CfE HIGHER CHEMISTRY

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BrightRED Study Guide

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CHEMISTRY

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BRIGHTRED STUDY GUIDE: HIGHER CHEMISTRY

INTRODUCING HIGHER CHEMISTRY

The Higher Chemistry course is divided into four sections:

- Chemical Changes and Structure
- Nature's Chemistry
- Chemistry in Society
- Researching Chemistry

THE BENEFITS OF HIGHER CHEMISTRY

Next time you visit a large supermarket, look around you. Not a product in the shop, from the paper bags used to collect organic mushrooms to the electronic goods on offer, has been produced without the hard work and help of chemists. Behind the scenes, chemists are working on all sorts of projects to keep us all supplied with the food and products we need. They could be creating fertilisers to help crops grow, formulating new types of ice-creams, developing shower gels or even designing higher performance rechargeable batteries for your mobile phone. This Higher Chemistry course equips you with the knowledge to understand what these chemists do, and even begins to equip you with the concepts and skills required to develop new products and work out how they can be manufactured for maximum commercial profit.

In Chemical Changes and Structure you will learn about the fundamental ideas of bonding and intermolecular forces. These ideas allow chemists to understand and predict the properties of materials from their formulae. Nature's Chemistry highlights the chemistry of key families of naturally occurring compounds. It shows you how chemists can design and manufacture novel compounds to bring the public exciting new products. Chemistry in Society allows you to understand how to take an idea for a product from the lab into commercial production. By understanding equilibrium, enthalpy, percentage yield and atom economy, chemists can turn a manufacturing process from one that could be making a financial loss, to an immensely profitable operation. Researching Chemistry allows you to develop the skills required to carry out chemical research.

Whether you choose to follow a chemistry related career or not, Higher Chemistry is highly regarded by all employers as this course also develops numeracy and problem-solving skills and starts to build a good awareness of commercial considerations in manufacturing. The course will also allow you to better understand the chemistry behind the products you buy.

THE EXTERNAL ASSESSMENT

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

Component 1: Question paper 1: multiple choice – 17% of total mark

This is involves a question paper of 40 minutes duration with a total allocation of 25 marks.

The majority of the marks will be awarded for applying knowledge and understanding. The other marks will be awarded for applying scientific inquiry, scientific analytical thinking and problem-solving skills.

Component 2: Question paper 2 – 63% of total mark

This is a question paper of 2 hours and 20 minutes duration with a total allocation of 95 marks. The majority of marks will be awarded for applying knowledge and understanding. The other marks will be awarded for applying scientific enquiry, scientific analytical thinking and problem-solving skills.

contd

In addition, there will be two open-ended questions in the written 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 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.

Component 3: Assignment – 20% of total mark

The assignment has two stages – a research stage and a communication stage and in the course of the assignment you are required to:

- choose a relevant topic in chemistry
- state appropriate aim(s)
- research the topic by selecting relevant data/information
- carry out a risk assessment of procedure(s)
- process and present relevant data/information
- analyse data/information
- state conclusions
- evaluate your investigation
- explain the underlying chemistry of the topic researched
- present the findings of the research in a report.

The research stage will be conducted under some supervision and control and the communication stage will be conducted under a high degree of supervision.

There will be 20 marks allocated to the assignment 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 related to the topic chosen.

HOW WILL THIS GUIDE HELP YOU MEET THE CHALLENGES?

The aims of the Higher Chemistry course include developing your curiosity, interest and enthusiasm for chemistry in a range of contexts and we hope that this book helps you to meet these aims. Using this book should also help equip you with some understanding of the importance of chemistry in everyday life.

However the main aim of this book is to help you achieve success in the SQA exam by providing you with a concise coverage of the key areas of the course. Helpful hints are provided in the "Don't forget" features

The "Things to do and think about" and the online tests should also help you develop other skills you will be expected to demonstrate in the exam. These skills include applying what you have learned to new situations and being able to analyse information and solve problems.

DON'T FORGET

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

DON'T FORGET

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

ONLINE

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

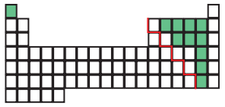
PERIODICITY 2

DON'T FORGET

Atoms in a covalent bond are held together by the electrostatic forces of attraction between positively charged nuclei and negatively charged shared electrons.

COVALENT ELEMENTS

Most non-metallic elements can form covalent bonds. Covalent bonds are formed by the merging or overlapping of half-filled outer electron clouds between the positive nuclei of two atoms. The positive nuclei of both atoms attract the electrons in the overlap region and this is what holds the two atoms together.

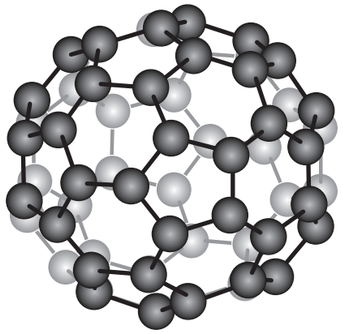


COVALENT MOLECULAR ELEMENTS

Covalent molecular elements are made up of molecules. A **molecule** is a group of atoms held together by covalent bonds.

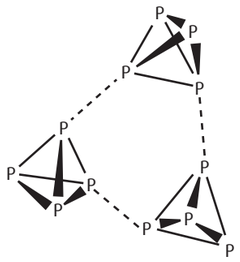
Elements 1–20 with covalent molecular structures include:

- hydrogen, H–H; nitrogen, N≡N; oxygen, O=O; fluorine, F–F; and chlorine, Cl–Cl
- phosphorus, with P_4 molecules
- sulfur, with S_8 molecules
- carbon, in its fullerene form, with molecules such as C_{60}.

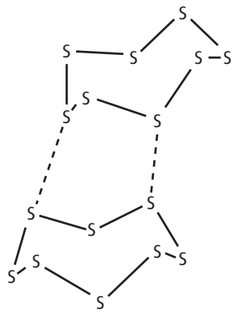


Fullerenes are molecular forms of carbon. This one, with 60 atoms, has 360 electrons in each molecule, so the boiling point is relatively high.

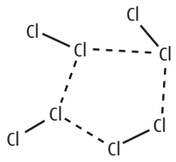
Elements which have covalent molecular structures have low melting and boiling points because there are only very weak London dispersion forces between the molecules. Some of these must be overcome at the melting point when the solid becomes a liquid and all of them have to be overcome at the boiling point when the liquid changes to a gas. The strong covalent bonds inside the molecules are not broken at the melting or boiling points of the elements.



P_4 molecules
Four atoms × 15 e^- per atom
60 electrons in each molecule
Boiling point 280°C



S_8 molecules
Eight atoms × 16 e^- per atom
128 electrons in each molecule
Boiling point 445°C



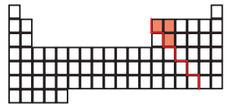
Cl_2 molecules
Two atoms × 17 e^- per atom
34 electrons in each molecule
Boiling point −35°C

VIDEO LINK

Learn more by watching the clip at www.brightredbooks.net

DON'T FORGET

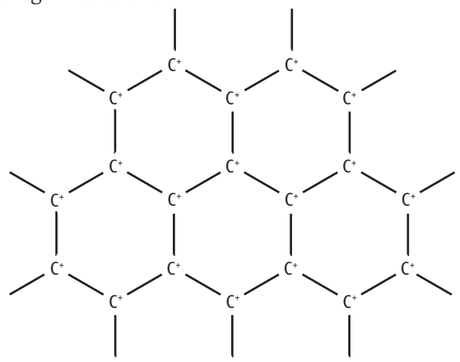
The strength of London dispersion forces depends upon the number of electrons in the molecules.



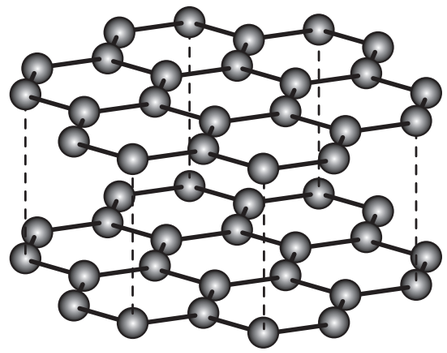
COVALENT NETWORK ELEMENTS

A covalent network structure consists of a giant lattice of covalently bonded atoms. There are three elements in the first 20 elements of the Periodic Table which have covalent network structures. These are boron, silicon and carbon (as diamond or graphite). These elements have very high melting and boiling points because the covalent bonds, which are very strong, have to be broken at their melting and boiling points. They are very hard materials because it is not possible to move any of the atoms in the structure without breaking the very strong covalent bonds.

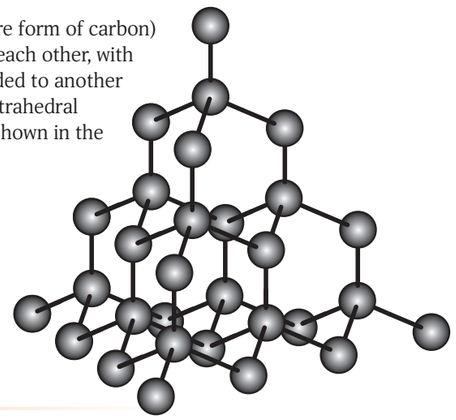
The diagram on the right shows part of the structure of graphite, another pure form of carbon. The carbon atoms form layers of hexagonal rings. Carbon has four electrons in its outer shell. Three of these electrons are used to form covalent bonds. The spare electron in each carbon atom becomes delocalised within the layer, just like the delocalisation of the outer electrons in metallic structures. This explains why graphite is a good conductor of electricity.



The layers of carbon atoms in graphite are attracted to the layers above and below by London dispersion forces as shown in this diagram. These are much weaker than the strong covalent bonds so, although the atoms within each layer are held together strongly, the layers can easily slide across each other. Graphite is used as the 'lead' in pencils because, as it moves across the paper, layers rub off leaving a mark on the paper. Graphite is also used as a lubricant.



Silicon and diamond (a pure form of carbon) have similar structures to each other, with each atom covalently bonded to another four atoms in a gigantic tetrahedral arrangement of atoms as shown in the diagram on the right.



Boron is another non-metal with a covalent network structure.

DON'T FORGET

Elements with covalent network structures have very high melting points because every atom is locked in place by strong covalent bonds.

VIDEO LINK

For a great video about carbon, head to www.brightredbooks.net

ONLINE TEST

Test yourself on periodicity online at www.brightredbooks.net

THINGS TO DO AND THINK ABOUT

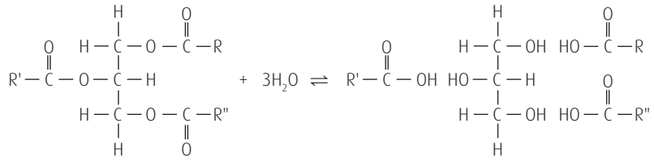
Which bonds or intermolecular forces are being broken when the following elements melt: sulfur, zinc, phosphorus, argon, chlorine, carbon in the form of diamond, carbon in the form of a fullerene?

SOAPS, SOAPLESS DETERGENTS AND EMULSIONS

SOAPS

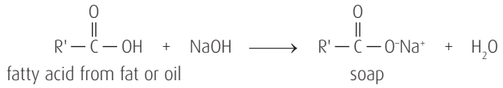
Making soaps

Just as a simple ester can undergo **hydrolysis** (reaction with water) to form an alcohol and carboxylic acid, fats and oils can also be hydrolysed to produce glycerol and fatty acids:



Notice that for every one mole of fat or oil that is hydrolysed, one mole of glycerol and three moles of fatty acids are formed.

It is this hydrolysis reaction that forms the basis of **soap-making**. In the manufacture of soaps, fats and oils are boiled with sodium (or potassium) hydroxide solution. The alkali first catalyses the hydrolysis reaction and then neutralises the fatty acids to form their sodium (or potassium) salts:



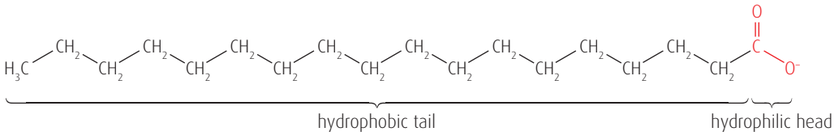
It is these **sodium (or potassium) salts of fatty acids** that are **soaps**.

DON'T FORGET

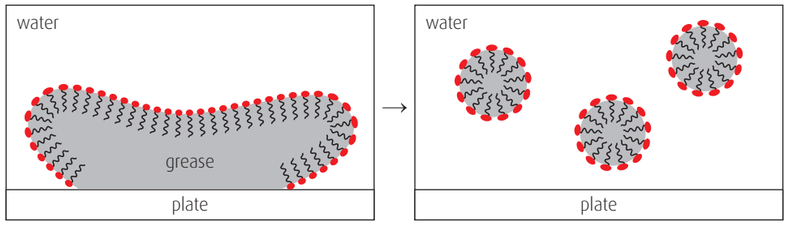
Soaps are the sodium (or potassium) salts of fatty acids.

Cleansing action of soaps

Examples of soaps include sodium stearate, $CH_3(CH_2)_{16}COO^-Na^+$, and potassium palmitate, $CH_3(CH_2)_{14}COO^-K^+$. Their cleansing action can be explained in terms of the structure and bonding of their negative ions. Take the stearate ion, for example:



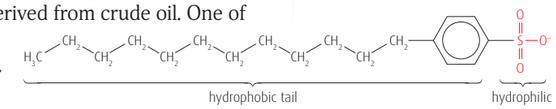
The **hydrophilic head** of the soap ion is **soluble in water** because it is **ionic**. The long **hydrocarbon tail** is **non-polar** and is **insoluble in water** (**hydrophobic**), but it is **soluble** in organic materials, such as **oil or grease**. When soap is used to clean greasy plates, for example, its hydrophobic tails bury themselves in the grease while the hydrophilic heads remain in the water. With agitation, the soap ions dislodge the grease from the surface of the plates and the grease splits up into tiny droplets which are dispersed in the water, leaving the plates clean. This process is illustrated in the following diagram, where ∿● represents a soap ion:



As the head of each soap ion is negatively charged, the grease droplets repel each other, thus preventing them from joining together again. The grease is effectively dispersed through the water. Without the soap, the grease and water would not mix.

SOAPLESS DETERGENTS

Detergents include soaps and soapless detergents. The latter can be found in a variety of household cleaning products, including washing powders, washing-up liquids, carpet cleaners and shampoos. They are synthetic and usually derived from crude oil. One of the most common synthetic detergents in use today is sodium dodecylbenzenesulfonate, $CH_3(CH_2)_{11}C_6H_4SO_3^-Na^+$. The negative ion of this salt has the structure shown on the right.



Like the soap ion, the soapless detergent ion has a long, non-polar hydrocarbon tail (hydrophobic) and an ionic head (hydrophilic). This means that the cleansing action of soapless detergent ions is identical to that of soap ions.

One advantage that soapless detergents have over soaps, however, is their use in hard water areas. Water is described as being hard when it contains $Ca^{2+}(aq)$ and/or $Mg^{2+}(aq)$. These ions react with soap ions to form insoluble salts known as scum. This reduces the efficiency of soaps as cleansing agents. However, when soapless detergents are used, no scum is formed because the calcium and magnesium salts of soapless detergents are soluble in water.

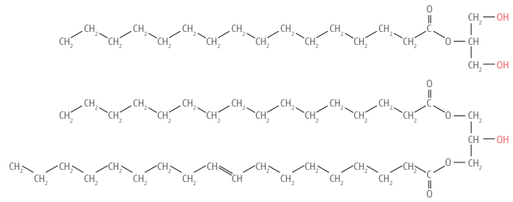
DON'T FORGET

The cleansing action of both soap and soapless detergent ions can be explained in terms of their hydrophilic heads and hydrophobic tails.

EMULSIONS

When two immiscible liquids – that is, liquids which do not dissolve in each other – are added together and vigorously shaken, an emulsion is formed. An **emulsion** is therefore a **mixture** and not a solution and consists of one of the liquids dispersed throughout the other. Vegetable oils and water are often used in emulsions and if such emulsions are left to stand, the oil and water separate into two distinct layers. To prevent this happening, **emulsifiers** are added. They are compounds similar in structure to soap and detergent ions in that they have hydrophobic tails and hydrophilic heads. The structures of two typical emulsifiers are illustrated below:

Like the triglycerides found in fats and oils (see page 30), these compounds are esters of glycerol and fatty acids.



The compound on top is a **monoglyceride** as it has only **one** fatty acid linked to the glycerol, whereas the compound below it has **two** fatty acids and is known as a **diglyceride**. It is the –OH groups (coloured red) which make the heads of these molecules hydrophilic and therefore soluble in water. The tails, made up of non-polar fatty acid chains, are hydrophobic and are soluble in oil. These monoglycerides and diglycerides stabilise the emulsions and prevent the oil and water separating out. It should be noted that triglycerides cannot act as emulsifiers as they do not contain any –OH groups to allow them to dissolve in water. Emulsifiers for use in food can be made by reacting edible oils with glycerol.

Examples of emulsions include ice cream, milk, salad cream, mayonnaise, butter, low-fat spreads and moisturising lotions.

VIDEO LINK

Watch a short clip introducing emulsifiers at www.brightredbooks.net

VIDEO LINK

Watch the clip on emulsifiers at www.brightredbooks.net

DON'T FORGET

Monoglycerides and diglycerides, but not triglycerides, can be used as emulsifiers.

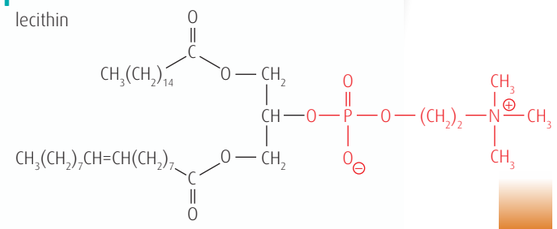
ONLINE TEST

Test yourself on this topic at www.brightredbooks.net

THINGS TO DO AND THINK ABOUT

The basic ingredients of mayonnaise are egg yolks, olive oil and vinegar. The egg yolks and vinegar are first beaten together and the oil is then added, drop by drop, with continual whisking until the emulsion is formed. With mayonnaise there is no need to add an artificial emulsifier because the egg yolk already contains a natural emulsifier. It is called lecithin. The branch (coloured red) has ionic charges and so is hydrophilic. The fatty acid branches on the left make up the hydrophobic part of the emulsifier.

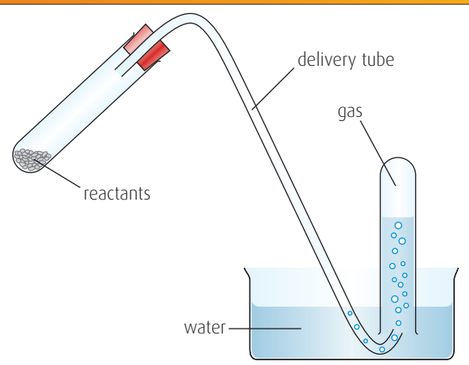
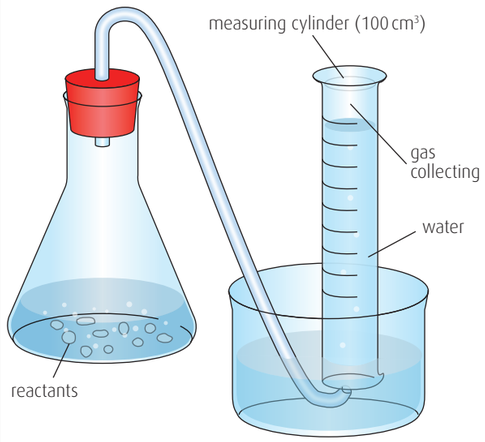
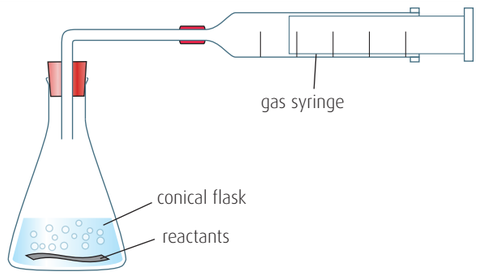
lecithin



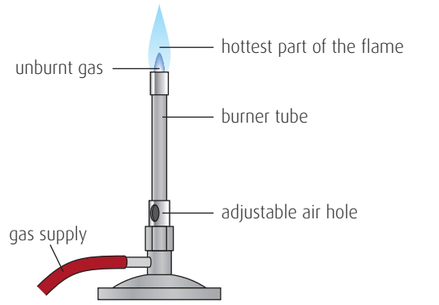
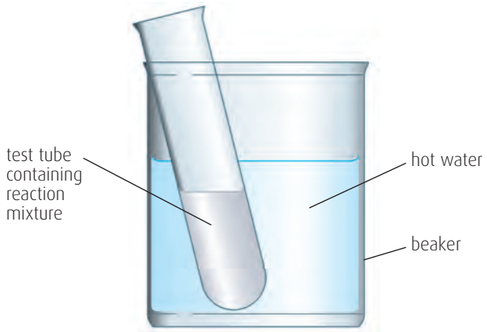
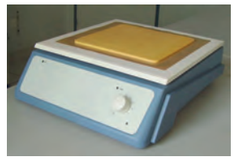
RESEARCHING CHEMISTRY

TECHNIQUES 1

METHODS FOR COLLECTION OF GASES

Methods for collection of gases		Advantages	Disadvantages
Collection over water		• Very cheap • Very simple	• Can only be used with gases that are insoluble in water • Gas collected will contain a little water vapour • Does not measure volume of gas produced
Collection over water using a measuring cylinder		• Very cheap • Simple • Measures volume of gas produced	• Can only be used with gases that are insoluble in water • Gas collected will contain a little water vapour • Hard not to let some air into the measuring cylinder when setting up
Gas syringe		• Can be used to collect any gas • Gas collected is free from any water vapour • Measures volume of gas produced	• Very expensive • Easily broken

SAFE HEATING METHODS

Safe heating methods		Advantages	Disadvantages
Bunsen burner		• Very cheap • Can achieve temperatures of over 1000°C • Instant change in temperature when you adjust the air hole	• **Must never be used to heat flammable compounds**  • Does not apply heat evenly • Hard to control temperature accurately
Water-bath		• Can be used to heat flammable compounds • Can heat the entire surface of the reaction vessel • Can achieve very fine control of temperature	• Cannot be used to heat to above about 95°C • Takes time to reach any given temperature
Heating mantle or hot-plate	 Heating mantle  Hot-plate	• Can be used to heat flammable compounds • Can reach temperatures of about 400°C • Can achieve reasonable control of temperature	• Very expensive • Takes time to reach any given temperature • You may need different heating mantles for different sizes of flask

THINGS TO DO AND THINK ABOUT

Sulfur dioxide gas is very soluble and dissolves to form an acidic solution. What would be the most appropriate method for collecting and measuring the volume of sulfur dioxide produced in a reaction?

VIDEO LINK

Head to www.brightredbooks.net for a great video about the safe methods of heating listed in the table.

DON'T FORGET

Alcohols and esters are highly flammable. They must never be heated using a Bunsen burner.

BrightRED Study Guides

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CHEMISTRY

Bill Beveridge, Archie Gibb and David Hawley

This BrightRED Study Guide is the ultimate companion to your CfE Higher Chemistry studies! Written by our trusted authors and experienced Chemistry teachers, Bill Beveridge, Archie Gibb and David Hawley, this book is full-colour and packed with clear and accessible information, excellent examples, activities and advice. Inside, you will find:

- **All the essential course information, fully up-to-date with SQA course changes,** arranged in easily digestible double-page topic spreads.
- **Detailed full-colour** diagrams, illustrations and data boxes to make sure all that study sticks!
- ***Don't forget*** pointers offering advice on the key facts to remember, and on how to avoid common mistakes.
- ***Things to do and think about*** sections encouraging the regular review of key points covered.
- ***Digital Zone* activities and tests** to supercharge your learning efforts online!
- **An index** of key terms to help when revising.

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