share it with the person next to them. You could also ask them to write down any area they found challenging, indicate if they would like it reviewed, and note down the areas that they feel they have grasped or understood. Collect their responses and evaluate what they have written.

Check! solutions

1 Four physical properties of metals are:
- they can be flattened into sheets, or are malleable
- they are generally hard and strong and melt when heated
- they are shiny, or have a metallic lustre
- they are good conductors of heat and electricity.

2 A monatomic gas is one in which the atoms do not combine with each other (eg He, Ne and Ar). A diatomic gas is one in which the atoms combine with each other in pairs (eg H_2, O_2 and N_2).

3 An allotrope is a different form of an element. Carbon exists in four different allotropes: diamond, graphite, charcoal and 'buckyballs'.

4 Graphite consists of layers or sheets of carbon atoms that are only weakly bonded together and therefore able to slide past each other. This explains why it is flaky and feels greasy.

5 The orange-red flame is a test for the metal calcium. Toni can conclude that eggshell, marble chips and garden lime contain calcium.

Graphite can be turned into diamond by squeezing it to push the layers of atoms closer together until they interlock and make diamond. But the pressure needed to make this happen is enormous, and so far only small artificial diamonds have been made this way.

Recently scientists have discovered another allotrope of carbon called *buckyballs* in which the carbon atoms are linked to form single molecules rather than a giant network. The first buckyball to be found contained 60 carbon atoms and is shaped like a soccer ball. Other shapes such as buckytubes have also been discovered.

Scientists are searching for uses for buckyballs and buckytubes. For example, it has been suggested that they could be used to make nanomachines like these gears, about a millionth of a millimetre in size. You can find out more about this by going to www.scienceworld.net.au and following the links to **Buckyballs**.

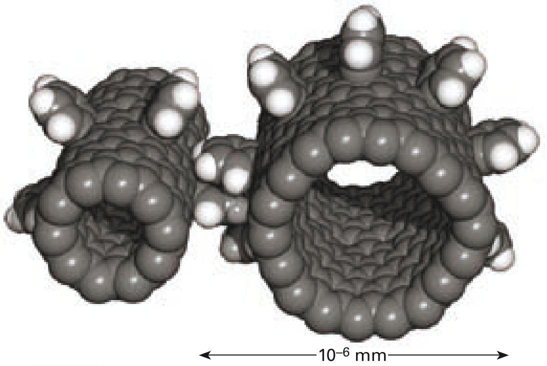


Fig 22 Buckytubes could be used to make gears in nanomachines.

Check!

1 List four physical properties of metals.

2 What is the difference between a monatomic and a diatomic gas? Give examples of each.

3 What is an allotrope? What are the names of the four allotropes of carbon?

4 Explain in terms of its structure why graphite is flaky and feels greasy.

5 Toni tested a piece of eggshell, a marble chip and some garden lime. She dissolved each in hydrochloric acid and used the solution for a flame test. In each case she observed the same orange-red flame. What can she conclude from her observations?

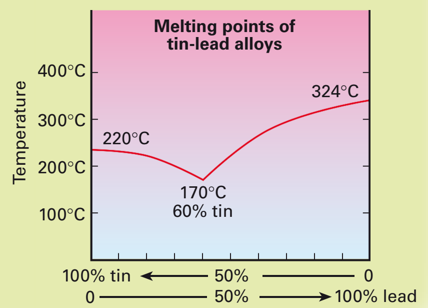
challenge

1 Suggest how buckyballs might be useful as lubricants.

2 Alloying iron with carbon makes it harder. Explain this in terms of the structure of alloys.

3 Explain the following properties of metals in terms of their structure:
   a high melting point
   b high density
   c malleable (can be rolled into sheets)

4 The graph on the right shows how the melting point of solder (a tin–lead mixture) changes as its composition changes. A 60% tin mixture gives the lowest melting point. If the percentage of tin is lower or higher than this, the solder has a higher melting point.
   a What would be the approximate melting point of an alloy of composition 25% tin and 75% lead?
   b What are the possible compositions for a solder with a melting point of 200°C?



Learning experience

Students could find out what nanotechnology is and give a presentation to the class. Some key words to investigate are *nanotubes* and *nanobots*. What possible applications do these have? What are nanotubes made of? Have students write an article for a science and technology magazine to announce the latest carbon technology. Creative students could film a TV newsflash video that could be put on YouTube, or distributed as a podcast.

Challenge solutions

1 'Buckyballs' would be useful as lubricants to reduce friction because they are very strong and would act as tiny ball bearings between two surfaces.

2 The carbon atoms are much smaller than the iron atoms and fit into the gaps in the lattice. This makes the lattice stronger and the iron harder.

3 The properties can be explained as follows:
   a Metals have a high melting point because the atoms are bonded together very tightly and require a lot of energy to pull them apart and change into the liquid state.
   b Metals have a high density because their atoms are tightly packed together in a lattice.
   c Metals are malleable (can be rolled into sheets) because the layers of positive ions can slide over each other and the free electrons can easily move into new positions. See the diagram on page 266 (bottom left).

4 From the graph:
   a The melting point of this alloy would be approximately 300°C.
   b There are actually two possible compositions. One would have about 55% tin and 45% lead, and the other would have about 70% tin and 30% lead.

11.3 Extracting metals

The pie chart below shows the main elements found in the Earth's crust. As you can see, the most common elements are the non-metals oxygen and silicon. These two elements are often combined as the compound silicon dioxide (SiO_2), found in sand and in rocks (as quartz).

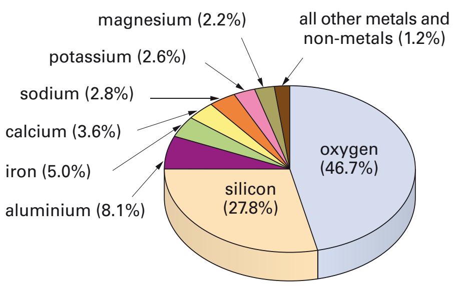


Fig 25 The composition of the Earth's crust

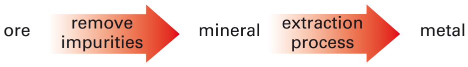
Fig 26 Gold is usually found in its uncombined state. This is the Poseidon Nugget found in central Victoria in 1906. It weighed 27 kilograms.

The metals are usually found as compounds with non-metals, although the unreactive metals such as gold can be found as elements (see Fig 26). Compounds of the reactive metals are fairly abundant: for example sodium chloride (common salt) and calcium carbonate (limestone). However, compounds of the less reactive metals such as copper, zinc, silver, tin and lead are quite rare. This is why mining companies spend so much money on exploration.

Metal compounds are called **minerals** when found in large amounts in rocks. If these rocks contain enough minerals to make it economical to mine them, they are called **ores**. The table below gives examples of ores commonly mined in Australia.

Ore	Chemical composition	Metal extracted
bauxite	aluminium oxide (Al_2O_3)	aluminium
chalcopyrite	copper iron sulfide ($CuFeS_2$)	copper
galena	lead sulfide (PbS)	lead
gold	found as element (Au)	gold
haematite	iron oxide (Fe_2O_3)	iron
pitchblende	uranium oxide (U_3O_8)	uranium
rutile	titanium oxide (TiO_2)	titanium
sphalerite	zinc sulfide (ZnS)	zinc

Before a metal can be extracted from its mineral, the impurities in the ore must be removed. One way to do this is by a process called *froth flotation*, which was developed at Broken Hill in Australia. (To see an animation of this, open the **Froth flotation** animation on the CD.) The ore is crushed and added to water in a tank. A frothing agent is added and air is bubbled through the mixture. The frothing agent attaches itself to the bits of mineral and rises to the surface as a froth. The froth containing the mineral is then scraped off and the mineral is dried, ready for the next step in the extraction process.



Hints and tips

You could ask some reflective questions at various points throughout the chapter. Questions should be focused on students' understanding and thinking, interpersonal development and personal learning. Questions could be:

- What did you learn?
- How do you know that you have learned it?
- How will you use that learning again?

Issues

'Mining is destructive to the environment and bad for human health.' Have students debate this statement. In groups, they should research the immediate and long-term effects on the environment, how communities (such as Indigenous people) and townships are affected, and how the economy is shaped by mining. What are the students' viewpoints—how do they feel about what they have researched? They could present their information as a media article, journal article, letter to the government, or as a class debate (one team for mining, and one against).

Learning experience

What ores are mined in Australia? Where are the major mines? Have the students find a map showing these details. They could highlight any sites that are relatively close to where they live.

Learning experience

Have there been any recent or well-known reports about the harmful effects of mining? What do students think about reports linking Mount Isa's mine to health issues in the Mount Isa community? Australia's BHP Billiton and the operators of the Ok Tedi copper mine in Papua New Guinea are being sued for civil damages by villagers on the Ok Tedi River. Find out more about why they are being sued. Have students summarise a news report that outlines how a group of people have been affected by mining. Alternatively, students could write their own newspaper report.

Hints and tips

Reinforce the concept of a reduction reaction, where a metallic ion in a mineral gains electrons to form the metal. Have students practise writing equations, and ask them to check if the examples given on this page are balanced.

Lab notes

Provide a bucket or other container for waste solids—do not let students dispose of waste solids down the sink.

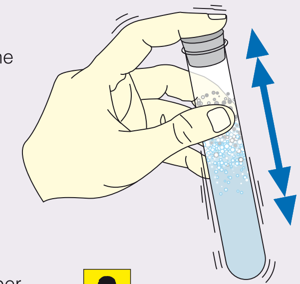
Homework

Revise words and meanings from this chapter. A good way for students to do this is in a 'match the word and meaning' worksheet that they can place in their notebooks, to be marked in class.

Investigate 24 FROTH FLOTATION

Aim

To model on a small scale the process of froth flotation.



Materials

- fine sand
- kerosene
- spatula
- liquid detergent
- watch glass
- large test tube with stopper
- powdered **chalcopyrite**, **galena** or **haematite**

Method

1 Mix a spatula of powdered mineral with the same amount of sand in a large test tube. Then half-fill the test tube with water.

2 Put the stopper in the test tube and shake it. Do the sand and the mineral separate?

3 Add 2 mL of detergent and a few drops of kerosene.

4 Shake the test tube again.

5 Use the spatula to scoop off the froth into a watch glass and check that it contains the mineral.

6 Dispose of the sand and mineral in a waste bucket at the front of the class—not down the sink.

Discussion

1 Suggest a method of obtaining dry mineral from the froth in the watch glass.

2 What happened to the sand initially mixed with the mineral?

3 Suggest ways of improving the process.

Smelting

Thousands of years ago humans managed to extract metals without any idea of the chemical reactions involved. The metals were probably first extracted by accident, when rocks containing the ore were thrown on a fire and the new metal was observed the following day. From this, early humans worked out that two things were needed—heat and charcoal (carbon). Many metal ores are oxides, and we now know that when a metal oxide is heated with carbon, the oxide is converted to the metal. At the same time the carbon combines with the oxygen from the oxide to form carbon dioxide. For example, lead is extracted from lead oxide.

$$2PbO(s) + C(s) \rightarrow 2Pb(s) + CO_2(g)$$

This process is called **smelting** and the metal in the ore is said to be *reduced*, because it gains electrons. Hence the extraction of a metal from its ore is called *reduction*. The equation for the reduction of lead ore is:

$$Pb^{2+}(s) + 2e^- \rightarrow Pb(s)$$

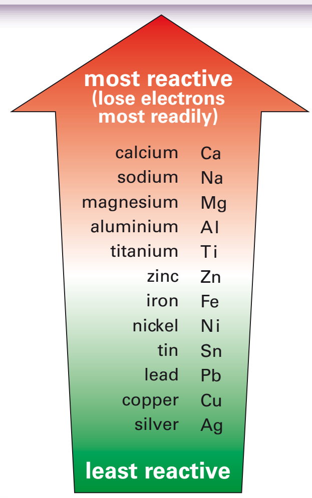


Fig 29 The metals can be listed from the most reactive to the least reactive. This is called the *activity series*. The metals at the top are harder to extract than the ones at the bottom. Do your results from Investigate 21 on page 267 agree with this?

Learning experience

For section 11.3, have students construct a flow chart showing the different processes of extracting metals from ores. At the end of each extraction process, they should list the metals that are extracted this way. Is there an association between the steps in the chart and the activity series? Are the more reactive metals more costly to extract? Ask them to explain. Alternatively, students could convey the same information by drawing cartoon concepts for each extraction process.

The ore of iron is iron oxide (Fe_2O_3). The iron can be extracted in a *blast furnace*. In Australia there are blast furnaces at Port Kembla in New South Wales, Whyalla in South Australia and Kwinana in Western Australia. A mixture of iron oxide, coke (made from coal), and limestone is fed into the top of the furnace. Very hot air is blasted in near the bottom, causing the coke to burn and form the gas carbon monoxide. The carbon monoxide then reacts with the iron oxide, reducing it to iron.

$$2C(s) + O_2(g) \rightarrow 2CO(g)$$

$$Fe_2O_3(s) + 3CO(g) \rightarrow 2Fe(s) + 3CO_2(g)$$

The molten iron collects in the bottom of the furnace, where it is tapped off from time to time, as shown in Fig 30 below. Impurities in the ore combine with the limestone to form slag, which floats on the molten metal. The slag is used as a road-surfacing material or in cement manufacture. The molten iron is converted to steel in another furnace.

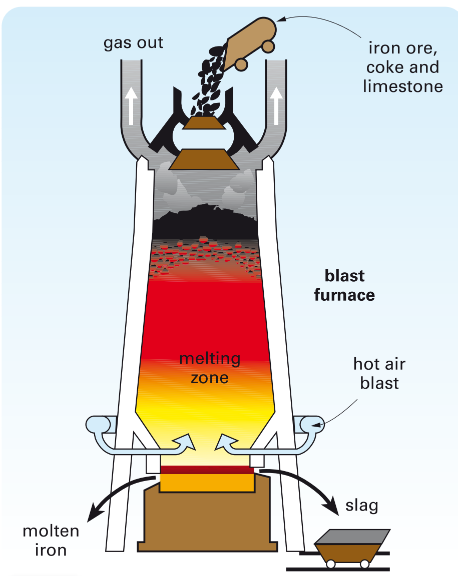


Fig 30 Smelting in a blast furnace

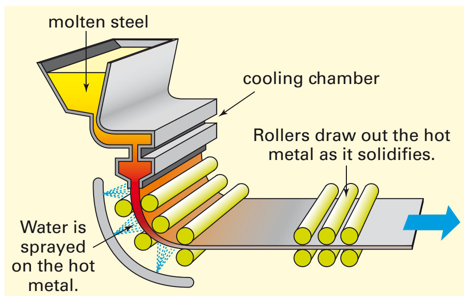


Fig 32 The molten steel is rolled into flat sheets and cut into sheets or rolled up as in the photo.

Copper can be extracted from its ore by 'roasting'. The chalcopyrite $CuFeS_2$ is converted to copper sulfide Cu_2S which then reacts with oxygen, forming copper metal and the gas sulfur dioxide.

$$Cu_2S(s) + O_2(g) \rightarrow 2Cu(s) + SO_2(g)$$

In the past copper producers built high chimneys to release the poisonous sulfur dioxide into the atmosphere. The high chimneys were used to avoid producing dangerous levels of the gas at ground level where people could be affected. However, high levels of sulfur dioxide in the atmosphere can cause acid rain. For this reason environmental laws now require producers to collect the sulfur dioxide and use it to make sulfuric acid or fertiliser.

Hints and tips

An interesting revision tool is to get students to interview class members about the chapter so far. They should share their thinking and ask questions about the topic. Groups of three work best. Students take on the roles of interviewer, reporter and interviewee within each group, then rotate roles after each interview. What would they like to know more about? Which areas did they find challenging and why? Collect their responses for evaluation.

Homework

In 2006, the Beaconsfield mine in Tasmania made headline news. Why? Is the mine still operating? What is mined there?

Learning experience

Choose some Australian mines, and ask students to find out which metal is being extracted and the type of process used. Can they find any 'virtual mining' websites that they can share with the class?

Hints and tips

Students could construct a spider map or sunshine wheel about extracting metals, or for this chapter as a whole. Alternatively, the spider map could be divided in half so that four 'legs' are assigned for metals and the other four for non-metals. This activity doesn't have to be limited to theoretical concepts. Emotions, viewpoints and thoughts about the topic could also be explored. The maps could also incorporate points from Chapter 10.

Activity notes

- Warn students about using silver nitrate, as it stains easily. Make sure they wear gloves when handling the solution.
- Conical flasks and a cork stopper could be used as an alternative to the test tube. Loosely coil the wire and push one end into the stopper to hold it in place.

Electrolysis

The copper from a copper smelter is only about 98% pure, but it can be made 99.9% pure by the process of **electrolysis** (ee-lek-TROL-e-sis), where electricity is used to produce chemical reactions. The impure copper is made into a thick plate which is connected to the positive terminal of a power source. A thin plate of pure copper is connected to the negative terminal. Both plates are then placed in a bath of copper sulfate solution and sulfuric acid. As the current flows through this solution, the impure copper dissolves and pure copper is deposited on the thin plate in a reduction reaction.

$$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$$

The 'mud' that falls to the bottom of the bath contains less reactive metals such as silver and gold which can be recovered. The process uses considerable electricity, so the copper refinery must be close to a source of abundant, cheap power. This is why copper produced in the smelter at Mt Isa in Queensland is shipped to Townsville for refining.

More reactive metals such as aluminium and magnesium cannot be extracted by smelting, but can be obtained by electrolysis. For example, to produce aluminium, the ore (aluminium oxide) is melted and electricity passed through it.

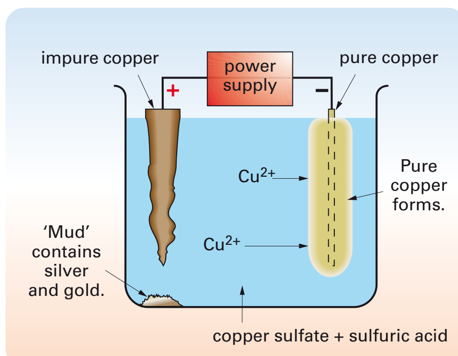


Fig 33 Purifying copper by electrolysis

Displacement

In Investigate 21 Part B (page 267) you put magnesium in copper sulfate solution. Did you find that copper fell to the bottom of the test tube? This reaction is called *displacement*, because the more reactive magnesium displaced (pushed out) the less reactive copper from the copper sulfate solution. This method is used to extract some metals. For example, titanium is displaced from titanium chloride solution by adding magnesium.

$$TiCl_4(aq) + 2Mg(s) \rightarrow Ti(s) + 2MgCl_2(aq)$$

The titanium and the magnesium swap places. The magnesium metal goes into solution as magnesium chloride, and the titanium comes out of the solution as the metal.

Activity

You will need a test tube and rack, silver nitrate solution, 15–20 cm of copper wire and a pen.

Toxic

1 Three-quarters fill the test tube with silver nitrate solution. **Be very careful not to spill any as it stains hands, clothing and benches.**

2 Twist the copper wire around a pen to make a spiral, with a bit left over to make a hook. Put it in the test tube, hooking it over the lip of the tube.

3 Leave the test tube in a dark cupboard overnight. In the morning observe what has happened.

What new substances have been formed?

Write a word equation for the reaction that has occurred, then a balanced symbol equation.

Learning experience

Are there alternatives to mining ores for metal extraction? What recycling programs have been implemented to reduce metal wastage? It is cheaper to recycle aluminium than it is to produce new aluminium. Do students' households recycle their cans?

Gold is used in electronic circuitry. Ask students to find out what steps have been taken to recycle it. What other recycling programs are there for metals? Are there any in the school's vicinity?

Learning experience

Maths enthusiasts might like to find out what the current prices of metals are and prepare a bar graph to show the class.

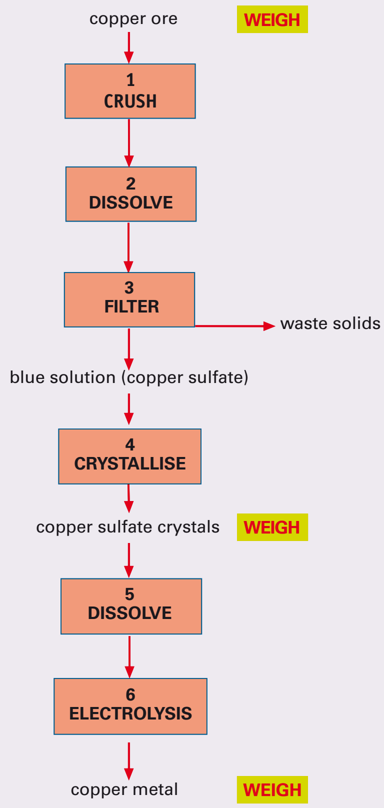
Investigate 25 COPPER METAL FROM COPPER ORE

Aim
To extract copper sulfate and copper metal from a simulated ore.

Materials
- copper ore made by mixing copper sulfate, sand and plaster of Paris, adding water and allowing to set
- balance
- mortar and pestle
- 2 beakers or conical flasks
- filter funnel and stand
- filter paper
- burner, tripod and gauze
- watch glass
- hand lens
- spatula
- sodium chloride
- stirring rod
- power pack
- strips of lead and copper
- 2 connecting wires
- steel wool

Wear safety glasses.

Wear a lab coat or apron.

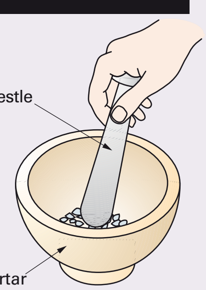


Planning and Safety Check
This is a complex investigation which will take several days. You will need to work carefully so that you don't lose any copper.
- In a group, describe what you will be doing in each of the six steps shown in the flow diagram on the right.
- When will you need to weigh things?
- What safety precautions will be necessary?

Method
1 CRUSH

a Use a balance to find the mass of the ore to start with.

b Crush the ore thoroughly in a mortar using a pestle (PES-el) until it is a powder.



2 DISSOLVE

Put the crushed ore in a beaker. Add enough water to dissolve it when you heat it for 5 minutes.

What is the colour of the mixture?

3 FILTER

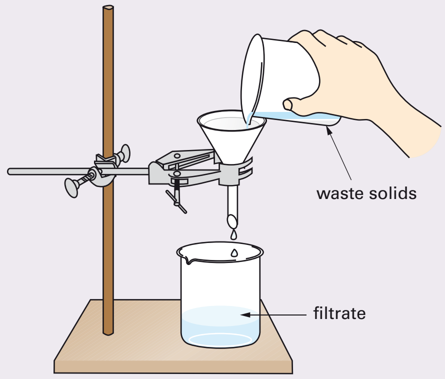
a Let the mixture cool for a few minutes while the solid settles.

b Decant the mixture through filter paper in a filter funnel. Keep as much of the solid as possible in the beaker because it may clog the filter paper. (Fluted filter paper is faster.)

Lab notes
- The copper ore should be made a few days ahead of time.
- This investigation works well, but only if the instructions are followed carefully. It is a good idea to read the method together as a class and allow time for questions. This will help minimise errors.
- In step 1, the ore must be crushed to a powder.
- In step 3, filter paper works better if it is fluted.

Lab notes

- The partly processed materials may need to be labelled and stored between lessons.
- In step 6:
  - — It is very important to thoroughly clean the metal strips with steel wool.
  - — Make sure students connect the lead electrode to the positive terminal and the copper electrode to the negative terminal.



c Rinse the solid left in the beaker with a further 10 mL of water, and filter this rinse water as well.

What is the colour of the filtrate? What is it?

What are the solids left in the filter paper? (Discard the filter paper and waste solids into a bin.)

4 CRYSTALLISE

a Boil the copper sulfate filtrate until only a few millilitres remain. Turn off the burner and leave the beaker until the crystals that form are dry.

b Scrape all the crystals onto a watch glass and weigh them.

Describe the copper sulfate crystals. (Use a hand lens.)

c Calculate your percentage yield as follows:

$$\% \text{ yield} = \frac{\text{mass of copper sulfate}}{\text{mass of ore}} \times 100$$

5 DISSOLVE

a Dissolve the copper sulfate in water. Stir to make sure it is completely dissolved.

b Add a spatula of sodium chloride. This is to help the solution conduct electricity in the next step.

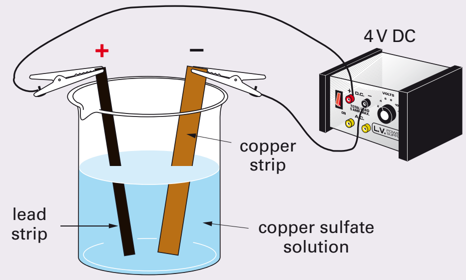
6 ELECTROLYSIS

a Thoroughly clean a strip of lead and a strip of copper with steel wool.

b Weigh the copper strip.

c Set up the electrolysis apparatus as shown below, with the lead connected to positive and the copper to negative.

d Set the power pack to 4 volts DC and turn it on.



At which electrode is copper deposited?

What happens at the other electrode?

What happens to the solution?

e When the solution is clear, or after 15 minutes, switch the power pack off.

f Remove the copper strip, wash it and leave it to dry. Then weigh it again.

Calculate the mass of copper deposited. (If there is any copper in the bottom of the beaker you need to collect and weigh it too.)

Calculate the percentage of copper in the copper ore you started with.

Discussion

1. Suggest why the ore had to be crushed before any processing was done.
2. Describe how the copper mineral was separated from the worthless material in Steps 2 and 3.
3. Why was the solution boiled in Step 4?
4. In which steps did the process need an input of energy?
5. Suggest a use for the waste solids from Step 3.
6. How accurate do you think your percentage of copper is? Explain.
7. Could you improve your method to get a higher percentage of copper? How?

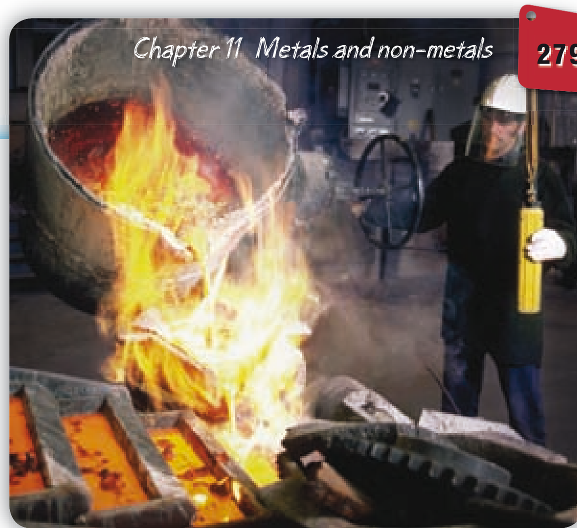


Fig 39 Pouring molten steel in a steelworks

Check!

1 Use the table below to answer these questions.
  a How is copper extracted from its ore?
  b Which elements are in bauxite? Chalcopyrite?
  c Which metal is found as an element rather than as a compound?
  d Why is there a blank space for the method of extracting gold?
  e Which is the most reactive element in the table? (See Fig 29 on page 274.)
  f Infer which is the most difficult metal to extract.
  g Suggest reasons for the order in which the four metals were first extracted.

Metal	Main ore	Method of extraction	First extracted
aluminium	aluminium oxide (bauxite)	electrolysis	19th century
iron	iron oxide (haematite)	smelt with coke (carbon)	1500 BC
copper	copper iron sulfide (chalcopyrite)	heat ore in air	3000 BC
gold	found uncombined		5000 BC or earlier

2 Use the pie chart on page 273 to answer these questions.
  a Which is the most common non-metal in the Earth's crust?
  b Which is the most common metal?
  c What does the pie chart tell you about commonly used metals such as copper, lead, zinc and silver?

3 Aluminium is the most abundant metal in the Earth's crust, but it is not the cheapest. Suggest why.

4 Write a chemical equation for the smelting of copper oxide using carbon. (See page 274.)

5 Would you expect miners to find nuggets (lumps) of magnesium metal? Explain your answer.

6 Four minerals—A, B, C and D—have the following properties:
  A is soluble in acid
  B is insoluble in acid, and floats in a water frothing agent mixture
  C is insoluble in water and in acid
  D is magnetic
  Use this information to work out how you could separate each mineral from a mixture containing all four.

7 Why is it that one Cu^{2+} ion combines with two electrons?

8 Write down at least three uses for copper.

9 In what ways do the mining of metal ores and the extraction of metals affect the environment?

1 Using the table given:
  a Copper is extracted from its ore by heating it in air.
  b The mineral bauxite contains the elements aluminium and oxygen. The mineral chalcopyrite contains the elements copper, iron and sulfur.
  c Gold is usually found in an uncombined state as an element rather than as a compound.
  d There is a blank space because gold is found uncombined as a metal and does not need to be extracted.
  e The most reactive metal in the table is aluminium.
  f The most difficult metal to extract is aluminium.
  g The metals are listed (down) in order of decreasing activity and also greater time since extraction. This can be explained because the less reactive metals are not as tightly combined with non-metals to form the minerals. It is therefore easier to conduct a chemical reaction to remove the non-metallic atoms to produce the metals.

2 Using the pie chart on page 273:
  a The most common non-metal in the Earth's crust is oxygen.
  b The most common metal in the Earth's crust is aluminium.
  c The chart tells you that these metals are quite rare in the crust of the Earth.

3 Aluminium is not the cheapest because it is a very reactive metal. This means it is very strongly bonded to oxygen in bauxite and requires considerable electrical energy to separate the atoms in a process called electrolysis. This electricity costs a lot of money.

4 The equation is: $2CuO(s) + C(s) \rightarrow 2Cu(s) + CO_2(g)$

5 You would not expect to find nuggets of magnesium because it is a very reactive metal and will react with water and gases in the air to form compounds like MgO and $MgCO_3$.

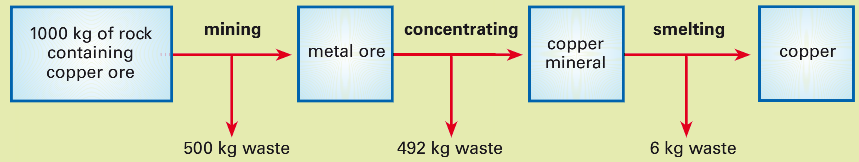
6 The best way to separate each mineral from a mixture containing all four would be to:
  1 Pass the mixture over a strong magnet, which will attract mineral D but not the others.
  2 Mix with acid, filter and then evaporate the filtrate to obtain mineral A.
  3 Mix the remainder with acid and a frothing agent and bubble air through it. The froth containing mineral B can be scraped off and then dried.
  4 C should remain after separating out the other three minerals.

7 Because each copper atom has lost two electrons to become a copper ion with two positive charges, it will need to combine with two electrons to become a neutral atom again.

8 Three uses of copper are electrical wiring, as alloys (brass and bronze) and pipes for carrying water and gas.

9 The mining of ores can affect the environment in several ways. Native vegetation is often removed and not always replaced after the mine is closed. In addition, mining requires large amounts of fuel for machinery and produces wastes that go into the air, soil and water and cause pollution. The extraction of metals can also affect the environment because gases like sulfur dioxide and carbon dioxide are produced. These gases cause air pollution and may cause acid rain, water pollution and even add to the 'greenhouse effect'. In addition, the solid waste materials need to be disposed of, usually as landfill, and these areas take a long time to revegetate.

challenge



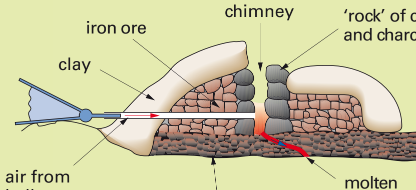
1 The flow chart above shows the extraction of pure copper from rock containing copper ore.
   - **a** From each tonne (1000 kg) of rock from the mine, how much of the following do you obtain:
     - metal ore?
     - copper mineral?
     - copper?
   - **b** From each tonne of rock mined, how much is waste?
   - **c** How would this waste be disposed of?
   - **d** What is the average percentage of copper in the mined rock?
   - **e** The average percentage of copper in the Earth's crust is 0.005%. Suggest why copper cannot be extracted from ordinary rocks.

2 Which non-metals are commonly found combined with metals in metal ores?

3 When a metal oxide is heated with carbon, a metal is produced. What happens to the oxygen from the oxide? Explain using an example and write an equation.

4 **a** Which ions were present in the blue solution in Step 6 of Investigate 25? Which ions were attracted towards the negative copper strip?
   - **b** Write an equation for the reaction that occurred at the copper strip.
   - **c** When you add an iron nail to copper sulfate solution a displacement reaction occurs (see page 276) and the blue colour disappears. Explain what displacement is and write an equation for the reaction.
   - **d** Objects made of iron exposed to water seeping from copper mines become coated with copper. Explain why this happens.

5 The diagram below shows how iron was extracted from its ore by people in Africa thousands of years ago. How is this similar to the blast furnaces used today? How is it different?



try this

1 Use library resources to research a metal of your choice. Make sure you find out:
- where in Australia the metal is found
- what the metal is used for
- the ore from which the metal is extracted
- how and where the metal is refined
- its possible impact on the environment.

Display your findings, for example on a poster.

2 See if you can design a process to extract copper from a mixture of sand and copper oxide, which is insoluble in water.

Check your plan with your teacher, then try it. Record what you do and what happens.

Challenge solutions

1 Referring to the flow chart:
   - **a** From each tonne of rock you would obtain:
     - 500 kg of metal ore
     - 8 kg of copper mineral
     - 2 kg of copper metal.
   - **b** For each tonne mined there is 998 kg of waste.
   - **c** The waste is normally disposed of by putting it back in the mine.
   - **d** Copper is about 0.2% of the mined rock.
   - **e** Copper is not normally extracted from ordinary rocks because the percentage of copper is so low. The extraction process would cost more than what the copper metal is worth.

2 The non-metals that are normally combined with metals are oxygen and sulfur.

3 The oxygen from the oxide combines with the carbon to form carbon dioxide. This equation shows an example:

$$2PbO + C \rightarrow 2Pb + CO_2$$

4 Referring to Investigate 25:
   - **a** The blue copper sulfate solution contains Cu^{2+} and SO_4^{2-} ions. It will also contain H^+ and OH^- from the water. The ions attracted to the negative electrode are the positive ones, which are Cu^{2+} and H^+.
   - **b** The reaction that occurs at the copper electrode is:
     $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$
   - **c** When the iron nail was added to the solution, it displaced the copper from the solution because iron is more reactive. This explains the disappearance of the colour, which was due to copper ions in the solution. The equation for the reaction is:
     $Cu^{2+} + SO_4^{2-} + Fe(s) \rightarrow Cu(s) + Fe^{2+} + SO_4^{2-}$
   - **d** This happens because iron is more reactive than copper and will displace it from solution and cause it to be deposited on iron objects, as explained in **c** above.

5 The similarities are that air is forced over the iron ore, the furnace is surrounded by an insulating material, charcoal is present and the molten iron is drained off at the bottom. The differences are that the African furnace is not as large or mechanised, does not get as hot, would not be as efficient and does not use limestone to remove impurities.

MAIN IDEAS

Copy and complete these statements to make a summary of this chapter. The missing words are on the right.

1 Elements can be divided into two groups: metals and ______.

2 The ______ is a way of classifying elements according to their ______. Elements with similar properties are grouped together. It is extremely useful in explaining and predicting the ______ and reactions of elements.

3 The electrons in an atom are arranged in shells around the nucleus. The number of ______ in the outer shell determines the chemical properties of the element.

4 The number of electrons lost or gained by an element determines its ______. For example, alkali metals have a valency of 1+ and ______ have a valency of 1–.

5 All metals conduct heat and are malleable. Some are more ______ than others.

6 Metals can be extracted from their ______ by smelting, ______ or displacement.

7 During the extraction of a metal the positive ions in the mineral ______ electrons to form metal atoms.

atomic number
electrons
electrolysis
gain
halogens
non-metals
ores
periodic table
properties
reactive
valency

Try doing the Chapter 11 crossword on the CD. Working with technology

REVIEW

1 In the periodic table, all the gases except hydrogen are:
A in the first period
B in the first group
C in the same family
D on the right-hand side

2 Use the periodic table on pages 260 and 261 to predict which one of the following elements has properties different from the other three.
A aluminium
B barium
C calcium
D radium

3 A sample of lead could be obtained in the laboratory by:
A heating lead oxide very strongly
B heating lead oxide with carbon
C adding gold to lead nitrate solution
D adding dilute sulfuric acid to lead carbonate

4 Air Pollution Control finds that a smelter is producing excessive levels of poisonous sulfur dioxide gas. What would you suggest be done?
A Shut down the smelter.
B Convert the sulfur dioxide into useful substances.
C Shift the smelter into the desert.
D Cut down production in the smelter so that less sulfur dioxide is produced.
E Increase the height of the smelter's chimneys.
Say why you rejected the other alternatives.

5 An impure copper sample contains a silver impurity. During electrolytic refining of this sample:
a what happens to the copper?
b what happens to the silver?

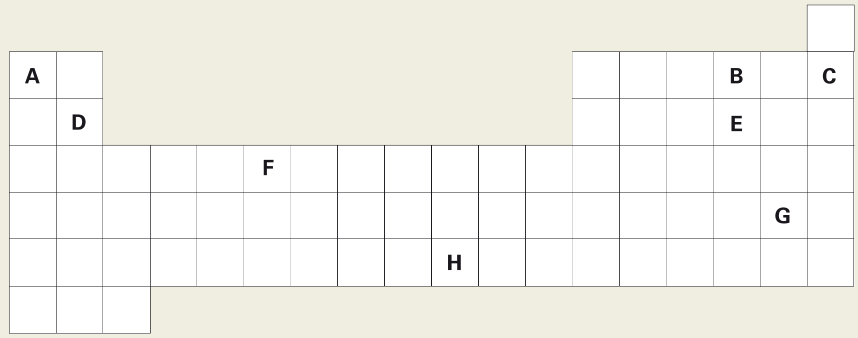
Main ideas solutions

1 non-metals
2 periodic table, atomic number, properties
3 electrons
4 valency, halogens
5 reactive
6 ores, electrolysis
7 gain

Review solutions

1 D
2 A
3 B—see pages 274 and 275
4 B—would seem to be the best alternative
A—could have serious effects on the economy
C—expensive and only shifts the problem elsewhere
D—only decreases the size of the problem
E—not a long-term solution and the SO_2 is still being released into the atmosphere
(Different people may have different opinions.)
5 **a** The copper goes into solution as copper ions Cu^{2+} which move to the negative terminal, where they accept electrons to form copper metal. (See Fig 33 on page 276.)
b The silver is very unreactive and simply falls to the bottom of the container.

REVIEW



6 In the periodic table above some elements have been replaced by letters. Use the letters to answer these questions. Find:
- **a** the two elements that are in the same group
- **b** two elements that are in the same period
- **c** the two elements that are gases at room temperature
- **d** the elements that are metals
- **e** the two transition metals
- **f** the element that is a noble gas
- **g** the element that is an alkali metal
- **h** the element that is a halogen
- **i** two elements that are likely to react.

7 Platinum exists as an uncombined element in nature. Copper can exist uncombined but more commonly occurs as a compound. Zinc is always found as a compound.
- **a** Arrange the three metals in order from most reactive to least reactive.
- **b** Which metal would be the best to polish and use as a mirror? Why?

8 Imagine that you are searching for two undiscovered elements with atomic numbers 117 and 118. Use the periodic table on pages 260 and 261 to predict the chemical properties of each of these elements.

9 Prepare a flow chart showing the sequence of processes used to convert copper ore (chalcopyrite) to copper metal suitable for electrical wiring.

10 Explain in terms of their chemical structures why copper is a good conductor of electricity and diamond is an insulator.

11
- **a** Copy and complete the table below using the information on pages 263 and 264.
- **b** Which element has six protons in its nucleus?
- **c** Which element has all its electron shells full?
- **d** How many valence electrons does sodium have?
- **e** Which elements are likely to gain or lose one electron?

Element	Symbol	Atomic number	Number of electrons in		
			first shell	second shell	third shell
hydrogen carbon neon sodium chlorine					

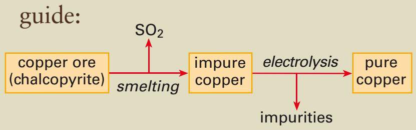
Check your answers on pages 338–339.

6
- **a** B and F
- **b** A, B and C; or D and E
- **c** B and C
- **d** A, D, F and H are all metals
- **e** F and H are transition metals
- **f** C
- **g** A
- **h** G
- **i** The reactive metals on the left of the periodic table (A and D) are likely to react with the non-metals on the right (B, E and G).

7
- **a** zinc (most reactive), then copper, and then platinum (least reactive)
- **b** Platinum would make the best mirror because it does not corrode and hence its surface stays shiny.

8 If you go to the last element (111) in the periodic table and start numbering to the right, element 117 fits into group VII. You would therefore expect it to be very reactive, like the other halogens in Group VII. Element 118 fits into Group VIII so you would expect it to be unreactive, like the other noble gases in Group VIII.

9 Using the flow chart on page 280 as a guide:



10 In copper the electrons are not firmly bound to the atomic nuclei and can move freely in the spaces between the atoms (see page 266). Hence copper is a good conductor of electricity. In diamond all four of carbon's valence electrons are involved in strong covalent bonds with other carbon atoms (see page 271). Hence diamond does not conduct electricity.

11
- **a**

Element	Symbol	Atomic number	No. of electrons		
			1st shell	2nd shell	3rd shell
hydrogen	H	1	1		
carbon	C	6	2	4	
neon	Ne	10	2	8	
sodium	Na	11	2	8	1
chlorine	Cl	17	2	8	7

- **b** carbon
- **c** neon
- **d** 1
- **e** hydrogen, sodium and chlorine