N5

National 5 CHEMISTRY

BrightRED PUBLISHING

BrightRED Study Guide

Curriculum for Excellence

N5 CHEMISTRY

REVISED AND UPDATED FOR SQA CHANGES

BrightRED DIGITAL ZONE

Don't forget to check out the BrightRED Digital Zone

NEW EDITION

INTRODUCING NATIONAL 5 CHEMISTRY

This course allows you to develop a wide range of life and scientific skills that will equip you for a future of changing challenges. Its structure provides you with opportunities to develop and extend a wide range of chemistry-focused skills, while helping you to develop an understanding of chemistry's role in the scientific issues that affect society.

THE BENEFITS OF NATIONAL 5 CHEMISTRY

The course is split into three units, each with a real-life theme. The course content will help you to develop knowledge and understanding of the chemistry around you. There will be plenty of opportunity to develop skills of scientific inquiry, as well as investigative and analytical thinking skills, within a chemistry context. Experimental work will allow development of planning and practical skills as well as building an awareness of safety considerations.

The National 5 course is a way to greatly enhance your understanding of the chemistry affecting your everyday life, while developing skills that will help you unravel the scientific issues affecting society and support you in many aspects of your life.

There is quite a lot to come to terms with in this course but, broken down as it is here, it is fairly straightforward. So, what is the structure?

THE EXTERNAL ASSESSMENT

At the end of the course you will be assessed externally by two components:

Component 1 – Question Paper (80% of total mark)

This involves a two-hour question paper in which:

- 25 marks are allocated to an objective test
- 75 marks are allocated to the written paper, which will include questions requiring a mixture of short (restricted) and extended answers.

The majority of marks are given for demonstrating and applying knowledge and understanding. The other marks will be given for applying scientific inquiry, analytical thinking skills.

The question paper will sample skills, knowledge and understanding of the key areas listed below.

The key areas are:

- rates of reaction
- atomic structure and bonding related to properties of materials
- formulae and reacting quantities
- acids and bases
- systematic carbon chemistry
- everyday consumer products
- energy from fuels
- metals
- plastics
- fertilisers
- nuclear chemistry
- chemical analysis.

These key areas may be grouped together into three units: Chemical Changes and Structure, Nature's Chemistry and Chemistry in Society.

In addition, there will be two open-ended questions in the paper. Each question will be awarded 3 marks and can be recognised by the phrase 'using your knowledge of chemistry'. The question will not directly assess knowledge taught during the course. Instead you are to

cont

use the knowledge you do have to suggest possible answers. There is no correct answer and marks will be awarded according to whether you have shown that you have a 'good' (3 marks), 'reasonable' (2 marks) or 'limited' (1 mark) understanding of the chemistry in the question.

A data booklet containing relevant data and formulae will be provided.

The question paper will be written and marked by the Scottish Qualifications Authority (SQA).

Component 2 – Assignment (20% of total mark)

The assignment will be an in-depth study of a chemistry topic chosen by you. You will investigate and research the underlying chemistry of the topic as well as the impact the topic has on society or the environment.

There will be 20 marks awarded for the assignment (and this will be scaled to 25) and the majority of these will be awarded for applying scientific inquiry and analytical thinking skills. The other marks will be awarded for applying knowledge and understanding relating to the topic.

The assignment will assess skills such as handling and processing of data gathered from an experiment and research data that cannot be assessed through the question paper.

There are two stages to the assignment.

First stage – Research

This will be carried out under some supervision and control and during this stage you will:

- agree a topic with your teacher
- agree an aim – you will be given advice to help you choose a suitable aim
- carry out an experiment which allows measurements to be made
- undertake research using websites, journals and/or books to provide data and information that can be used to compare with your experimental results.

Second stage – Report

This will be carried out under a high degree of supervision and control and a maximum of 1 hour and 30 minutes is allowed. It is marked externally by SQA. Your report should include:

- an aim
- chemistry knowledge and understanding relating to the topic
- a description of the experiment
- data from your experiment – both raw and processed, including graphical representation
- data from an internet or literature source along with a reference
- analysis of your results
- conclusion
- evaluation.

During the report stage you will only be allowed to take in:

- the Instructions for Candidates
- your raw experimental data
- the internet or literature data
- information on the underlying chemistry
- the experimental methods.

HOW WILL THIS GUIDE HELP YOU MEET THE CHALLENGES?

The aim of this book is to help you achieve success in the final exam by providing you with a concise coverage of the key areas of the course. Helpful hints are provided throughout the book in the 'Don't forget' features, while there are plenty of opportunities to practise applying your knowledge through 'Things to do and think about' and the online tests. Some of the skills you will be expected to demonstrate are also covered in the book. These may be in with the relevant key areas or covered in separate sections.

ONLINE

This book is supported by the BrightRED Digital Zone! Head to www.brightredbooks.net/N5Chemistry and discover a world of tests, videos, activities and more!

FORMULAE AND REACTION QUANTITIES: THE MOLE 4 – EQUATIONS AND CALCULATIONS

Space shuttle

VIDEO LINK

Check out the clip 'Calculating Moles from a Balanced Chemical Equation' at www.brightredbooks.net/N5Chemistry.

ONLINE TEST

Take the test at www.brightredbooks.net/N5Chemistry.

DON'T FORGET

These calculations will always involve just two of the substances in the equation. It is very important to correctly identify the substances that the question refers to. This is done by selecting the substances for which a mass is given and for which a mass is to be found.

DON'T FORGET

Whichever method you choose, remember to show all your working. This is true for any chemistry calculation. If you are not careful it is easy to make mistakes. An incorrect answer *on its own* will receive no marks. Partial marks will be awarded if correct working is shown.

WHAT DO EQUATIONS TELL US?

Chemical equations tell us what substances are reacting and what substances are produced. Additionally, a balanced chemical equation indicates the mole ratio in which the substances react or in which they are produced. This point is very important in chemistry. It allows chemists to determine the actual quantities of chemicals required in a reaction and how much product will be produced.

The large orange external tank on the space shuttle actually has two smaller tanks inside it. The larger of these contains liquid hydrogen. The smaller tank contains liquid oxygen. The reaction of hydrogen with oxygen produces the power required to lift the shuttle. NASA scientists know that hydrogen reacts with oxygen in a two mole to one mole ratio because they know the balanced equation for the reaction:

$2H_2 + O_2 \rightarrow 2H_2O$

Two moles of hydrogen react with one mole of oxygen to produce two moles of water. As a consequence, the tanks are designed to hold at least twice as much hydrogen as oxygen.

MASS CALCULATIONS

You must be able to calculate the mass of a reactant or product in a reaction given the balanced chemical equation.

EXAMPLE 1

Iron(III) oxide reacts with carbon to produce iron and carbon dioxide:

$2Fe_2O_3 + 3C \rightarrow 4Fe + 3CO_2$

Calculate the mass of carbon that will react with 1·6 g of iron(III) oxide.

Step 1 – Select the required chemicals and write down the number of moles of each as they appear in the balanced equation:

$2Fe_2O_3 \leftrightarrow 3C$

2 moles ↔ 3 moles

Step 2 – Convert the given mass into a number of moles.

moles of $Fe_2O_3 = \frac{\text{mass}}{\text{GFM}} = \frac{1{\cdot}6}{160} = 0{\cdot}01\,\text{mol}$

Step 3 – Use the mole ratio from the equation to find the number of moles of the substance asked for in the question.

2 moles ↔ 3 moles

$0{\cdot}01 \leftrightarrow (\frac{3}{2}) \times 0{\cdot}01 = 0{\cdot}015\,\text{mol}$

Step 4 – Convert the number of moles into mass.

mass of $C = n \times \text{GFM} = 0{\cdot}015 \times 12 = 0{\cdot}18\,\text{g}$

This calculation shows that 0·18 g of carbon is needed to react with 1·6 g of iron(III) oxide.

Alternative method for Example 1

Step 1 – Select the required chemicals and write down the number of moles of each as they appear in the balanced equation.

$2Fe_2O_3 \leftrightarrow 3C$

2 moles ↔ 3 moles

Step 2 – Convert the moles into masses.

contd

$2[(2 \times 56) + (3 \times 16)] \leftrightarrow 3 \times 12$

$= 320\,\text{g} \leftrightarrow = 36\,\text{g}$

Step 3 – Use the mass given in the question to find the mass of the unknown by simple proportion.

$1{\cdot}6\,\text{g} \leftrightarrow (\frac{1{\cdot}6}{320}) \times 36$

$= 0{\cdot}18\,\text{g}$

EXAMPLE 2

Ethanol (C_2H_5OH) burns in oxygen to produce carbon dioxide and water:

$C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$

Calculate the mass of carbon dioxide produced when 11·5 g of ethanol is burned in excess oxygen.

Step 1 – Select the substance for which a mass has been given (ethanol) and for which a mass has to be found (carbon dioxide).

$C_2H_5OH \leftrightarrow 2CO_2$

1 mole ↔ 2 moles

Step 2 – Calculate the number of moles of ethanol.

$\text{mol} = \frac{\text{mass}}{\text{GFM}} = \frac{11{\cdot}5}{46} = 0{\cdot}25\,\text{mol}$

Step 3 – Use the mole ratio from the equation to find the number of moles of carbon dioxide.

1 mole ↔ 2 moles

$0{\cdot}25 \leftrightarrow 0{\cdot}25 \times 2 = 0{\cdot}5\,\text{mol}$

Step 4 – Calculate the mass of carbon dioxide.

$\text{mass} = n \times \text{GFM} = 0{\cdot}5 \times 44 = 22\,\text{g}$

An alternative method for Example 2

$1\,\text{mol} \rightarrow 2\,\text{mol}$

$46\,\text{g} \rightarrow 88\,\text{g}$

$11{\cdot}5\,\text{g} \rightarrow \frac{(11{\cdot}5 \times 88)}{46}$

$= 22\,\text{g}$

THINGS TO DO AND THINK ABOUT

1 Sodium reacts with chlorine to produce sodium chloride.

$2Na + Cl_2 \rightarrow 2NaCl$

(a) How many moles of sodium react with one mole of chlorine?

(b) How many moles of sodium chloride are produced from six moles of chlorine?

(c) How many moles of sodium chloride are produced from five moles of sodium?

2 Magnesium reacts with dilute hydrochloric acid to produce hydrogen gas.

$Mg + 2HCl \rightarrow MgCl_2 + H_2$

Calculate the mass of magnesium needed to produce 100 g of hydrogen.

3 Methane (CH_4) is a major component of natural gas. Calculate the mass of carbon dioxide produced when 32 kilograms of methane are burned.

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

DON'T FORGET

Equation calculations will often state that one of the reactants is in excess. Notice that in this example the oxygen was in excess. As the quantities of the other substances in the reaction cannot be determined from the excess reactant, it should be ignored in the calculation.

DON'T FORGET

Occasionally this type of question may involve kilograms or tonnes of chemical rather than grams. In examples of this kind, the method used in the calculation will not change. However, the final unit will need to be altered. For example, in the ethanol example, using 11·5 kilograms of ethanol would produce 22 kilograms of carbon dioxide and using 11·5 tonnes of ethanol would produce 22 tonnes of carbon dioxide.

ONLINE

Try out more calculations at www.brightredbooks.net/N5Chemistry.

NATURE'S CHEMISTRY

EVERYDAY CONSUMER PRODUCTS

THE IMPORTANCE OF HYDROCARBONS

Hydrocarbon compounds and substituted hydrocarbon compounds are involved in many aspects of our lives.

If we look at a typical morning routine we can see the range and variety of carbon-containing compounds that impact on our lives.

Before you are even awake you will be interacting with carbon-based products. The bed linen you are lying on is likely to be made from a thread that is hydrocarbon based, the alarm clock that wakes you up is likely to contain plastic – plastic materials are based on hydrocarbon compounds. Read more about the important role plastics play in the Chemistry in Society chapter (page 82). The shampoo or shower gel that you use in the shower will contain hydrocarbon-based compounds.

If you have a look around your house you will come across many examples of hydrocarbon-based consumer products. As well as shampoos and other soaps, other personal care products that contain hydrocarbon-based compounds include conditioners, deodorants and cosmetics.

OTHER IMPORTANT COMPOUNDS

There are many compounds containing carbon and hydrogen that are used in our everyday lives. In many ingredients lists there are alcohol compounds and acid compounds listed. These are, again, large families containing many different compounds and their structure and properties will be looked at in more detail later on.

Alcohols

The **alcohol** that most people are aware of is ethanol, which is the alcohol present in alcoholic drinks.

As well as drinks, alcohol compounds are used in a wide variety of commercial products. Benzyl alcohol, for example, is added to many products as it can add fragrance and also acts as a solvent and a preservative. Alcohols are used in skin toners as they can help to dissolve oils.

Alcohols are also good at killing bacteria and so are now commonly used in disinfectant wipes and hand gels.

Carboxylic acids

One of the best-known members of the **carboxylic acid** family is ethanoic acid. One of its most common uses is in vinegar. Carboxylic acids, like alcohols, are also used as preservatives.

Citric acid is another carboxylic acid. It occurs naturally in large quantities in lemons, oranges and limes. It is also listed in the ingredients of shampoo and nail varnish. It is added as a preservative but can also be added to help adjust the pH of the product.

ONLINE TEST

What do you know about the chemistry of everyday consumer products? Test yourself online at www.brightredbooks.net/N5Chemistry.

WHAT ARE ALCOHOL MOLECULES?

Alcohols are a group of compounds based on hydrocarbons that all have a hydrogen atom replaced with the –OH group (**hydroxyl**). We have already seen that they have many uses in our everyday life including alcoholic drinks and as disinfectants.

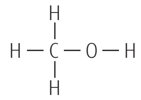
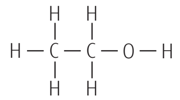
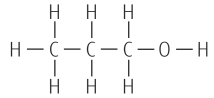
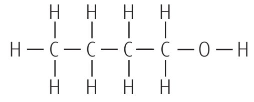
The alcohol in drinks is called ethanol. Its name does not end in **-ane**. This is because there is an OH group in the molecule, which means that it is not part of the alkane homologous series. The **-an-** in the middle of the name tells us that there are only carbon-to-carbon single bonds in the molecule.

Another major use for alcohols is in making esters.

contd

STRAIGHT-CHAIN ALCOHOLS

Let us look at the first four members of the straight-chain alcohols family.

Alcohol	Full structural Formula	Shortened structural formula	Molecular formula
methanol		CH_3OH or CH_3–OH	CH_3OH
ethanol		CH_3CH_2OH or CH_3–CH_2–OH	C_2H_5OH
propanol		$CH_3CH_2CH_2OH$ or CH_3–CH_2–CH_2–OH	C_3H_7OH
butanol		$CH_3CH_2CH_2CH_2OH$ or CH_3–CH_2–CH_2–CH_2–OH	C_4H_9OH

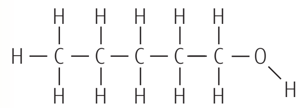
The **-ol** ending is used to identify the presence of the –OH functional group, which characterises the alcohols.

The **general formula** for the straight-chain alcohols is $C_nH_{2n+1}OH$.

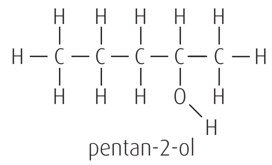
You may have realised that for the alcohols propanol and butanol there is a choice of carbon atoms to the hydroxyl (OH) group is attached.

Let us look at two straight-chain isomers of pentanol.

The position of the hydroxyl group is denoted using the number and as with naming branched chain alkanes and alkenes, the carbon atoms are numbered in such a way as to give the carbon atom with the hydroxyl group the lowest number.



pentan-1-ol



pentan-2-ol

PROPERTIES OF ALCOHOLS

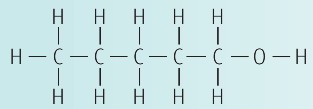
The smaller, straight-chain alcohols are miscible (soluble) in water. Methanol, ethanol and propanol are completely miscible in water. As the carbon chain of the alcohol increases the solubility of the alcohol decreases. Similar to alkanes, alkenes and cycloalkanes, as alcohols increase in size, their melting and boiling points also increase due to the increasing strength of the intermolecular forces.

Alcohols are used as solvents. Their presence in skincare products such as facial washes and toners is in part due to their ability to dissolve the oils present on the skin.

Alcohol compounds are highly flammable and so can be used as fuels. They have the added advantage that they burn with a much cleaner, less sooty flame than hydrocarbon fuels. A common example that you may have come across is in some camping stoves. Ethanol, made from fermenting renewable plants, is also becoming used more widely as a fuel for vehicles.

THINGS TO DO AND THINK ABOUT

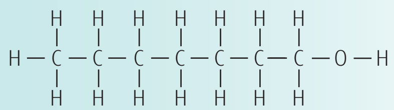
1 Name the following alcohols:

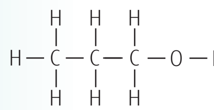
(a) 

(b) $CH_3CH_2CH_2CH_2CH_2CH_2OH$ (c) $C_7H_{15}OH$

2 Draw full and shortened structural formulae for: (a) octanol (b) $C_6H_{13}OH$

3 For the examples below, write a shortened structural formula and name the compound:

(a) 

(b) 

DON'T FORGET

The -OH functional group is known as the hydroxyl functional group.

ONLINE

For another look at this, check out the 'Uses of Alcohols' link at www.brightredbooks.net/N5Chemistry.

DON'T FORGET

Fermentation is the reaction that is catalysed by enzymes in yeast and converts the sugar from plant sources into ethanol.

CHEMISTRY IN SOCIETY

METALS: EXTRACTION OF METALS

Gold metal trapped in rocks

DON'T FORGET

Unreactive metals are found at the bottom of the reactivity series.

DON'T FORGET

An element is a substance made up of one kind of atom. An element cannot be broken down into anything simpler.

DON'T FORGET

The term reduction can also be used to describe a reaction in which there is a loss of oxygen.

DON'T FORGET

Reactivity series – potassium, sodium, lithium, calcium, magnesium, aluminium, zinc, iron, tin, lead, copper, silver and gold.

DON'T FORGET

Oxygen gas, O_2, is diatomic.

VIDEO LINK

Watch the clip 'Reduction of copper oxide' at www.brightredbooks.net/N5Chemistry.

ONLINE TEST

Take the test 'Metals: extraction of metals' at www.brightredbooks.net/N5Chemistry.

METAL ORES

Metals such as gold and silver are unreactive and are found uncombined in the Earth's crust as the metallic element.

Most metals are found in the ground combined with other elements in the form of **ionic** compounds called **ores**. An ore is a naturally occurring metal compound found in rocks or underground.

Examples of ores are shown in the table:

Name of ore	Metal compound found in the ore
haematite	iron oxide
bauxite	aluminium oxide
iron pyrite (fool's gold)	iron sulfide

EXTRACTION OF METALS

A metal can be extracted from its ore. Extraction involves separating the metal from the other elements found in the ore. During the extraction, the metal ion is reduced to form the metal atom. The method used to extract a metal depends on the position of the metal in the reactivity series (see page 70).

- Extracting metals from ores is an example of a **reduction** reaction.
- The metal ore is reduced to the metal.

REDUCTION

- Reduction is a term used to describe reactions that involve the gain of electrons.
- Reduction of a metal occurs whenever a metal compound breaks up into its elements.
- The metal in the ore is in the form of a positive ion.
- Metal ions must gain electrons to become metal atoms. For example, when aluminium metal is extracted from its ore, the aluminium Al^{3+} ion in the ore must gain three electrons to form an aluminium atom: $Al^{3+} + 3e^- \rightarrow Al$

METHODS OF EXTRACTION

Using heat alone (silver and gold)

Metals that are unreactive, such as silver and gold, can be found as oxides. They can be extracted easily from the oxide using heat alone. Heat energy is sufficient to break the ionic bonds, allowing the metal to be extracted: $2(Ag^+)_2O^{2-}(s) \xrightarrow{heat} 4Ag(s) + O_2(g)$

Each of the silver ions gains an electron to become a silver atom: $Ag^+ + e^- \rightarrow Ag$

Where do these electrons come from? When extracting metals from their ores the ionic bonds break and the metal and non-metal ions form atoms. Remember earlier in the course, when you learned about ionic bonding:

- Metal atoms usually lose electrons to form positive metal ions.
- Non-metal atoms usually gain electrons to form negative non-metal ions.

When extracting metals from their ores the opposite happens – the ionic bond breaks and the metal and non-metal ions form atoms.

The electrons that the non-metal atom gained from the metal atom in the formation of the ions are returned. The metal ions gain electrons to form metal atoms and the non-metal ions lose electrons to form non-metal atoms.

contd

Each oxide ion loses two electrons to form an oxygen atom, which will join with another to form an oxygen molecule: $2O^{2-}(s) \rightarrow O_2(g) + 4e^-$

Heating with carbon or carbon monoxide (copper, lead, tin, iron and zinc)

Heat alone is not sufficient to provide the energy required to extract metals found in the middle of the reactivity series from their ores. Instead, the ores must be heated with a **reducing agent** such as carbon or carbon monoxide. The carbon or carbon monoxide removes the oxygen from the ore and is **oxidised** to carbon dioxide.

The ionic equation for this reaction is: $2Cu^{2+}O^{2-}(s) + C(s) \rightarrow 2Cu(s) + CO_2(g)$

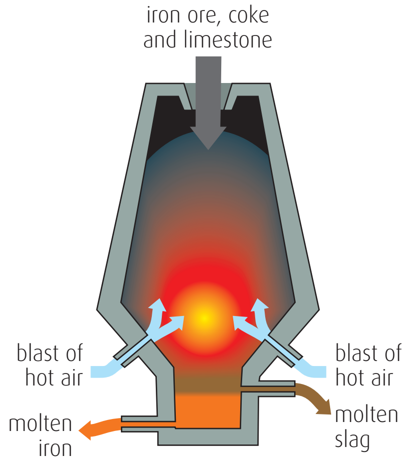
Carbon reduces the copper oxide to copper metal and in the process is oxidised to carbon dioxide gas.

Extracting iron metal

Iron metal is extracted from its ore (haematite, Fe_2O_3) in a blast furnace.

Iron ore, coke (a form of carbon) and limestone (calcium carbonate) are added to the blast furnace. It is called a blast furnace because of the blasts of hot air that are used to increase the temperature inside the furnace and also to supply oxygen.

The carbon (coke) reacts with this oxygen to form, in the first instance, carbon dioxide, which then further reacts with more of the carbon to form carbon monoxide, which is a reducing agent. The carbon monoxide reacts with the iron oxide (ore), reducing it to iron metal and is itself oxidised to carbon dioxide gas.



The high temperatures in the furnace produce the extracted iron in the form of a **molten** liquid.

The ionic equation for this reaction is: $(Fe^{3+})_2(O^{2-})_3(s) + 3CO(g) \rightarrow 2Fe(s) + 3CO_2(g)$

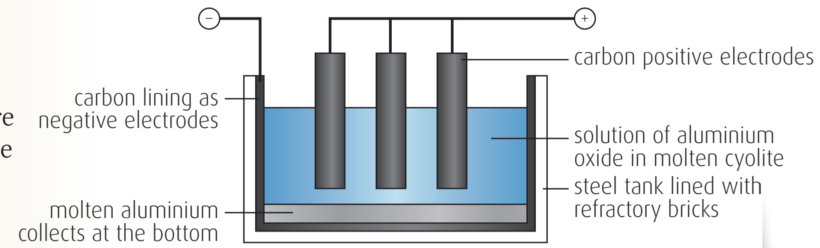
The iron (Fe^{3+}) ion is reduced to an iron atom. The carbon monoxide gains oxygen to become carbon dioxide. A reaction like this is called a **redox** reaction because both reduction and oxidation are taking place.

Electrolysis of molten ore (aluminium, magnesium, calcium, lithium, sodium and potassium)

Very reactive metals are strongly bonded in their ores and cannot be extracted using carbon/carbon monoxide. More energy is required and this is provided by **electrolysis**. Electrolysis is a process that separates an ionic compound into its elements using electrical energy (electricity).

Aluminium metal is extracted from its molten ore (bauxite Al_2O_3) using electrolysis.

Electrolysis requires a d.c. (direct current) supply, which produces a positively charged electrode and a negatively charged electrode. When electricity is passed through the molten ore, the positive ions are attracted to the negative electrode and the negative ions are attracted to the positive electrode.



Reaction at the negative electrode

Aluminium ions gain electrons (reduction) to form the metal atoms, as shown in the following ion electron equation: $Al^{3+}(l) + 3e^- \rightarrow Al(l)$

Reaction at the positive electrode

Oxygen ions lose electrons (oxidation) to form oxygen gas: $2O^{2-}(l) \rightarrow O_2(g) + 4e^-$

THINGS TO DO AND THINK ABOUT

1 Write an ion-detection equation for the reduction Sn^{2+} ions.

2 Cassiterite (SnO_2) is an ore containing tin. Calculate the percentage composition of Cassiterite which is tin.

ONLINE

Work your way through the electrolysis process online by checking out the 'Electrolysis of aluminium oxide' link at www.brightredbooks.net/N5Chemistry.

VIDEO LINK

Check out the clip of a blast furnace at www.brightredbooks.net/N5Chemistry.

DON'T FORGET

In solid ionic compounds, ions are arranged in a crystal lattice and are not free to move. When melted (molten) the lattice breaks and the charged ions are free to move around.

BrightRED Study Guides

NEW EDITION

Curriculum for Excellence

N5 CHEMISTRY

Shona Scheuerl, Shona Wallace and Robert West

This BrightRED Study Guide is just the thing you need to tackle your course and gain the exam skills essential to succeed at National 5 Chemistry. Written by trusted subject experts and experienced Chemistry teachers Shona Scheuerl, Shona Wallace and Robert West, this book is packed with brilliant examples, tasks and advice. It is the ultimate companion to your studies.

- **Contains all of the essential course information**, arranged in easily digestible topics.
- **Designed in full colour, highly illustrated, accessible and engaging** to make sure all that study sticks!
- ***Don't forget!*** pointers offer advice on key facts and on how to avoid common mistakes.
- ***Things to do and think about*** sections at the end of each topic allow for further practice and research.
- **Worked examples** show you how to approach a range of concepts and questions.
- **A glossary of key terms** helps you really learn and revise important course concepts.

Let BrightRED lead you to success in your National 5 studies and beyond!

REVISED AND UPDATED FOR SQA CHANGES

BrightRED

ISBN 978-1-906736-95-8

9 781906 736958