

Module C1: Air quality**C1.1 Which chemicals make up air, and which ones are pollutants? How do I make sense of data about air pollution?**

1. recall that the atmosphere (air) that surrounds the Earth is made up mainly of nitrogen, oxygen and argon, plus small amounts of water vapour, carbon dioxide and other gases
2. recall that air is a mixture of different gases consisting of small molecules with large spaces between them
3. recall that the relative proportions of the main gases in the atmosphere are approximately 78% nitrogen, 21% oxygen and 1% argon
4. understand that other gases or particulates may be released into the atmosphere by human activity or by natural processes (e.g. volcanoes), and that these can affect air quality
5. understand how the Earth's early atmosphere was probably formed by volcanic activity and consisted mainly of carbon dioxide and water vapour
6. understand that water vapour condensed to form the oceans when the Earth cooled
7. explain how the evolution of photosynthesising organisms added oxygen to, and removed carbon dioxide from, the atmosphere
8. explain how carbon dioxide was removed from the atmosphere by dissolving in the oceans and then forming sedimentary rocks, and by the formation of fossil fuels
9. understand how human activity has changed the composition of the atmosphere by adding:
 - a. small amounts of carbon monoxide, nitrogen oxides and sulfur dioxide to the atmosphere
 - b. extra carbon dioxide and small particles of solids (e.g. carbon) to the atmosphere
10. understand that some of these substances, called pollutants, are directly harmful to humans (e.g. carbon monoxide reduces the amount of oxygen that blood can carry), and that some are harmful to the environment and so cause harm to humans indirectly (e.g. sulfur dioxide causes acid rain).

Module C1: Air quality**C1.2 What chemical reactions produce air pollutants? What happens to these pollutants in the atmosphere?**

1. recall that coal is mainly carbon
2. recall that petrol, diesel fuel and fuel oil are mainly compounds of hydrogen and carbon (hydrocarbons)
3. understand that, when fuels burn, atoms of carbon and/or hydrogen from the fuel combine with atoms of oxygen from the air to produce carbon dioxide and/or water (hydrogen oxide)
4. understand that a substance chemically combining with oxygen is an example of oxidation, that loss of oxygen is an example of reduction, and that combustion reactions therefore involve oxidation
5. understand that fuels burn more rapidly in pure oxygen than in air
6. recall that oxygen can be obtained from the atmosphere and can be used to support combustion (e.g. in oxy-fuel welding torches)
7. understand that in a chemical reaction the properties of the reactants and products are different
8. understand that atoms are rearranged during a chemical reaction
9. interpret representations of the rearrangement of atoms during a chemical reaction
10. understand that during the course of a chemical reaction the numbers of atoms of each element must be the same in the products as in the reactants, **thus conserving mass**
11. understand how sulfur dioxide is produced if the fuel that is burned contains any sulfur
12. understand how burning fossil fuels in power stations and for transport pollutes the atmosphere with:
 - a. carbon dioxide and sulfur dioxide
 - b. carbon monoxide and particulate carbon (from incomplete burning)
 - c. nitrogen oxides (from the reaction between atmospheric nitrogen and oxygen at the high temperatures inside engines)
13. relate the formulae for carbon dioxide CO_2 , carbon monoxide CO , sulfur dioxide SO_2 , nitrogen monoxide NO , nitrogen dioxide NO_2 and water H_2O to visual representations of their molecules
14. **recall that nitrogen monoxide NO is formed during the combustion of fuels in air, and is subsequently oxidised to nitrogen dioxide NO_2 (NO and NO_2 are jointly referred to as 'NOx')**
15. understand that atmospheric pollutants cannot just disappear, they have to go somewhere:
 - a. particulate carbon is deposited on surfaces, making them dirty
 - b. sulfur dioxide and nitrogen dioxide react with water and oxygen to produce acid rain which is harmful to the environment
 - c. carbon dioxide is used by plants in photosynthesis
 - d. carbon dioxide dissolves in rain water and in sea water.

Module C1: Air quality**C1.3 What choices can we make personally, locally, nationally or globally to improve air quality?**

1. understand how atmospheric pollution caused by power stations that burn fossil fuels can be reduced by:
 - a. using less electricity
 - b. removing sulfur from natural gas and fuel oil
 - c. removing sulfur dioxide and particulates from the flue gases emitted by coal-burning power stations
2. **understand how the acid gas sulfur dioxide is removed from flue gases by wet scrubbing:**
 - a. **using an alkaline slurry e.g. a spray of calcium oxide and water**
 - b. **using sea water**

① *Candidates are not required to write word or symbol equations*
3. understand that the only way of producing less carbon dioxide is to burn less fossil fuels
4. understand how atmospheric pollution caused by exhaust emissions from motor vehicles can be reduced by:
 - a. burning less fuel, for example by having more efficient engines
 - b. using low sulfur fuels
 - c. using catalytic converters (in which nitrogen monoxide is reduced to nitrogen by loss of oxygen, and carbon monoxide is oxidised to carbon dioxide by gain of oxygen)
 - d. adjusting the balance between public and private transport
 - e. having legal limits to exhaust emissions (which are enforced by the use of MOT tests)
5. **understand the benefits and problems of using alternatives to fossil fuels for motor vehicles, limited to biofuels and electricity.**

3.4.2 Module C2: Material choices

Overview

Our way of life depends on a wide range of materials produced from natural resources. The Earth's crust provides us with crude oil, which is a source of fuel and raw material for producing synthetic polymers. Natural polymers can also be useful and can be obtained from living things. This module considers how measurements of the properties of materials can inform the choice of material for a particular purpose. By taking their own measurements, candidates can explore some of the issues that arise when trying to establish accurate and meaningful data.

Key ideas in this module are illustrated through polymers. Candidates learn how the molecules that make up a polymer fit together and how strongly they are bonded to each other, providing an explanation of the properties of materials. This provides an example of a scientific explanation that makes sense of a wide range of observations.

Candidates also learn how polymers can be modified to give them more desirable properties by the introduction of nanoparticles, which have different properties when compared with larger particles of the same material.

Issues for citizens	Questions that science may help to answer
How can we pick a suitable material for a particular product or task?	<p>How do we measure the properties of materials and why are the results useful?</p> <p>Why is crude oil important as a source of new materials such as plastics and fibres?</p> <p>Why does it help to know about the molecular structure of materials such as plastics and fibres?</p> <p>What is nanotechnology and why is it important?</p>

Opportunities for mathematics

This module offers opportunities to develop mathematics skills. For example:

- develop a sense of scale in the context of polymers and nanoparticles
- carry out calculations using experimental data, including finding the mean and the range
- use ideas of proportion in the context of surface area
- plot, draw and interpret graphs and charts from candidates' own and secondary data
- extract information from charts showing properties of materials.

Opportunities for practical work

This module offers opportunities for practical work in teaching and learning. For example:

- test the properties of materials
- make polymers and modifying their properties
- perform or observe the distillation of crude oil.

Opportunities for ICT

This module offers opportunities to illustrate the use of ICT in science. For example:

- logging and storing data, and displaying data in a variety of formats for analysis and evaluation.

Use of ICT in teaching and learning can include:

- using spreadsheets to record and display measurements of the properties of materials
- video clips to illustrate the main stages from extraction of oil to production of synthetic plastic or fibre
- using still images and diagrams to create presentations to show how the properties of a material depend on its molecular structure.

Opportunities for teaching the Ideas about Science

Examples of Ideas about Science for which there are particular opportunities for introduction or development in this module include:

Data: their importance and limitations

laS 1.1 – 1.6

Cause-effect explanations

laS 2.2

Module C2: Material choices**C2.1 How do we measure the properties of materials and why are the results useful?**

1. interpret information about how solid materials can differ with respect to properties such as melting point, strength (in tension or compression), stiffness, hardness and density
2. relate properties to the uses of materials such as plastics, rubbers and fibres
3. relate the effectiveness and durability of a product to the materials used to make it
4. interpret information about the properties of materials such as plastics, rubbers and fibres to assess the suitability of these materials for particular purposes.

Module C2: Material choices**C2.2 Why is crude oil important as a source of new materials such as plastics and fibres?**

1. recall that the materials we use are chemicals or mixtures of chemicals, and include metals, ceramics and polymers
2. recall that materials can be obtained or made from living things, and give examples such as cotton, paper, silk and wool
3. recall that there are synthetic materials that are alternatives to materials from living things
4. recall that raw materials from the Earth's crust can be used to make synthetic materials
5. interpret representations of rearrangements of atoms during a chemical reaction
6. understand that in a chemical reaction the numbers of atoms of each element must be the same in the products as in the reactants
7. recall that crude oil consists mainly of hydrocarbons, which are chain molecules of varying lengths made from carbon and hydrogen atoms only
8. recall that only a small percentage of crude oil is used for chemical synthesis and that most is used as fuels
9. understand that the petrochemical industry refines crude oil by fractional distillation; hydrocarbons are separated into fractions of different boiling points, to produce fuels, lubricants and the raw materials for chemical synthesis
10. relate the size of the forces between hydrocarbon molecules to the size of the molecules
11. relate the strength of the forces between hydrocarbon molecules in crude oil to the amount of energy needed for them to break out of a liquid and form a gas, and to the temperature at which the liquid boils
12. understand that some small molecules called monomers can join together to make very long molecules called polymers, and that the process is called polymerisation
13. recall two examples of materials that, because of their superior properties, have replaced materials used in the past.

Module C2: Material choices**C2.3 Why does it help to know about the molecular structure of materials such as plastics and fibres?**

1. understand that it is possible to produce a wide range of different polymers with properties that make them each suited to a particular use
2. understand how the properties of polymers depend on how their molecules are arranged and held together
3. relate the strength of the forces between the molecules in a polymer to the amount of energy needed to separate them from each other, and therefore to the strength, stiffness, hardness and melting point of the solid
4. understand how modifications in polymers produce changes to their properties (see C2.1), to include modifications such as:
 - a. increased chain length
 - b. cross-linking
 - c. the use of plasticizers
 - d. **increased crystallinity.**

Module C2: Material choices**C2.4 What is nanotechnology and why is it important?**

1. recall that nanotechnology involves structures that are about the same size as some molecules
2. understand that nanotechnology is the use and control of structures that are very small (1 to 100 nanometres in size)
3. understand that nanoparticles can occur naturally (for example in seaspray), by accident (for example as the smallest particulates from combustion of fuels), and by design
4. understand that nanoparticles of a material show different properties compared to larger particles of the same material, and that one of the reasons for this is the much larger surface area of the nanoparticles compared to their volume
5. understand that nanoparticles can be used to modify the properties of materials, and give examples including:
 - a. the use of silver nanoparticles to give fibres antibacterial properties
 - b. adding nanoparticles to plastics for sports equipment to make them stronger
6. understand that some nanoparticles may have harmful effects on health, and that there is concern that products with nanoparticles are being introduced before these effects have been fully investigated.

3.4.3 Module C3: Chemicals in our lives – risks and benefits

Overview

Thanks to its geological history, Britain is a country that has large deposits of valuable resources including salt and limestone as well as coal, gas and oil. These raw materials have been the basis of a chemical industry for over 200 years. At first many of the industrial processes were highly polluting. This led to new laws and the establishment of regulatory organisations to control the industry. Today the industry is under great pressure to operate processes that are efficient in their use of energy and which do minimal harm to health and the environment.

Salt is particularly important. Salt is necessary in the diet but is hazardous if eaten to excess. Chemists have learnt to convert salt to alkalis and to chlorine, chemicals that are used to make many valuable products.

The use of manufactured chemicals has brought both benefits and risks. Society has become increasingly concerned that there are many chemicals that are used in large amounts, but which have never been thoroughly tested to evaluate their effects on people and the environment.

The data from Life Cycle Assessments shows that in selecting a product for a particular job we should assess not only its 'fitness for purpose' but also the total effects of using the materials that make up the product over its complete life cycle, from its production using raw materials to its disposal.

Issues for citizens	Questions that science may help to answer
Why do we need to use manufactured chemicals?	Why are there valuable sources of raw materials for making chemicals in Britain?
What can society do to ensure that it uses chemicals in ways that are safe and sustainable?	Why are salt and limestone so important for the chemical industry?
When choosing a product made from a particular chemical, what else should we consider besides its cost and how well it does its job?	What are the benefits and risks of making chemicals with chlorine?

Opportunities for mathematics

This module offers opportunities to develop mathematics skills. For example:

- develop a sense of scale in the context of geological time
- carry out calculations using fractions and percentages
- interpret graphs and charts from secondary data
- extract information from charts, graphs and tables about water quality and health
- use ideas about probability in the context of risk.

Opportunities for practical work

This module offers opportunities for practical work in teaching and learning. For example:

- purify rock salt
- experiments with acids and alkalis
- make soap
- perform the electrolysis of brine.

Opportunities for ICT

This module offers opportunities to illustrate the use of ICT in science. For example:

- simulating the movement of the continents over geological time periods.

Use of ICT in teaching and learning can include:

- video clips to illustrate the extraction of raw materials and the production of useful chemicals
- animations to illustrate chemical processes
- simulations to explore the impact of choices made during the life cycle of a product
- using the internet to explore case studies of the safe and sustainable use of polymers and materials.

Opportunities for teaching the Ideas about Science

Examples of Ideas about Science for which there are particular opportunities for introduction or development in this module include:

Developing scientific explanations

laS 3.3

Risk

laS 5.1 – 5.7

Making decisions about science and technology

laS 6.1 – 6.4

Module C3: Chemicals in our lives – risks and benefits**C3.1 What were the origins of minerals in Britain that contribute to our economic wealth?**

1. understand that geologists explain most of the past history of the surface of the Earth in terms of processes than can be observed today
2. understand that movements of tectonic plates mean that the parts of ancient continents that now make up Britain have moved over the surface of the Earth
3. understand how geologists use magnetic clues in rocks to track the very slow movement of the continents over the surface of the Earth
4. understand that the movements of continents means that different rocks in Britain formed in different climates
5. understand how processes such as mountain building, erosion, sedimentation, dissolving and evaporation have led to the formation of valuable resources found in England including coal, limestone and salt
6. understand how geologists study sedimentary rocks to find evidence of the conditions under which they were formed, to include:
 - a. fossils
 - b. shapes of water borne grains compared to air blown grains
 - c. presence of shell fragments
 - d. ripples from sea or river bottom
7. understand that chemical industries grow up where resources are available locally, e.g. salt, limestone and coal in north west England.

Module C3: Chemicals in our lives – risks and benefits**C3.2 Where does salt come from and why is it so important?**

1. understand the importance of salt (sodium chloride) for the food industry, as a source of chemicals and to treat roads in winter
2. recall that salt can be obtained from the sea or from underground salt deposits
3. understand how underground salt can be obtained by mining, or by solution in water
4. understand why the method used to obtain salt may depend on how the salt is to be used
5. understand how the methods of obtaining salt can have an impact on the environment
6. understand the advantages of adding salt to food as flavouring and as a preservative
7. recall the health implications of eating too much salt
8. be able to evaluate data related to the content of salt in food and health
9. recall that Government departments, such as the Department of Health and the Department for Environment, Food and Rural Affairs, have a role in:
 - a. carrying out risk assessments in relation to chemicals in food
 - b. advising the public in relation to the effect of food on health.

Module C3: Chemicals in our lives – risks and benefits**C3.3 Why do we need chemicals such as alkalis and chlorine and how do we make them?**

1. recall that, even before industrialisation, alkalis were needed to neutralise acid soils, make chemicals that bind natural dyes to cloth, convert fats and oils into soap and to manufacture glass
2. recall that traditional sources of alkali included burnt wood or stale urine
3. understand that alkalis neutralise acids to make salts
4. **recall that soluble hydroxides and carbonates are alkalis**
5. **predict the products of the reactions of soluble hydroxides and carbonates with acids**
6. understand that increased industrialisation led to a shortage of alkali in the nineteenth century
7. understand that the first process for manufacturing alkali from salt and limestone using coal as a fuel caused pollution by releasing large volumes of an acid gas (hydrogen chloride) and creating great heaps of waste that slowly released a toxic and foul smelling gas (hydrogen sulfide)
8. understand that pollution problems can sometimes be solved by turning wastes into useful chemicals
9. understand that oxidation can convert hydrogen chloride to chlorine, and that the properties of a compound are completely different from the elements from which it is made
10. recall that chlorine is used to kill microorganisms in domestic water supplies and as a bleach
11. understand how the introduction of chlorination to treat drinking water made a major contribution to public health
12. interpret data about the effects of polluted water on health and the impact of water treatment with chlorine to control disease
13. understand that there may be disadvantages of chlorinating drinking water, including possible health problems from traces of chemicals formed by reaction of chlorine with organic materials in the water
14. understand that an electric current can be used to bring about chemical change and make new chemicals through a process called electrolysis
15. recall that chlorine is now obtained by the electrolysis of salt solution (brine)
① Technical details and the ionic reactions are not required
16. recall examples of important uses by industry of the sodium hydroxide, chlorine and hydrogen produced by electrolysis of brine
17. interpret data about the environmental impact of the large scale electrolysis of brine.

Module C3: Chemicals in our lives – risks and benefits**C3.4 What can we do to make our use of chemicals safe and sustainable?**

1. understand that there is a large number of industrial chemicals with many widespread uses, including consumer products, for which there is inadequate data to judge whether they are likely to present a risk to the environment and/or human health
2. understand that some toxic chemicals cause problems because they persist in the environment, can be carried over large distances, and may accumulate in food and human tissues
3. recall that PVC is a polymer that contains chlorine as well as carbon and hydrogen
4. understand that the plasticizers used to modify the properties of PVC can leach out from the plastic into the surroundings where they may have harmful effects
5. understand that a Life Cycle Assessment (LCA) involves consideration of the use of resources including water, the energy input or output, and the environmental impact, of each of these stages:
 - a. making the material from natural raw materials
 - b. making the product from the material
 - c. using the product
 - d. disposing of the product
6. when given appropriate information from a Life Cycle Assessment (LCA), compare and evaluate the use of different materials for the same purpose.

3.5 Summary of Unit A172: Chemistry A Modules C4, C5, C6

Unit A172 assesses the content of *Modules C4, C5 and C6* together with the Ideas about Science.

The modules in Unit A172 give emphasis and space to fundamental ideas in the sciences, ensure that appropriate skills are developed in preparation for further study, and provide a stimulating bridge to advanced level studies in science. The emphasis of the unit is on 'science for the scientist' and those aspects of 'How Science Works' that relate to the process of science.

3.5.1 Module C4: Chemical patterns

Overview

This module features a central theme of modern chemistry. It shows how theories of atomic structure can be used to explain the properties of elements and their compounds. The module also includes examples to show how spectra and spectroscopy have contributed to the development of chemical knowledge and techniques. This module shows how atomic structure can be used to help explain the behaviour of elements.

The first topic looks at the Periodic Table, the history of its development, and patterns that exist within it, focusing on Group 1 and Group 7. This topic also introduces the use of symbols and equations as a means of describing a chemical reaction. An explanation of the patterns is then developed in the next topic by linking atomic structure with chemical properties.

The third, and final, topic takes this further by introducing ions and showing how ionic theory can account for properties of compounds of Group 1 with Group 7 elements.

Topics

C4.1 What are the patterns in the properties of elements?

The history of the development of the Periodic Table
 Classifying elements by their position in the Periodic Table
 Patterns in Group 1 and patterns in Group 7
 Using symbols and equations to represent chemical reactions

C4.2 How do chemists explain the patterns in the properties of elements?

Flame tests and spectra and their use for identifying elements and studying atomic structure
 Classifying elements by their atomic structure
 Linking atomic structure to chemical properties

C4.3 How do chemists explain the properties of compounds of Group 1 and Group 7 elements?

Ions, and linking ion formation to atomic structure
 Properties of ionic compounds of alkali metals and halogens

Opportunities for mathematics

This module offers opportunities to develop mathematics skills. For example:

- develop a sense of scale in the context of atomic structure
- use ideas of ratios in the context of the formulae of ionic compounds
- plot, draw and interpret graphs and charts from secondary data
- extract information from the Periodic Table
- extract information from charts and graphs including patterns in the properties of elements
- balance chemical equations.

Opportunities for practical work

This module offers opportunities for practical work in teaching and learning. For example:

- reactions of the alkali metals
- reactions of the halogens
- experiments to test the properties of ionic compounds.

Opportunities for ICT

This module offers opportunities to illustrate the use of ICT in science. For example:

- storing large sets of data
- selecting and presenting data in a variety of forms to explore patterns and trends.

Use of ICT in teaching and learning can include:

- using an interactive Periodic Table to explore similarities and differences between elements
- using a spreadsheet to display patterns in chemical data
- video clips to test predictions about the reactions of elements such as caesium and fluorine
- using the internet to research the uses of alkali metals or halogens and their compounds.

Opportunities for teaching the Ideas about Science

Examples of Ideas about Science for which there are particular opportunities for introduction or development in this module include:

Developing scientific explanations

laS 3.1 – 3.4

The scientific community

laS 4.1 – 4.4

Module C4: Chemical patterns

C4.1 What are the patterns in the properties of elements?

1. understand that atoms of each element have different proton numbers
2. understand that arranging the elements in order of their proton numbers gives repeating patterns in the properties of elements
3. understand that early attempts to find connections between the chemical properties of the elements and their relative atomic mass were dismissed by the scientific community
4. recall the significant stages in the history of the development of the Periodic Table to include the ideas of Döbereiner, Newlands and Mendeleev
5. understand how Mendeleev used his Periodic Table to predict the existence of unknown elements
6. use the Periodic Table to obtain the names, symbols, relative atomic masses and proton numbers of elements
7. understand that a group of elements is a vertical column in the Periodic Table and that the elements in a group have similar properties
8. recall that a period is a row of elements in the Periodic Table
9. use the Periodic Table to classify an element as a metal or non-metal
10. use patterns in the Periodic Table to interpret data and predict properties of elements
 - ① *Candidates will be given a copy of the Periodic Table (as in Appendix E) with the examination paper*
11. recall and recognise the chemical symbols for the Group 1 metals (also known as the alkali metals) lithium, sodium and potassium
12. recall that the alkali metals are shiny when freshly cut but tarnish rapidly in moist air due to reaction with oxygen
13. use qualitative and quantitative data to identify patterns and make predictions about the properties of Group 1 metals (for example, melting point, boiling point, density, formulae of compounds and relative reactivity)
14. describe the reactions of lithium, sodium and potassium with cold water
15. recall that alkali metals react with water to form hydrogen and an alkaline solution of a hydroxide with the formula MOH
16. recall that alkali metals react vigorously with chlorine to form colourless, crystalline salts with the formula MCl
17. understand and give examples to show that the alkali metals become more reactive as the group is descended
18. recall the main hazard symbols and be able to give the safety precautions for handling hazardous chemicals (limited to explosive, toxic, corrosive, oxidizing, and highly flammable)
 - ① *See Appendix G for guidance on recent changes to hazard labelling*
19. state and explain the precautions necessary when working with Group 1 metals and alkalis
20. recall and recognise the chemical symbols for the atoms of the Group 7 elements (also known as the halogens) chlorine, bromine and iodine
21. recall the states of these halogens at room temperature and pressure

C4.1 What are the patterns in the properties of elements?

22. recall the colours of these halogens in their normal physical state at room temperature and as gases
23. recall that the halogens consist of diatomic molecules
24. use qualitative and quantitative data to identify patterns and make predictions about the properties of the Group 7 elements (for example melting point, boiling point, formulae of compounds and relative reactivity)
25. understand that the halogens become less reactive as the group is descended and give examples to show this
26. understand how a trend in reactivity for halogens can be shown by their displacement reactions and by their reactions with alkali metals and with iron
27. state and explain the safety precautions necessary when working with the halogens
28. recall the formulae of:
 - a. hydrogen, water and halogen (limited to chlorine, bromine and iodine) molecules
 - b. the chlorides, **bromides and iodides (halides)** of Group 1 metals (limited to lithium, sodium and potassium)
29. write word equations for reactions of alkali metals and halogens in this module and for other reactions when given appropriate information
30. interpret symbol equations, including the number of atoms of each element, the number of molecules of each element or covalent compound and the number of 'formulas' of ionic compounds, in reactants and products
 - ① *In this context, 'formula' is used in the case of ionic compounds as an equivalent to molecules in covalent compounds; the concept of the mole is not covered in the specification*
- 31. balance unbalanced symbol equations**
- 32. write balanced equations, including the state symbols (s), (g), (l) and (aq), for reactions of alkali metals and halogens in this module and for other reactions when given appropriate information**
33. recall the state symbols (s), (l), (g) and (aq) and understand their use in equations.

Module C4: Chemical patterns

C4.2 How do chemists explain the patterns in the properties of elements?

1. describe the structure of an atom in terms of protons and neutrons in a very small central nucleus with electrons arranged in shells around the nucleus
2. recall the relative masses and charges of protons, neutrons and electrons
3. understand that in any atom the number of electrons equals the number of protons
4. understand that all the atoms of the same element have the same number of protons
5. understand that the elements in the Periodic Table are arranged in order of proton number
6. recall that some elements emit distinctive flame colours when heated (for example lithium, sodium and potassium)

① *Recall of specific flame colours emitted by these elements is not required*
7. understand that the light emitted from a particular element gives a characteristic line spectrum
8. understand that the study of spectra has helped chemists to discover new elements
9. understand that the discovery of some elements depended on the development of new practical techniques (for example spectroscopy)
- 10. use the Periodic Table to work out the number of protons, electrons and neutrons in an atom**
11. use simple conventions, such as 2.8.1 and dots in circles, to represent the electron arrangements in the atoms of the first 20 elements in the Periodic Table, when the number of electrons or protons in the atom is given (**or can be derived from the Periodic Table**)
12. understand that a shell (or energy level) fills with electrons across a period
13. understand that elements in the same group have the same number of electrons in their outer shell and how this relates to group number
- 14. understand that the chemical properties of an element are determined by its electron arrangement, illustrated by the electron configurations of the atoms of elements in Groups 1 and 7.**

Module C4: Chemical patterns**C4.3 How do chemists explain the properties of compounds of Group 1 and Group 7 elements?**

1. understand that molten compounds of metals with non-metals conduct electricity and that this is evidence that they are made up of charged particles called ions
2. understand that an ion is an atom (or group of atoms) that has gained or lost electrons and so has an overall charge
3. account for the charge on the ions of Group 1 and Group 7 elements by comparing the number and arrangement of the electrons in the atoms and ions of these elements
4. **work out the formulae of ionic compounds given the charges on the ions**
5. **work out the charge on one ion given the formula of a salt and the charge on the other ion**
6. recall that compounds of Group 1 metals with Group 7 elements are ionic
7. understand that solid ionic compounds form crystals because the ions are arranged in a regular lattice
8. describe what happens to the ions when an ionic crystal melts or dissolves in water
9. explain that ionic compounds conduct electricity when molten or when dissolved in water because the ions are charged and they are able to move around independently in the liquid.

3.5.2 Module C5: Chemicals of the natural environment

Overview

Chemistry is fundamental to an understanding of the scale and significance of human impacts on the natural environment. Knowledge of natural processes makes it possible to appreciate the environmental consequences of extracting and processing minerals.

The module uses environmental contexts to introduce theories of structure and bonding. The first topic explains the characteristics of covalent bonding, and intermolecular forces in the context of the chemicals found in the atmosphere. The second topic explains ionic bonding in the context of reactions in the hydrosphere, and includes the detection and identification of ions.

The third topic looks at the properties of giant structures with strong covalent bonding found in the Earth's crust, including silicon dioxide. The final topic covers the distribution, structure and properties of metals through a study of their extraction from ores. This includes the use of relative atomic masses to give a quantitative interpretation of chemical formulae.

Topics

C5.1 What types of chemicals make up the atmosphere?

The structure and properties of chemicals found in the atmosphere

C5.2 What reactions happen in the hydrosphere?

The structure and properties of chemicals found in the hydrosphere, and detecting and identifying ions

C5.3 What types of chemicals make up the Earth's lithosphere?

Relating the properties of chemicals to their giant structure using examples found in the Earth's lithosphere

C5.4 How can we extract useful metals from minerals?

Relating the structure and properties of metals to suitable methods of extraction

Using ionic theory to explain electrolysis

Discussing issues relating to metal extraction and recycling

Opportunities for mathematics

This module offers opportunities to develop mathematics skills. For example:

- develop a sense of scale in the context of the Earth and its atmosphere
- carry out calculations to find the percentage of an element in a compound and the mass of an element that can be obtained from its compound
- plot, draw and interpret graphs and charts from candidates' own and secondary data
- extract information from charts, graphs and tables including the abundance of elements on the Earth
- calculate relative formula masses
- balance ionic equations.

Opportunities for practical work

This module offers opportunities for practical work in teaching and learning. For example:

- crystallisation experiments
- using precipitation reactions to identify ions in salts
- extracting metals with carbon
- extracting metals by electrolysis.

Opportunities for ICT

This module offers opportunities to illustrate the use of ICT in science. For example:

- modelling molecules and giant structures to explain properties.

Use of ICT in teaching and learning can include:

- animations to show the movement of molecules in a gas over a range of temperatures
- modelling software to show the shapes of molecules and illustrate giant structures
- video clips to show metals being extracted on a large scale
- animations to illustrate the ionic theory of electrolysis.

Opportunities for teaching the Ideas about Science

Examples of Ideas about Science for which there are particular opportunities for introduction or development in this module include:

Developing scientific explanations

laS 3.1, 3.2

Risk

laS 5.1

Making decisions about science and technology

laS 6.1, 6.2, 6.5, 6.6

Module C5: Chemicals of the natural environment

C5.1 What types of chemicals make up the atmosphere?

1. recall that dry air consists of gases, some of which are elements (for example, oxygen, nitrogen and argon) and some of which are compounds (for example, carbon dioxide)
2. recall that the relative proportions of the main gases in the atmosphere are about 78% nitrogen, 21% oxygen, 1% argon and 0.04% carbon dioxide
3. recall the symbols for the atoms and molecules of these gases in the air
4. recall that most non-metal elements and most compounds between non-metal elements are molecular
5. understand that molecular elements and compounds with small molecules have low melting and boiling points
6. interpret quantitative data (for example, melting and boiling points) and qualitative data about the properties of molecular elements and compounds
7. understand that molecular elements and compounds, such as those in the air, have low melting and boiling points, and are gases at room temperature, because they consist of small molecules with weak forces of attraction between the molecules
8. understand that pure molecular compounds do not conduct electricity because their molecules are not charged
9. understand that bonding within molecules is covalent **and arises from the electrostatic attraction between the nuclei of the atoms and the electrons shared between them**
10. understand that covalent bonds are strong, in contrast to the weak forces of attraction between small covalent molecules
11. translate between representations of molecules including molecular formulae, 2-D diagrams in which covalent bonds are represented by lines, and 3-D diagrams for:
 - a. elements that are gases at 20°C
 - b. simple molecular compounds.

Module C5: Chemicals of the natural environment**C5.2 What reactions happen in the hydrosphere?**

1. recall that the Earth's hydrosphere (oceans, seas, lakes and rivers) consists mainly of water with some dissolved compounds, called salts
2. understand that the ions in crystals of a solid ionic compound are arranged in a regular way forming a lattice
3. understand that ions in a crystal are held together by forces of attraction between oppositely charged ions and that this is called ionic bonding
4. understand how the physical properties of solid ionic compounds (melting point, boiling point, electrical conductivity) relate to their bonding and giant, three-dimensional structures
5. describe what happens to the ions when an ionic crystal dissolves in water
6. explain that ionic compounds conduct electricity when dissolved in water because the ions are charged and they are able to move around independently in the solution
7. **work out the formulae for salts in seawater given the charges on ions (for example sodium chloride, magnesium chloride, magnesium sulfate, sodium sulfate, potassium chloride and potassium bromide)**
8. understand that the ions in an ionic compound can be detected and identified because they have distinct properties and they form compounds with distinct properties
9. understand that an insoluble compound may precipitate on mixing two solutions of ionic compounds
10. **be able to write ionic equations for precipitation reactions when given appropriate information**
11. **interpret given information on solubility to predict chemicals that precipitate on mixing solutions of ionic compounds**
12. understand that some metal ions can be identified in solution by adding alkali because they form insoluble hydroxides with characteristic colours
13. interpret the results of adding aqueous sodium hydroxide to solutions of salts, given a data sheet of tests for positively charged ions and appropriate results
 - ① *Candidates will be given a qualitative analysis data sheet showing tests for positively charged ions (as in Appendix F) with the examination paper*
14. understand that some negative ions in salts can be identified in solution by adding a reagent that reacts with the ions to form an insoluble solid
15. interpret the results of tests for carbonate, chloride, bromide, iodide and sulfate ions given a data sheet of tests for negatively charged ions and appropriate results (using dilute acid, lime water, silver nitrate and barium chloride or barium nitrate as the reagents).
 - ① *Candidates will be given a qualitative analysis data sheet showing tests for negatively charged ions (as in Appendix F) with the examination paper*

Module C5: Chemicals of the natural environment**C5.3 What types of chemicals make up the Earth's lithosphere?**

1. recall that the Earth's lithosphere (the rigid outer layer of the Earth made up of the crust and the part of the mantle just below it) is made up of a mixture of minerals
2. recall that diamond and graphite are minerals, both of which are composed of carbon atoms
3. explain the properties of diamond in terms of a giant structure of atoms held together by strong covalent bonding (for example, melting point, boiling point, hardness, solubility and electrical conductivity)
4. understand how the giant structure of graphite differs from that of diamond, and how this affects its properties
5. recall that silicon, oxygen and aluminium are very abundant elements in the Earth's crust
6. interpret data about the abundances of elements in rocks
7. recall that much of the silicon and oxygen is present in the Earth's crust as the compound silicon dioxide
8. understand that silicon dioxide is another giant covalent compound and so has properties similar to diamond.

Module C5: Chemicals of the natural environment**C5.4 How can we extract useful metals from minerals?**

1. recall that ores are rocks that contain varying amounts of minerals from which metals can be extracted
2. understand that for some minerals, large amounts of ore need to be mined to recover small percentages of valuable minerals (for example, in copper mining)
3. recall that zinc, iron and copper are metals that can be extracted by heating their oxides with carbon, and write simple word equations for these reactions
 - ① *Technical details not required*
4. understand that when a metal oxide loses oxygen it is reduced, while the carbon gains oxygen and is oxidised
5. understand that some metals are so reactive that their oxides cannot be reduced by carbon
6. write word equations when given appropriate information
7. interpret symbol equations, including the number of atoms of each element, the number of molecules of each element or covalent compound and the number of 'formulas' of ionic compounds, in reactants and products
 - ① *In this context, 'formula' is used in the case of ionic compounds as an equivalent to molecules in covalent compounds; the concept of the mole is not covered in the specification*
- 8. balance unbalanced symbol equations**
- 9. write balanced equations, including the state symbols (s), (l), (g) and (aq), when given appropriate information**
10. recall the state symbols (s), (l), (g) and (aq) and understand their use in equations.
11. use the Periodic Table to obtain the relative atomic masses of elements
12. use relative atomic masses to calculate relative formula masses
13. calculate the mass of an element in the gram formula mass of a compound
- 14. calculate the mass of the metal that can be extracted from a mineral given its formula or an equation**
15. describe electrolysis as the decomposition of an electrolyte with an electric current
16. understand that electrolytes include molten ionic compounds
17. describe what happens to the ions when an ionic crystal melts
18. understand that, during electrolysis, metals form at the negative electrode and non-metals form at the positive electrode
19. describe the extraction of aluminium from aluminium oxide by electrolysis

C5.4 How can we extract useful metals from minerals?

20. **understand that during electrolysis of molten aluminium oxide, positively charged aluminium ions gain electrons from the negative electrode to become neutral atoms**
21. **understand that during electrolysis of molten aluminium oxide, negatively charged oxide ions lose electrons to the positive electrode to become neutral atoms which then combine to form oxygen molecules**
22. **use ionic theory to explain the changes taking place during the electrolysis of a molten salt to account for the conductivity of the molten salt and the changes at the electrodes**
23. understand that the uses of metals are related to their properties (limited to strength, malleability, melting point and electrical conductivity)
24. explain the physical properties of high strength and high melting point of metals in terms of a giant structure held together by strong bonds (metallic bonding)
25. **understand that in a metal crystal there are positively charged ions, held closely together by a sea of electrons that are free to move, and use this to explain the physical properties of metals, including malleability and conductivity**
26. evaluate, given appropriate information, the impacts on the environment that can arise from the extraction, use and disposal of metals.

3.5.3 Module C6: Chemical synthesis

Overview

Synthesis provides many of the chemicals that people need for food processing, health care, cleaning and decorating, modern sporting materials and many other products. The chemical industry today is developing new processes for manufacturing these chemicals more efficiently and with less impact on the environment.

In this context, the module explores related questions that chemists have to answer: 'How much?' and 'How fast?' in the context of the chemical industry. Quantitative work includes the calculation of yields from chemical equations and the measurement of rates of reaction.

A further development of ionic theory shows how chemists use this theory to account for the characteristic behaviours of acids and alkalis. Energy level diagrams are used to describe the exothermic and endothermic nature of chemical reactions.

Topics

C6.1 Chemicals and why we need them

The scale and importance of the chemical industry; acids, alkalis and their reactions
Neutralisation explained in terms of ions

C6.2 Planning, carrying out and controlling a chemical synthesis

Planning chemical syntheses
Procedures for making pure inorganic products safely
Comparing alternative routes to the same product
Calculating reacting quantities and yields
Measuring purity by simple titration
Controlling the rate of change

Opportunities for mathematics

This module offers opportunities to develop mathematics skills. For example:

- carry out calculations using experimental data, including finding the mean and the range
- carry out calculations to find percentage yield
- use ideas of ratios in the context of formulae of ionic compounds
- plot, draw and interpret graphs and charts from candidates' own and secondary data
- use an equation for calculating the rate of a reaction
- use ideas about correlation in the context of rates of reaction
- balance equations
- calculate reacting masses and yield.

Opportunities for practical work

This module offers opportunities for practical work in teaching and learning. For example:

- reactions of acids
- reactions of alkalis
- exothermic and endothermic reactions
- titration experiments
- rate of reaction experiments
- synthesis of a salt.

Opportunities for ICT

This module offers opportunities to illustrate the use of ICT in science. For example:

- logging and storing data, and displaying data in a variety of formats for analysis.

Use of ICT in teaching and learning can include:

- video clips to illustrate the manufacture of chemicals on a large-scale in industry
- using sensors and data loggers to monitor neutralisation reactions and the rates of chemical changes.

Opportunities for teaching the Ideas about Science

Examples of Ideas about Science for which there are particular opportunities for introduction or development in this module include:

Data: their importance and limitations

laS 1.1 – 1.6

Cause-effect explanations

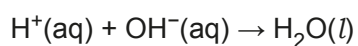
laS 2.1 – 2.3, 2.6, **2.7**

Module C6: Chemical synthesis**C6.1 Chemicals and why we need them**

1. understand the importance of chemical synthesis to provide food additives, fertilisers, dyestuffs, paints, pigments and pharmaceuticals
2. interpret information about the sectors, scale and importance of chemical synthesis in industry and in laboratories
3. recall the formulae of the following chemicals: chlorine gas, hydrogen gas, nitrogen gas, oxygen gas, hydrochloric acid, nitric acid, sulfuric acid, sodium hydroxide, sodium chloride, sodium carbonate, sodium nitrate, sodium sulfate, potassium chloride, magnesium oxide, magnesium hydroxide, magnesium carbonate, magnesium chloride, magnesium sulfate, calcium carbonate, calcium chloride and calcium sulfate
4. **work out the formulae of ionic compounds given the charges on the ions**
5. **work out the charge on one ion given the formula of a salt and the charge on the other ion**
6. recall the main hazard symbols and be able to give the safety precautions for handling hazardous chemicals (limited to explosive, toxic, corrosive, oxidizing, and highly flammable)
① See Appendix G for guidance on recent changes to hazard labelling
7. recall examples of pure acidic compounds that are solids (citric and tartaric acids), liquids (sulfuric, nitric and ethanoic acids) or gases (hydrogen chloride)
8. recall that common alkalis include the hydroxides of sodium, potassium and calcium
9. recall the pH scale
10. recall the use of litmus paper, universal indicator and pH meters to detect acidity and alkalinity, and the use of universal indicator and pH meters to measure pH
11. recall the characteristic reactions of acids that produce salts, to include the reactions with metals and their oxides, hydroxides and carbonates
12. write word equations when given appropriate information
13. interpret symbol equations, including the number of atoms of each element, the number of molecules of each element or covalent compound and the number of 'formulas' of ionic compounds, in reactants and products
① In this context, 'formula' is used in the case of ionic compounds as an equivalent to molecules in covalent compounds; the concept of the mole is not covered in the specification
14. **balance unbalanced symbol equations**
15. **write balanced equations, including the state symbols (s), (l), (g) and (aq), to describe the characteristic reactions of acids and other reactions when given appropriate information**
16. recall the state symbols (s), (l), (g) and (aq) and understand their use in equations
17. recall that the reaction of an acid with an alkali to form a salt is a neutralisation reaction

C6.1 Chemicals and why we need them

18. explain that acidic compounds produce aqueous hydrogen ions, $\text{H}^+(\text{aq})$, when they dissolve in water
19. explain that alkaline compounds produce aqueous hydroxide ions, $\text{OH}^-(\text{aq})$, when they dissolve in water
20. write down the name of the salt produced given the names of the acid and alkali
- 21. write down the formula of the salt produced given the formulae of the acid and alkali**
22. explain that during a neutralisation reaction, the hydrogen ions from the acid react with hydroxide ions from the alkali to make water:



23. understand the terms endothermic and exothermic
24. use and interpret simple energy level diagrams for endothermic and exothermic reactions
25. understand the importance of the energy change during a reaction to the management and control of a chemical reaction.

Module C6: Chemical synthesis**C6.2 Planning, carrying out and controlling a chemical synthesis**

1. identify the stages in a given chemical synthesis of an inorganic compound (limited to acid-alkali reactions), including:
 - a. choosing the reaction or series of reactions to make the required product
 - b. carrying out a risk assessment
 - c. working out the quantities of reactants to use**
 - d. carrying out the reaction in suitable apparatus in the right conditions (such as temperature, concentration)
 - e. separating the product from the reaction mixture (limited to filtration)
 - f. purifying the product (limited to evaporation, crystallisation and drying in an oven or desiccator)
 - g. measuring the yield and checking the purity of the product (by titration)
2. understand the purpose of these techniques: dissolving, crystallisation, filtration, evaporation, drying in an oven or desiccator
3. understand the importance of purifying chemicals and checking their purity
4. understand that a balanced equation for a chemical reaction shows the relative numbers of atoms and molecules of reactants and products taking part in the reaction
5. understand that the relative atomic mass of an element shows the mass of its atom relative to the mass of other atoms
6. use the Periodic Table to obtain the relative atomic masses of elements
7. calculate the relative formula mass of a compound using the formula and the relative atomic masses of the atoms it contains
8. substitute relative formula masses and data into a given mathematical formula to calculate reacting masses and/or products from a chemical reaction
- 9. calculate the masses of reactants and products from balanced equations**
10. calculate percentage yields given the actual and the theoretical yield
11. describe how to carry out an acid-alkali titration accurately, when starting with a solution or a solid to be dissolved to make up a solution
 - ⓘ *Making up of standard solutions is not required*
12. substitute results in a given mathematical formula to interpret titration results quantitatively
13. understand why it is important to control the rate of a chemical reaction (to include safety and economic factors)
14. explain what is meant by the term 'rate of chemical reaction'

C6.2 Planning, carrying out and controlling a chemical synthesis

15. describe methods for following the rate of a reaction (for example, by collecting a gas, weighing the reaction mixture or observing the formation or loss of a colour or precipitate)
16. interpret results from experiments that investigate rates of reactions
17. understand how reaction rates vary with the size of solid particles, the concentration of solutions of chemicals and the temperature of the reaction mixture
 - ① *A qualitative treatment only is expected*
18. understand that catalysts speed up chemical reactions while not being used up in the reaction
19. interpret information about the control of rates of reaction in chemical synthesis
20. use simple ideas about collisions to explain how chemical reactions take place
21. use simple collision theory and ideas about collision frequency to explain how rates of reaction depend on the size of solid particles and on the concentration of solutions of dissolved chemicals.
 - ① *The effect of temperature on collision frequency is not considered since activation energy has a greater influence*

3.6 Summary of Unit A173: Chemistry A Module C7

Unit A173 assesses the content of *Module C7* together with the Ideas about Science.

Unit A173 includes additional content to enhance progression and to give a greater understanding of the subjects concerned. This unit continues the emphasis on 'science for the scientist' in preparation for further study, and provides a stimulating bridge to advanced level studies in science.

3.6.1 Module C7: Further Chemistry

Overview

The five topics in this longer module introduce new chemical ideas while illustrating important features of the applications of chemistry and exploring Ideas about Science from IaS1: Data and their limitations, IaS3: Developing explanations, and IaS6: Making decisions about science and technology.

The module starts with an introduction to green chemistry and describes how the chemical industry is reinventing processes so that the manufacture of bulk and fine chemicals is more sustainable. The theme of green chemistry runs through the module, presenting several opportunities to see how the principles are applied in real life.

The second topic covers introductory organic chemistry taking alcohols and carboxylic acids as the main examples. This builds on the coverage of hydrocarbon molecules in Modules C1 and C2.

The third and fourth topics lay the foundations for more advanced study of physical chemistry by exploring chemical concepts on a molecular scale including the connection between energy changes and bond breaking, as well as the notion of dynamic equilibrium.

The fifth topic introduces concepts of valid analytical measurements in contexts where the results of analysis matter. The two main analytical methods featured are chromatography and volumetric analysis.

Topics**C7.1 Green chemistry**

The chemical industry

The characteristics of green chemistry

C7.2 Alcohols, carboxylic acids and esters

Organic molecules and functional groups

Alcohols

Carboxylic acids

Esters

C7.3 Energy changes in chemistry

Why are there energy changes during chemical reactions?

C7.4 Reversible reactions and equilibria

Introducing dynamic equilibrium

C7.5 Analysis

Analytical procedures

Chromatography

Quantitative analysis by titration

Opportunities for mathematics

This module offers opportunities to develop mathematics skills. For example:

- carry out calculations using experimental data, including finding the mean and the range
- carry out calculations to find percentage yield and atom economy
- plot, draw and interpret graphs and charts from candidates' own and secondary data
- use an equation to calculate R_f values in chromatography
- use an equation to calculate concentration using appropriate units for physical quantities
- calculate reacting masses
- extract information from charts, graphs and tables including comparing data about nitrogen fixation processes
- balance equations
- calculate energy changes using bond energies.

Opportunities for practical work

This module offers opportunities for practical work in teaching and learning. For example:

- reactions of alkanes, alcohols, and carboxylic acids
- synthesis of an ester
- exothermic and endothermic reactions
- reversible reactions
- chromatography
- acid alkali titrations
- experiments to investigate catalysts.

Opportunities for ICT

This module offers opportunities to illustrate the use of ICT in science. For example:

- modelling the structures of molecules
- the integral role of ICT in chemical instrumentation.

Use of ICT in teaching and learning can include:

- using modelling software to explore the shapes of organic molecules
- video clips to illustrate the manufacture of chemicals on large and small scales
- video clips to illustrate gas chromatography and other analytical techniques
- using the internet to research current developments in green chemistry.

Opportunities for teaching the Ideas about Science

Examples of Ideas about Science for which there are particular opportunities for introduction or development in this module include:

Data: their importance and limitations

laS 1.2 – 1.6

Developing scientific explanations

laS 3.1, 3.2

Making decisions about science and technology

laS 6.1, 6.2

Module C7: Further Chemistry

C7.1 Green chemistry

The chemical industry

1. understand and use the terms 'bulk' (made on a large scale) and 'fine' (made on a small scale) in the context of the chemical industry
2. recall examples of chemicals made on a large scale (ammonia, sulfuric acid, sodium hydroxide, phosphoric acid) and examples of chemicals made on a small scale (drugs, food additives, fragrances)
3. interpret information about the work done by people who make chemicals
① *Candidates are not expected to recall any specific details*
4. understand that the development of new chemical products or processes requires an extensive programme of research and development (for example, catalysts for new processes)
5. recall that governments have strict regulations to control chemical processes as well as the storage and transport of chemicals to protect people and the environment

What are the characteristics of green chemistry?

6. understand that the production of useful chemicals involves several stages to include:
 - a. the preparation of feedstocks
 - b. synthesis
 - c. separation of products
 - d. handling of by-products and wastes
 - e. the monitoring of purity
7. understand that sustainability of any chemical process depends on:
 - a. whether or not the feedstock is renewable
 - b. the atom economy
 - c. the nature and amount of by-products or wastes and what happens to them
 - d. the energy inputs or outputs
 - e. the environmental impact
 - f. the health and safety risks
 - g. the social and economic benefits
8. understand the term activation energy in terms of the energy needed to break bonds to start a reaction
9. understand that a catalyst provides an alternative route for a reaction with a lower activation energy
10. understand that some industrial processes use enzyme catalysts, and the restrictions this places on the conditions that are used
11. use the Periodic Table to obtain the relative atomic masses of elements and use these to calculate relative formula masses
- 12. calculate the masses of reactants and products from balanced equations.**

Module C7: Further Chemistry

C7.2 Alcohols, carboxylic acids and esters

Organic molecules and functional groups

- recall that there is a family of hydrocarbons called alkanes
- recall the names and molecular formulae of the alkanes: methane, ethane, propane and butane
- translate between molecular, structural and ball-and-stick representations of simple organic molecules
- understand that alkanes burn in plenty of air to give carbon dioxide and water
- understand that alkanes are unreactive towards aqueous reagents because they contain only C—C and C—H bonds, which are difficult to break and therefore unreactive
- recall that in saturated compounds, such as alkanes, all the carbon to carbon bonds are single, C—C, but that in unsaturated compounds there are carbon to carbon double bonds, C=C
- represent chemical reactions by word equations
- interpret symbol equations, including the number of atoms of each element, the number of molecules of each element or covalent compound and the number of 'formulas' of ionic compounds, in reactants and products
 - In this context, 'formula' is used in the case of ionic compounds as an equivalent to molecules in covalent compounds; the concept of the mole is not covered in the specification*
- represent chemical reactions by balanced equations, including state symbols**

Alcohols

- recall the names, molecular formulae and structural formulae of methanol and ethanol
- recall two uses of methanol and two uses of ethanol
- recognise the formulae of alcohols
- understand that the characteristic properties of alcohols are due to the presence of the —OH functional group
- recall how ethanol compares in its physical properties with water and with alkanes
- understand that alcohols burn in air to produce carbon dioxide and water because of the presence of a hydrocarbon chain
- recall the reaction of alcohols with sodium and how this compares with the reactions of water and alkanes with sodium**
- understand why there is a limit to the concentration of ethanol solution that can be made by fermentation
- understand how ethanol solution can be concentrated by distillation and that this can be used to make products such as whisky and brandy
- understand the optimum conditions for making ethanol by fermentation of sugar with yeast, taking into consideration temperature and pH
- understand how genetically modified *E. coli* bacteria can be used to convert waste biomass from a range of sources into ethanol and recall the optimum conditions for the process

C7.2 Alcohols, carboxylic acids and esters

21. recall in outline the synthetic route for converting ethane (from oil or natural gas) into ethanol (via ethene)
22. interpret data about the different processes involved in the production of ethanol, and evaluate their sustainability

Carboxylic acids

23. understand that the characteristic properties of carboxylic acids are due to the presence of the -COOH functional group
24. recall the names, molecular formulae and structural formulae of methanoic acid and ethanoic acid
25. recognise the formulae of carboxylic acids
26. recall that many carboxylic acids have unpleasant smells and tastes and are responsible for the smell of sweaty socks and the taste of rancid butter
27. understand that carboxylic acids show the characteristic reactions of acids with metals, alkalis and carbonates
28. recall that vinegar is a dilute solution of ethanoic acid
29. understand that carboxylic acids are called weak acids because they are less reactive than strong acids such as hydrochloric acid, sulfuric acid and nitric acid
30. understand that dilute solutions of weak acids have higher pH values than dilute solutions of strong acids

Esters

31. understand that carboxylic acids react with alcohols, in the presence of a strong acid catalyst, to produce esters
32. recall that esters have distinctive smells
33. recall that esters are responsible for the smells and flavours of fruits
34. recall the use of esters as food flavourings, solvents and plasticizers, and in perfumes
35. **understand the procedure for making an ester (such as ethyl ethanoate) from a carboxylic acid and an alcohol**
36. **understand the techniques used to make a liquid ester, limited to:**
 - a. **heating under reflux**
 - b. **distillation**
 - c. **purification by treatment with reagents in a tap funnel**
 - d. **drying**
37. recall that fats are esters of glycerol and fatty acids
38. recall that living organisms make fats and oils as an energy store
39. recall that animal fats are mostly saturated molecules and that vegetable oils are mostly unsaturated molecules.

Module C7: Further Chemistry**C7.3 Energy changes in chemistry**

Why are there energy changes during chemical reactions?

1. understand the terms exothermic and endothermic
2. use and interpret energy level diagrams for exothermic and endothermic reactions
3. understand that energy is needed to break chemical bonds and that energy is given out when chemical bonds form
4. **use given data on the energy needed to break covalent bonds to estimate the overall energy change in simple examples (for example, the formation of steam or hydrogen halides from their elements)**
5. understand the term activation energy in terms of the energy needed to break bonds to start a reaction.

Module C7: Further Chemistry**C7.4 Reversible reactions and equilibria***Introducing dynamic equilibrium*

1. understand that some chemical reactions are reversible and are shown by the symbol \rightleftharpoons
2. understand that reversible reactions can reach a state of equilibrium
3. **understand the dynamic equilibrium explanation for chemical equilibrium**
4. understand why fixing nitrogen by the Haber process is important
5. recall that the feedstocks of nitrogen and hydrogen for the Haber process are made from air, natural gas and steam
 - ① *Candidates do not need to know the details of the processes involved*
6. in the context of the Haber process:
 - a. understand that the reaction between hydrogen and nitrogen to form ammonia is a reversible reaction
 - b. understand how the yield of ammonia is increased by recycling unreacted hydrogen and nitrogen
 - c. explain the effect of changing temperature and pressure on the yield of ammonia at equilibrium
 - d. understand that the gases do not stay in the reactor long enough to reach equilibrium
 - e. understand that a catalyst is used to increase the rate of reaction in the Haber process
 - f. understand that the efficiency of the process can be improved by using a different catalyst
 - g. explain how the conditions used for the process are a compromise to produce an economically viable yield of ammonia**
7. understand that some living organisms 'fix' nitrogen at room temperature and pressure using enzymes as catalysts
8. understand why chemists are interested in producing new catalysts that mimic natural enzymes
9. understand the impact on the environment of the large scale manufacture of ammonia and the widespread use of fertilisers made from it
10. interpret data about nitrogen fixation processes and evaluate their sustainability.

Module C7: Further Chemistry**C7.5 Analysis***Analytical procedures*

1. understand the difference between qualitative and quantitative methods of analysis
2. understand that an analysis must be carried out on a sample that represents the bulk of the material under test
3. recall that many analytical methods are based on samples in solution
4. understand the need for standard procedures for the collection, storage and preparation of samples for analysis

Chromatography

5. understand that in chromatography, substances are separated by movement of a mobile phase through a stationary phase
6. understand and use the terms aqueous and non-aqueous as applied to solvents
7. understand that for each component in a sample there is a dynamic equilibrium between the stationary and mobile phases
8. understand how a separation by chromatography depends on the distribution of the components in the sample between the mobile and stationary phases
9. understand the use of standard reference materials in chromatography
10. describe and compare paper and thin-layer chromatography
11. use the formula:

$$R_f = \frac{\text{distance travelled by solute}}{\text{distance travelled by solvent}}$$

and understand the use of R_f values

12. understand the use of locating agents in paper and thin-layer chromatography
13. recall in outline the procedure for separating a mixture by gas chromatography (gc)
14. understand the term retention time as applied to gc
15. interpret print-outs from gc analyses, limited to retention times and peak heights

C7.5 Analysis*Quantitative analysis by titration*

16. understand the main stages of a quantitative analysis:
 - a. measuring out accurately a specific mass or volume of the sample
 - b. working with replicate samples
 - c. dissolving the samples quantitatively
 - d. measuring a property of the solution quantitatively
 - e. calculating a value from the measurements (IaS 1.4)
 - f. estimating the degree of uncertainty in the results (IaS 1.5–1.6)
17. understand that concentrations of solutions can be measured in g/dm^3
18. recall the procedure for making up a standard solution
- 19. calculate the concentration of a given volume of solution given the mass of solute**
- 20. calculate the mass of solute in a given volume of solution with a specified concentration**
21. recall the procedure for carrying out an acid-base titration using a pipette and burette
22. substitute results in a given formula to interpret titration results quantitatively
- 23. use the balanced equation and relative formula masses to interpret the results of a titration**
24. use values from a series of titrations to assess the degree of uncertainty in a calculated value.