

Edexcel Additional Science

Chemistry C2

Topic 5 — Synthesis

This topic gives students the opportunity to gain a fundamental appreciation of organic chemistry. Students should understand that organic chemistry is the chemistry of compounds containing carbon and hydrogen, often with other elements. A study of the simple but relatively unreactive alkanes can be used to introduce the more reactive alkenes and the useful polymers that can be made from them.

They should come to appreciate that chemists need to know what masses of reactants to use to produce the required amount of product. Students should also realise that chemical reactions do not produce the theoretical amount of product, but only a percentage of that maximum amount. This can lead to the idea of purity of products and appropriate tests for purity.

It is important for students to realise that yields are an important factor when manufacturing chemical products. The aim of manufacturers is to produce a pure product safely with a high yield. This will enable manufacturers to keep costs down and to use profit to further research and development.

Students need to appreciate that products must be pure and therefore the separation of the product from the impurities is an important feature of chemical production. Students need to appreciate the implications of not having a pure product. Students will need to be aware that there is a number of analytical tests that can be carried out to check the purity of products. In some instances, such as wine, it would be smell and taste.

Practical activities can be carried out to prepare polymers and investigate the properties of polymers. The implications of non-biodegradable plastics can be discussed. Students can identify applications of plastics and how additives can alter their properties or use in specific applications, eg UPVC. Students can also investigate the importance of the products obtained from crude oil.

Have you ever wondered?

- Only a small part of crude oil is petrol, so how do we make enough for all the cars in the world?
- Food labels give 'total fat' and 'saturated fat' – but what's the difference?
- How is plastic made from oil?
- How do those plastic creatures, that grow when put in water, actually work?
- How do you make slime/super-balls?
- Why would you want a biodegradable plastic bag?
- Is sucking plastic toys dangerous for a baby?
- How do chemists discover new drugs?

Learning objectives

- Organic compounds contain the elements carbon and hydrogen and many originate from living things.
- Many new substances are made from oil.
- Polymers are large molecules which can be formed by the repeated joining of monomer molecules.
- Disposal of some polymers is an environmental problem.
- Raw materials are converted into new and useful substances by chemical reactions.
- The amount of reactant needed to form a desired quantity of product can be calculated, but the actual yield is lower than the theoretical yield and this has financial implications.

Glossary

addition empirical percentage yield theoretical yield
alkane fats polymer thermoplastic
alkene formulae polyunsaturated thermosetting

covalent bond hydrogenate saturated hydrocarbon toxicity
cracking monomer sustainable development unsaturated
hydrocarbon
double bond monounsaturated synthesis unsaturated monomer

Students will be expected to:

- recall the formulae of elements and simple compounds in the topic
- represent chemical reactions by word equations and simple balanced equations and use state symbols (s), (l), (g) and (aq)
- write balanced equations to describe and explain a wide range of reactions in this topic.

Students will be assessed on their ability to:

- investigate cracking within the laboratory, eg of liquid paraffin
- explain that cracking involves the breaking down of larger hydrocarbon molecules into smaller, more useful ones
- recall that when alkanes are cracked, mixtures of alkanes and alkenes are formed
- explain that alkanes are saturated hydrocarbons, containing only single covalent bonds between carbon atoms, and that alkenes are unsaturated hydrocarbons containing one or more double covalent bonds between carbon atoms
- recall the formulae of methane, ethane, propane, butane and draw the structures of their molecules
- recall the formulae of ethene and propene and draw the structures of their molecules
- describe how bromine water is used to distinguish between alkanes and alkenes
- demonstrate understanding that the ability of a carbon atom to form four stable covalent bonds results in a large number of carbon compounds
- discuss how modern society depends on oil and predict the possible consequences when supplies are depleted
- explain why some vegetable oils are referred to as 'polyunsaturated' or 'monounsaturated'
- explain why polyunsaturated oils are far less viscous than saturated ones
- describe how vegetable oil can be hydrogenated to form hydrogenated vegetable oil and what this is used for in the food industry
- **explain how ethene can be reacted with water to make ethanol in industry, and the uses of ethanol**
- recall that polymers are large molecules which are formed by a combination of many smaller molecules
- draw repeating units of addition polymers given the monomer and vice versa
- explain how addition polymers are formed from unsaturated monomers (equations required but not conditions and mechanisms)
- predict uses of polymers given appropriate information about their properties (NB: no recall expected)
- explain the similarities and differences in properties between thermosetting and thermoplastic polymers in terms of their structure
- explain how the properties of a polymer can be altered, depending on the starting materials, conditions of reaction, and additives (limited to plasticisers, preservatives and cross linking), and relate properties of polymers to their structure and bonding
- discuss the problems of disposing of some polymers, including nonbiodegradability and breakdown to toxic products
- discuss the issue of toxicity to humans in how chemists synthesise new substances
- demonstrate understanding that chemists use information about known reactions to make new compounds and predict the products of a reaction given the reactants and products of similar reactions
- **use the formula: total mass of useful product / total mass of product x100% to calculate the 'atom economy' of a reaction**

- demonstrate understanding that reactions with high atom economy are important for sustainable development as they prevent waste
- calculate relative formula mass from relative atomic masses
- calculate the formulae of simple compounds from reacting masses and understand that these are empirical.
- **use chemical equations to calculate masses of reactants and products**
- **calculate theoretical and percentage yields of reactions**
- describe how staged methods of synthesis are used in drug development to speed up discovery of effective substances
- **calculate the number of possible products from a staged synthesis experiment, involving no more than four stages, given appropriate data.**

Topic 6 — In Your Element

In this topic students are able to extend their knowledge of naming substances and develop their ideas of atomic structure to understand the existence of isotopes and justify the existence of relative atomic masses which are not whole numbers. Studying this topic, students will begin to understand the usefulness of the periodic table. First of all, students should realise how the periodic table enables them to recall the electronic configurations of elements. Data from the periodic table should then be used to study changes in chemical reactivity of the elements with increasing atomic number in groups 1 and 7 of the table. Study of the chemical reactions should be used to show how a knowledge of electronic configurations can lead to an understanding of how the atoms combine to form ionic bonds. Knowledge of the structure of compounds can then be used to rationalise some general physical properties of solids formed from ionic bonds. Students can appreciate that the bonding in ionic substances largely determines their properties. Students can carry out investigations to obtain primary data for the physical properties of ionic compounds.

Have you ever wondered?

- What is the difference between 9 and 18 carat gold jewelry
- What makes platinum, diamond and zirconium look so different, when they're all made from the same basic ingredients?
- How is gold-plated jewelry made?
- Did you know the atoms in your body were born in a star?
- Why do some scientists think life began in space and came to Earth on a comet?
- How do scientists detect new elements (such as element-115) if they only last milliseconds before disintegrating?
- Did you know scientists can make 'heavy water', so that an ice cube sinks?
- Can the periodic table help you learn chemistry in a lot less time?

Learning objectives

- The number of outer electrons in an element determines its position in the periodic table and its reactivity.
- The process of electrolysis.
- The existence of isotopes and their relationship to relative atomic mass.
- The importance of electrons in ionic and metallic bonding.

Glossary

alloy electrolysis ionic bonding nucleus
atomic number electronic
configuration
isotope periodic table
binary salt electron malleability proton
conductivity formulae mass number relative atomic mass
electrode ion neutron

Students will be expected to:

- recall the formulae of elements and simple compounds in the topic
- represent chemical reactions by word equations and simple balanced equations and use state symbols (s), (l), (g) and (aq)
- write balanced equations to describe and explain a wide range of reactions in this topic.

Students will be assessed on their ability to:

- describe and explain the physical properties of metals, including conductivity, malleability, hardness and high melting/boiling points
- describe and explain how alloying can change the properties of metals, eg iron, aluminium and their alloys

- recall the relative charges and relative masses of protons, neutrons and electrons
- explain the terms atomic number, mass number and relative atomic mass
- describe the structure of an atom as a nucleus containing protons and neutrons, surrounded by orbiting electrons arranged in shells
- recall that an ion is an atom or group of atoms with a positive or negative charge
- explain that ionic bonds are formed by the transfer of electrons to form positively charged ions (cations) and negatively charged ions (anions)
- describe the formation of sodium ions (Na^+) and chloride ions (Cl^-) from their atoms and hence predict the formation of ions in other ionic compounds, from their atoms
- describe and explain the physical properties of giant ionic structures (eg sodium chloride (NaCl)) including their regularly shaped crystals, high melting and boiling points and ability to conduct an electric current when molten and in solution
- write the formulae of ionic compounds, given the charges on the ions
- **predict the products of electrolysis of a given molten binary salt, and write balanced half equations for the electrode reactions**
- demonstrate understanding that in electrolysis ions move towards electrodes of opposite charge
- explain the existence of isotopes
- **calculate the relative atomic mass of an element from the relative masses and abundance of its isotopes**
- explain that reactions of an element depends upon the arrangement of electrons in the outer shell of its atoms
- describe the connection between the number of outer electrons and the position of an element in the periodic table
- explain the lack of reactivity of the noble gases in terms of the electron configuration of their atoms
- write down the electronic configurations of the first 20 elements in the periodic table, given the atomic numbers, either as electron shell diagrams or in the form, eg 2.8.1
- explain the trends in the reactivity of the alkali metals and of the halogens in terms of their electronic configurations
- appreciate how creative insight influenced the discovery of the elements of the periodic table, eg appreciate Mendeleev's vision and understanding in predicting the properties of silicon before it was discovered.

Topic 7 – Chemical Structures

Study of this topic enables students to begin to understand how very useful the periodic table is. First of all, students should realise how the table enables them to recall the electronic configurations of elements. Data from the periodic table should then be used to study changes in physical properties and chemical reactivity of the elements with increasing atomic number in groups 1 and 7 of the table. Study of the chemical reactions should be used to show how a knowledge of electronic configurations can lead to an understanding of how the atoms combine to form covalent bonds. The knowledge of the structure of compounds can then be used to rationalise some general physical properties of simple molecular and giant molecular covalent compounds. Students can appreciate that the type of bonding in chemical substances can determine their properties. Students can carry out investigations to obtain primary data to compare the physical properties of compounds which have different types of structures.

Have you ever wondered?

- Did you know there is a molecule that has atoms arranged in the shape of a soccer ball?
- Do the essential oils that supermarkets spray into the air put you in a positive mood?
- Why do people think crystals have mysterious healing qualities?
- If homeopathy works, why don't scientists believe it?
- If particles in a solid are closer than in a liquid, why doesn't ice sink?
- Why are diamonds so expensive when scientists can create them in a few hours?
- Why is life on Earth based on the carbon atom?

Learning objectives

- Bonds result from the forces between the electrons and the nuclei of atoms.
- Atoms bond in different ways to form compounds.
- The structure and properties of substances are dependent on the nature of the bonding.

Glossary

Buckminsterfullerene covalent bond graphite inter-molecular force
carbon nanotube diamond halogen simple molecular
covalent structure
conductivity giant molecular
covalent structure
homeopathic

Students will be expected to:

- recall the formulae of elements and simple compounds in the topic
- represent chemical reactions by word equations and simple balanced equations and use state symbols (s), (l), (g) and (aq)
- write balanced equations to describe and explain a wide range of reactions in this topic.

Students will be assessed on their ability to:

- recognise the importance of chance in scientific discoveries such as that of Buckminsterfullerene
- recall that Buckminsterfullerene and carbon nanotubes are forms of carbon
- suggest uses for fullerenes and nanotubes, given data about their properties
- describe and explain the physical properties of simple molecular covalent substances including their low melting/boiling points and their inability to conduct an electric current
- **use appropriate information to draw conclusions about whether a chemical-based therapy is effective**
- describe why ideas, such as the effectiveness of homeopathic medicine, are difficult for scientists to accept when they conflict with established theories
- recall that metals conduct electricity because there are relatively free electrons in the giant structure of atoms

- **relate the physical properties of the halogens to their inter-molecular forces of attraction**
- describe how covalent bonds are formed by electron sharing and can result in the formation of simple molecules or giant molecules such as those of like diamond and graphite
- **draw dot and cross diagrams of simple molecules including hydrogen (H₂), hydrogen chloride (HCl), water (H₂O) and carbon dioxide (CO₂)**
- describe and explain the similarities and differences in physical properties between the giant molecular covalent structures of diamond and graphite, including high melting/boiling points, hardness and conductivity
- **demonstrate an understanding of the limitations of representing models of atoms and molecules in two dimensions and how three dimensional representations can clarify understanding.**

Topic 8 — How Fast? How Furious?

In this topic, studies of the way substances react are developed further. Practical evidence is obtained to show how different factors affect rates of reaction and to show the nature of heat changes when reactions occur. Students can carry out investigations where primary data can be collected, processed, interpreted and presented, and the results explained at an atomic level. Students need a knowledge of the different factors that need to be taken into account when developing the effectiveness and efficiency of a chemical reaction, and understand that organisations need to consider these factors when developing a new chemical product safely. Students are introduced to the idea that all reactions are reversible and that this results in a dynamic equilibria being established rather than a complete conversion of reactants into products.

Have you ever wondered?

- Why do some chemicals explode when you mix them?
- How do you make rocket fuel?
- Why do chips cook much faster than bigger roast potatoes?
- How do the hot and cold packs that athletes use to treat injury work?
- Can chemical reactions be undone?
- How did the production of ammonia allow twice the world's population to be fed?

Learning objectives

- Different chemical reactions occur at different rates and these rates can be changed.
- Some reactions give out energy while others take in energy.
- Chemical reactions involve breaking bonds and forming bonds.
- Reactions are reversible.

Glossary

catalyst endothermic reaction fertiliser rate of reaction
collision theory enzyme Haber process reversible
concentration equilibrium organic surface area
dynamic
equilibrium
exothermic reaction pressure temperature

Students will be expected to:

- recall the formulae of elements and simple compounds in the topic
- represent chemical reactions by word equations and simple balanced equations and use state symbols (s), (l), (g) and (aq)
- write balanced equations to describe and explain a wide range of reactions
- **write balanced ionic equations to describe and explain a wide range of reactions.**
- **Students will be assessed on their ability to:**
- recall that exothermic reactions are accompanied by an increase in temperature and endothermic reactions by a decrease in temperature
- define an exothermic reaction as one in which heat energy is given out and an endothermic reaction as one which heat energy is taken in and give examples of such reactions
- recall that the breaking of bonds is endothermic and that the making of bonds is exothermic
- describe and explain the effect of changes in temperature, concentration and surface area of a solid on a given rate of reaction
- describe experiments to investigate the effect of temperature, concentration and surface area of a solid on the rate of a reaction (data-logging equipment may be used here)
- describe the effect of a catalyst on the rate of reaction, **and interpret the results**
- **explain that reactions can occur when particles collide and that increasing the frequency and energy of collisions increases the rate of the reaction**

- recall that enzymes are biological catalysts and appreciate the importance of controlling the speed of chemical reactions for the maintenance of life
- describe the conditions under which ammonia is produced from nitrogen and hydrogen in the Haber process
- demonstrate understanding that this reaction is reversible and can reach a dynamic equilibrium
- **demonstrate understanding of how the position of a dynamic equilibrium can be affected by changes of temperature and pressure, to include the Haber process as an example**
- **demonstrate understanding of the consequential effect of these changes on the rate of attainment of equilibrium and the possible need to use a catalyst**
- explain that ammonia produced in the Haber process can be neutralized with nitric acid to produce artificial nitrogenous fertilisers
- discuss the arguments for and against using natural and artificial fertilisers in farming.