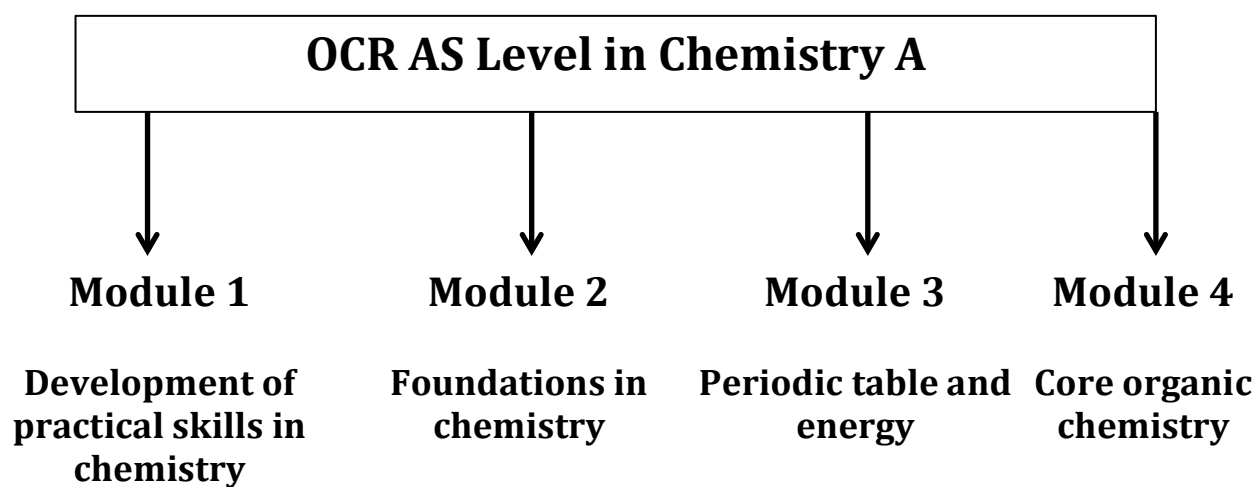


OCR AS Level in Chemistry A (H032)

Breadth in
Chemistry (01)
&
Depth in
Chemistry (02)



Dr. Faisal Rana
www.biochemtuition.com
Mobile: 07783919244
faisal.rana@biochemtuition.com

| OCR AS Level in Chemistry A (H032) – Breadth in Chemistry H032/01 | |
|---|-------------------------|
| 1. Exam paper- Breadth in Chemistry H032/01 1 hour 30 min written paper | 50 % of AS Chemistry |
| Overview of teaching modules | |
| Module 1: Development of practical skills in chemistry | |
| <ul style="list-style-type: none">• Practical skills assessed in a written examination. | |
| Module 2: Foundations in chemistry | |
| <ul style="list-style-type: none">• Atoms, compounds, molecules and equations.• Amount of substance.• Acid-base and redox reactions.• Electrons, bonding and structure. | |
| Module 3: Periodic table and energy | |
| <ul style="list-style-type: none">• The periodic table and periodicity• Group 2 and the halogens• Qualitative analysis• Enthalpy changes• Reactions rates and equilibrium (qualitative) | |
| Module 4: Core Organic Chemistry | |
| <ul style="list-style-type: none">• Basic concepts• Hydrocarbons• Alcohols and haloalkanes• Organic synthesis• Analytical techniques (IR and MS) | |
| Overview of assessment | |
| <ul style="list-style-type: none">• The unit is assessed through a 1-hour & 30 min examination paper set and marked by OCR.• The total number of marks is 70.• Grades A–E are available. | |

| | |
|---|-------------------------|
| OCR AS Level in Chemistry A (H032) – Depth in chemistry H032/02 | |
| 2. Exam paper- Depth in chemistry H032/01 1 hour 30 min written paper | 50 % of AS Chemistry |
| Overview of teaching modules | |
| Module 1: Development of practical skills in chemistry | |
| <ul style="list-style-type: none">• Practical skills assessed in a written examination. | |
| Module 2: Foundations in chemistry | |
| <ul style="list-style-type: none">• Atoms, compounds, molecules and equations.• Amount of substance.• Acid-base and redox reactions.• Electrons, bonding and structure. | |
| Module 3: Periodic table and energy | |
| <ul style="list-style-type: none">• The periodic table and periodicity• Group 2 and the halogens• Qualitative analysis• Enthalpy changes• Reactions rates and equilibrium (qualitative) | |
| Module 4: Core Organic Chemistry | |
| <ul style="list-style-type: none">• Basic concepts• Hydrocarbons• Alcohols and haloalkanes• Organic synthesis• Analytical techniques (IR and MS) | |
| Overview of assessment | |
| <ul style="list-style-type: none">• The unit is assessed through a 1-hour & 30 min examination paper set and marked by OCR.• The total number of marks is 70.• Grades A–E are available. | |

Three-pronged strategy to grade A or A*

How To Achieve Grade 'A' Breadth in chemistry & Depth in chemistry

Intensive tutoring

1. Complete Revision of Modules 1-4
2. Practice topic by topic examination style questions on Modules 1-4.

Past papers practice (2001-2014)

1. Solve relevant questions from past papers. We have dedicated question packs targeting MCQs, Short answer questions and extended answer questions.
2. Revisit the mistakes/revise topics.

Mock examination practice

1. Solve mock examination papers to prepare for the exam

OCR AS Chemistry Specification H032
Modules 1 to 4

2c. Content of modules 1 to 4

Module 1: Development of practical skills in chemistry

Chemistry is a practical subject and the development of practical skills is fundamental to understanding the nature of chemistry. Chemistry A gives learners many opportunities to develop the fundamental skills

needed to collect and analyse empirical data. Skills in planning, implementing, analysing and evaluating, as outlined in 1.1, will be assessed in the written papers.

1.1 Practical skills assessed in a written examination

Practical skills are embedded throughout all modules in this specification.

Learners will be required to develop a range of practical skills throughout the course in preparation for the written examinations.

1.1.1 Planning

| Learning outcomes | Additional guidance |
|---|---|
| <i>Learners should be able to demonstrate and apply their knowledge and understanding of:</i> | |
| (a) experimental design, including to solve problems set in a practical context | Including selection of suitable apparatus, equipment and techniques for the proposed experiment. Learners should be able to apply scientific knowledge based on the content of the specification to the practical context. HSW3 |
| (b) identification of variables that must be controlled, where appropriate | |
| (c) evaluation that an experimental method is appropriate to meet the expected outcomes. | HSW6 |

1.1.2 Implementing

| Learning outcomes | Additional guidance |
|---|--|
| <i>Learners should be able to demonstrate and apply their knowledge and understanding of:</i> | |
| (a) how to use a wide range of practical apparatus and techniques correctly | As outlined in the content of the specification. HSW4 |
| (b) appropriate units for measurements | MO.0 |
| (c) presenting observations and data in an appropriate format. | HSW8 |

1.1.3 Analysis

| Learning outcomes | Additional guidance |
|--|--|
| <i>Learners should be able to demonstrate and apply their knowledge and understanding of:</i> | |
| (a) processing, analysing and interpreting qualitative and quantitative experimental results | Including reaching valid conclusions, where appropriate. HSW5 |
| (b) use of appropriate mathematical skills for analysis of quantitative data | Refer to Section 5 for a list of mathematical skills that learners should have acquired competence in as part of the course. HSW3 |
| (c) appropriate use of significant figures | M1.1 |
| (d) plotting and interpreting suitable graphs from experimental results, including: (i) selection and labelling of axes with appropriate scales, quantities and units (ii) measurement of gradients. | M3.2 M3.3, M3.4, M3.5 |

1.1.4 Evaluation

| Learning outcomes | Additional guidance |
|---|---------------------|
| <i>Learners should be able to demonstrate and apply their knowledge and understanding of:</i> | |
| (a) how to evaluate results and draw conclusions | HSW6 |
| (b) the identification of anomalies in experimental measurements | |
| (c) the limitations in experimental procedures | |
| (d) precision and accuracy of measurements and data, including margins of error, percentage errors and uncertainties in apparatus | M1.3 |
| (e) refining experimental design by suggestion of improvements to the procedures and apparatus. | HSW3 |

Module 2: Foundations in chemistry

This module acts as an important bridge into AS and A Level Chemistry from the study of chemistry within science courses at GCSE level.

This module provides learners with a knowledge and understanding of the important chemical ideas that underpin the study of AS Chemistry:

- atomic structure
- quantitative chemistry: formulae, equations, amount of substance and the mole
- reactions of acids
- oxidation number and redox reactions
- bonding and structure.

The importance of these basic chemical concepts is seen as a prerequisite for all further chemistry modules, and it is recommended that this module should be studied first during this course.

This module allows learners to develop important quantitative techniques involved in measuring masses, gas and solution volumes, including use of volumetric apparatus.

Learners are also able to develop their mathematical skills during their study of amount of substance and when carrying out quantitative practical work.

2.1 Atoms and reactions

This section builds directly from GCSE Science, starting with basic atomic structure and isotopes.

Important basic chemical skills are developed: writing chemical formulae, constructing equations and calculating chemical quantities using the concept of amount of substance.

The role of acids, bases and salts in chemistry is developed in the context of neutralisation reactions.

Finally, redox reactions are studied within the context of oxidation number and electron transfer.

2.1.1 Atomic structure and isotopes

| Learning outcomes | Additional guidance |
|--|--|
| <p><i>Learners should be able to demonstrate and apply their knowledge and understanding of:</i></p> <p>Atomic structure and isotopes</p> <p>(a) isotopes as atoms of the same element with different numbers of neutrons and different masses</p> <p>(b) atomic structure in terms of the numbers of protons, neutrons and electrons for atoms and ions, given the atomic number, mass number and any ionic charge</p> | <p>HSW1 Different models for atomic structure can be used to explain different phenomena, e.g. the Bohr model explains periodic properties.</p> <p>HSW7 The changing accepted models of atomic structure over time. The use of evidence to accept or reject particular models.</p> |

Relative mass

- | | | |
|------|---|--|
| (c) | explanation of the terms <i>relative isotopic mass</i> (mass compared with 1/12th mass of carbon-12) and <i>relative atomic mass</i> (weighted mean mass compared with 1/12th mass of carbon-12), based on the mass of a ^{12}C atom, the standard for atomic masses | Definitions required. |
| (d) | use of mass spectrometry in: | <i>M0.2, M1.2, M3.1</i> |
| (i) | the determination of relative isotopic masses and relative abundances of the isotope | Knowledge of the mass spectrometer not required. Limited to ions with single charges. |
| (ii) | calculation of the relative atomic mass of an element from the relative abundances of its isotopes | |
| (e) | use of the terms <i>relative molecular mass</i> , M_r , and <i>relative formula mass</i> and their calculation from relative atomic masses. | For simple molecules, the term <i>relative molecular mass</i> will be used. For compounds with giant structures, the term <i>relative formula mass</i> will be used. Definitions of relative molecular mass and relative formula mass will not be required. |

2.1.2 Compounds, formulae and equations

Learning outcomes

Learners should be able to demonstrate and apply their knowledge and understanding of:

Formulae and equations

- | Learning outcomes | Additional guidance | |
|-------------------|---|--|
| (a) | the writing of formulae of ionic compounds from ionic charges, including: | Note that 'nitrate' and 'sulfate' should be assumed to be NO_3^- and SO_4^{2-} . |
| (i) | prediction of ionic charge from the position of an element in the periodic table | Charges on ions other than in (i) and (ii) will be provided. |
| (ii) | recall of the names and formulae for the following ions: NO_3^- , CO_3^{2-} , SO_4^{2-} , OH^- , NH_4^+ , Zn^{2+} and Ag^+ | |
| (b) | construction of balanced chemical equations (including ionic equations), including state symbols, for reactions studied and for unfamiliar reactions given appropriate information. | <i>M0.2</i> |

2.1.3 Amount of substance

| Learning outcomes | Additional guidance |
|---|---|
| <i>Learners should be able to demonstrate and apply their knowledge and understanding of:</i> | |
| The mole | |
| (a) explanation and use of the terms: | <i>M0.0, M0.1, M0.2, M0.4</i> |
| (i) <i>amount of substance</i> | Amount of substance will be used in exams using the formula of the substance e.g. amount of NaCl; amount of O ₂ . The value for N_A and the molar gas volume at RTP are provided on the <i>Data Sheet</i> . |
| (ii) <i>mole</i> (symbol 'mol'), as the unit for amount of substance | |
| (iii) the <i>Avogadro constant</i> , N_A (the number of particles per mole, $6.02 \times 10^{23} \text{ mol}^{-1}$) | |
| (iv) <i>molar mass</i> (mass per mole, units g mol^{-1}) | |
| (v) <i>molar gas volume</i> (gas volume per mole, units $\text{dm}^3 \text{ mol}^{-1}$) | |
| Determination of formulae | |
| (b) use of the terms: | Definitions not required. |
| (i) <i>empirical formula</i> (the simplest whole number ratio of atoms of each element present in a compound) | |
| (ii) <i>molecular formula</i> (the number and type of atoms of each element in a molecule) | |
| (c) calculations of empirical and molecular formulae, from composition by mass or percentage compositions by mass and relative molecular mass | <i>M0.2, M2.2, M2.3, M2.4</i> To include calculating empirical formulae from elemental analysis data. |
| (d) the terms <i>anhydrous</i> , <i>hydrated</i> and <i>water of crystallisation</i> and calculation of the formula of a hydrated salt from given percentage composition, mass composition or based on experimental results | <i>M0.2, M2.2, M2.3, M2.4</i> PAG1 |
| Calculation of reacting masses, gas volumes and mole concentrations | |
| (e) calculations, using amount of substance in mol, involving: | <i>M0.0, M0.1, M0.4, M1.1, M2.2, M2.3, M2.4</i> |
| (i) mass | Learners will be expected to express concentration in mol dm^{-3} and g dm^{-3} . |
| (ii) gas volume | |
| (iii) solution volume and concentration | |
| (f) the ideal gas equation: $pV = nRT$ | <i>M0.0, M0.1, M0.4, M1.1, M2.2, M2.3, M2.4</i> The value for R is provided on the <i>Data Sheet</i> . Learners will be expected to express quantities in SI units. |
| (g) use of stoichiometric relationships in calculations | <i>M0.2</i> |

Percentage yields and atom economy

- | | | |
|------|---|--|
| (h) | calculations to determine: | <i>M0.2, M1.1, M2.2, M2.3, M2.4</i> |
| (i) | the percentage yield of a reaction or related quantities | |
| (ii) | the atom economy of a reaction | |
| (i) | the techniques and procedures required during experiments requiring the measurement of mass, volumes of solutions and gas volumes | PAG1 HSW4 Many opportunities to carry out experimental and investigative work. |
| (j) | the benefits for sustainability of developing chemical processes with a high atom economy. | HSW10 Use of processes with high atom economy in chemical industry and other areas. |

2.1.4 Acids

Learning outcomes

Learners should be able to demonstrate and apply their knowledge and understanding of:

Additional guidance

Acids, bases, alkalis and neutralisation

- (a) the formulae of the common acids (HCl , H_2SO_4 , HNO_3 and CH_3COOH) and the common alkalis (NaOH , KOH and NH_3) and explanation that acids release H^+ ions in aqueous solution and alkalis release OH^- ions in aqueous solution
- (b) qualitative explanation of strong and weak acids in terms of relative dissociations
- (c) neutralisation as the reaction of:
- (i) H^+ and OH^- to form H_2O
 - (ii) acids with bases, including carbonates, metal oxides and alkalis (water-soluble bases), to form salts, including full equations

Acid–base titrations

- | | | |
|-----|---|--|
| (d) | the techniques and procedures used when preparing a standard solution of required concentration and carrying out acid–base titrations | PAG2 HSW4 Many opportunities to carry out experimental and investigative work. |
| (e) | structured and non-structured titration calculations, based on experimental results of familiar and non-familiar acids and bases. | <i>M0.1, M0.2, M1.1, M1.2, M2.2, M2.3, M2.4</i> |

2.1.5 Redox

| Learning outcomes | Additional guidance |
|---|---|
| <i>Learners should be able to demonstrate and apply their knowledge and understanding of:</i> | |
| Oxidation number | |
| (a) rules for assigning and calculating oxidation number for atoms in elements, compounds and ions | Learners will be expected to know oxidation numbers of O in peroxides and H in metal hydrides. |
| (b) writing formulae using oxidation numbers | HSW8 Appropriate use of oxidation numbers in written communication. |
| (c) use of a Roman numeral to indicate the magnitude of the oxidation number when an element may have compounds/ions with different oxidation numbers | Examples should include, but not be limited to, iron(II) and iron(III). Learners will be expected to write formulae from names such as chlorate(I) and chlorate(III) and <i>vice versa</i> . Note that 'nitrate' and 'sulfate', with no shown oxidation number, are assumed to be NO_3^- and SO_4^{2-} . HSW8 Systematic and unambiguous nomenclature. |
| Redox reactions | |
| (d) oxidation and reduction in terms of: (i) electron transfer (ii) changes in oxidation number | Should include examples of s-, p- and d-block elements. |
| (e) redox reactions of metals with acids to form salts, including full equations (see also 2.1.4 c) | Metals should be from s-, p- and d- blocks e.g. Mg, Al, Fe, Zn. Ionic equations not required. In (e), reactions with acids will be limited to those producing a salt and hydrogen. Reactions involving nitric acid or concentrated sulfuric acid could be assessed in the context of (f). |
| (f) interpretation of redox equations in (e), and unfamiliar redox reactions, to make predictions in terms of oxidation numbers and electron loss/gain. | MO.2 |

2.2 Electrons, bonding and structure

This section introduces the concept of atomic orbitals and develops a deeper understanding of electron configurations linked to the periodic table.

The central role of electrons in ionic and covalent bonding is then studied. The important role of

molecules is studied, including an explanation of polarity and intermolecular forces. Finally, this section looks at how bonding and structure contribute to properties of substances.

2.2.1 Electron structure

| Learning outcomes | Additional guidance |
|--|--|
| <i>Learners should be able to demonstrate and apply their knowledge and understanding of:</i> | |
| Energy levels, shells, sub-shells, atomic orbitals, electron configuration | |
| (a) the number of electrons that can fill the first four shells | |
| (b) atomic orbitals, including: <ul style="list-style-type: none"> (i) as a region around the nucleus that can hold up to two electrons, with opposite spins (ii) the shapes of s- and p-orbitals (iii) the number of orbitals making up s-, p- and d-sub-shells, and the number of electrons that can fill s-, p- and d-sub-shells | HSW1,7 Development of models to explain electron structure. |
| (c) filling of orbitals: <ul style="list-style-type: none"> (i) for the first three shells and the 4s and 4p orbitals in order of increasing energy (ii) for orbitals with the same energy, occupation singly before pairing | Learners are expected to be familiar with the 'electrons in box' representations. HSW1 Development of refined models for electron structure. |
| (d) deduction of the electron configurations of: <ul style="list-style-type: none"> (i) atoms, given the atomic number, up to $Z = 36$ (ii) ions, given the atomic number and ionic charge, limited to s- and p-blocks up to $Z = 36$. | Learners should use sub-shell notation, i.e. for oxygen: $1s^2 2s^2 2p^4$. The electron configurations of Cr and Cu will not be assessed. |

2.2.2 Bonding and structure

| Learning outcomes | Additional guidance |
|---|--|
| <i>Learners should be able to demonstrate and apply their knowledge and understanding of:</i> | |
| Ionic bonding | |
| (a) ionic bonding as electrostatic attraction between positive and negative ions, and the construction of 'dot-and-cross' diagrams | |
| (b) explanation of the solid structures of giant ionic lattices, resulting from oppositely charged ions strongly attracted in all directions e.g. NaCl | |
| (c) explanation of the effect of structure and bonding on the physical properties of ionic compounds, including melting and boiling points, solubility and electrical conductivity in solid, liquid and aqueous states | HSW1 Use of ideas about ionic bonding to explain macroscopic properties. |
| Covalent bonding | |
| (d) covalent bond as the strong electrostatic attraction between a shared pair of electrons and the nuclei of the bonded atoms | |
| (e) construction of 'dot-and-cross' diagrams of molecules and ions to describe: <ul style="list-style-type: none"> (i) single covalent bonding (ii) multiple covalent bonding (iii) dative covalent (coordinate) bonding | 'Dot-and-cross' diagrams of up to six electron pairs (including lone pairs) surrounding a central atom. |
| (f) use of the term <i>average bond enthalpy</i> as a measurement of covalent bond strength | Learners should appreciate that the larger the value of the average bond enthalpy, the stronger the covalent bond. Definition and calculations not required. Average bond enthalpies and related calculations are covered in detail in 3.2.1 f . |
| The shapes of simple molecules and ions | |
| (g) the shapes of, and bond angles in, molecules and ions with up to six electron pairs (including lone pairs) surrounding the central atom as predicted by electron pair repulsion, including the relative repulsive strengths of bonded pairs and lone pairs of electrons | <i>M4.1, M4.2</i> Learners should be able to draw 3-D diagrams to illustrate shapes of molecules and ions. HSW1,2 Using electron pair repulsion theory to predict molecular shapes. |
| (h) electron pair repulsion to explain the following shapes of molecules and ions: linear, non-linear, trigonal planar, pyramidal, tetrahedral and octahedral | Learners are expected to know that lone pairs repel more than bonded pairs and the bond angles for common examples of each shape including CH ₄ (109.5°), NH ₃ (107°) and H ₂ O (104.5°). |

Electronegativity and bond polarity

- (i) electronegativity as the ability of an atom to attract the bonding electrons in a covalent bond; interpretation of Pauling electronegativity values
- (j) explanation of:
 - (i) a polar bond and permanent dipole within molecules containing covalently-bonded atoms with different electronegativities
 - (ii) a polar molecule and overall dipole in terms of permanent dipole(s) and molecular shape

Learners should be aware that electronegativity increases towards F in the periodic table.

HSW1,2 Using ideas about electronegativity to predict chemical bond type.

A polar molecule requires polar bonds with dipoles that do not cancel due to their direction e.g. H_2O and CO_2 both have polar bonds but only H_2O has an overall dipole.

Intermolecular forces

- (k) intermolecular forces based on permanent dipole–dipole interactions and induced dipole–dipole interactions
- (l) hydrogen bonding as intermolecular bonding between molecules containing N, O or F and the H atom of $-\text{NH}$, $-\text{OH}$ or HF
- (m) explanation of anomalous properties of H_2O resulting from hydrogen bonding, e.g.:
 - (i) the density of ice compared with water
 - (ii) its relatively high melting and boiling points
- (n) explanation of the solid structures of simple molecular lattices, as covalently bonded molecules attracted by intermolecular forces, e.g. I_2 , ice
- (o) explanation of the effect of structure and bonding on the physical properties of covalent compounds with simple molecular lattice structures including melting and boiling points, solubility and electrical conductivity.

Permanent dipole–dipole and induced dipole–dipole interactions can **both** be referred to as van der Waals' forces.

Induced dipole–dipole interactions can also be referred to as London (dispersion) forces.

HSW1,2 Dipole interactions as a model to explain intermolecular bonding.

Including the role of lone pairs.

HSW1 Use of ideas about hydrogen bonding to explain macroscopic properties.

Module 3: Periodic table and energy

The focus of this module is inorganic and physical chemistry, the applications of energy use to everyday life and industrial processes, and current environmental concerns associated with sustainability.

The content within this module assumes knowledge and understanding of the chemical concepts developed in Module 2: Foundations in chemistry.

This module provides learners with a knowledge and understanding of the important chemical ideas that underpin the study of inorganic and physical chemistry:

- the periodic table: periodic and group properties
- enthalpy changes and their determination
- rates of reaction
- reversible reactions and chemical equilibrium
- consideration of energy and yield in improving sustainability.

This module allows learners to develop important qualitative practical skills, especially observational skills required for analysis, and accurate quantitative

techniques involved in determination of energy changes and reaction rates.

There are opportunities for developing mathematical skills when studying enthalpy changes and reaction rates and when carrying out quantitative practical work.

Synoptic assessment

This module provides a context for synoptic assessment and the subject content links strongly with content encountered in Module 2: Foundations in chemistry.

- Atoms, moles and stoichiometry
- Acid and redox reactions
- Bonding and structure

Knowledge and understanding of Module 2 will be assumed and examination questions will be set that link its content with this module and other areas of chemistry.

3.1 The periodic table

Periodic trends are first studied to extend the understanding of structure and bonding. Group properties are then studied using Group 2 and the halogens as typical metal and non-metal groups respectively, allowing an understanding of redox reactions to be developed further.

Finally, this section looks at how unknown ionic compounds can be analysed and identified using simple test-tube tests.

3.1.1 Periodicity

Learning outcomes

Learners should be able to demonstrate and apply their knowledge and understanding of:

Additional guidance

The structure of the periodic table

- (a)** the periodic table as the arrangement of elements:
- (i)** by increasing atomic (proton) number
 - (ii)** in periods showing repeating trends in physical and chemical properties (periodicity)
 - (iii)** in groups having similar chemical properties

HSW1,7,11 The development of the Periodic Law and acceptance by the scientific community.

HSW7,11 The extension of the periodic table through discovery and confirmation of new elements.

Periodic trend in electron configuration and ionisation energy

- (b)**
- (i)** the periodic trend in electron configurations across Periods 2 and 3 (**see also 2.2.1 d**)
 - (ii)** classification of elements into s-, p- and d-blocks
- (c)** first ionisation energy (removal of 1 mol of electrons from 1 mol of gaseous atoms) and successive ionisation energy, and:
- (i)** explanation of the trend in first ionisation energies across Periods 2 and 3, and down a group, in terms of attraction, nuclear charge and atomic radius
 - (ii)** prediction from successive ionisation energies of the number of electrons in each shell of an atom and the group of an element

M3.1

Definition required for first ionisation energy only. Explanation to include the small decreases as a result of s- and p-sub-shell energies (e.g. between Be and B) and p-orbital repulsion (e.g. between N and O).

HSW1,2 Trends in ionisation energy support the Bohr model of the atom.

Periodic trend in structure and melting point

- (d)** explanation of:
- (i)** metallic bonding as strong electrostatic attraction between cations (positive ions) and delocalised electrons
 - (ii)** a giant metallic lattice structure, e.g. all metals
- (e)** explanation of the solid giant covalent lattices of carbon (diamond, graphite and graphene) and silicon as networks of atoms bonded by strong covalent bonds

No details of cubic or hexagonal packing required.

HSW1,9 Use of ideas about bonding to explain the strength and conductive properties of graphene, and its potential applications and benefits.

- (f) explanation of physical properties of giant metallic and giant covalent lattices, including melting and boiling points, solubility and electrical conductivity in terms of structure and bonding
- (g) explanation of the variation in melting points across Periods 2 and 3 in terms of structure and bonding (see also 2.2.2 o).

Explanations should be in terms of the types of particle present in a lattice, the relative strength of forces and bonds, and the mobility of the particles involved, as appropriate.

HSW1 Use of ideas about bonding to explain macroscopic properties.

M3.1

Trend in structure from giant metallic to giant covalent to simple molecular lattice.

3.1.2 Group 2

Learning outcomes

Learners should be able to demonstrate and apply their knowledge and understanding of:

Redox reactions and reactivity of Group 2 metals

- (a) the outer shell s^2 electron configuration and the loss of these electrons in redox reactions to form $2+$ ions
- (b) the relative reactivities of the Group 2 elements $\text{Mg} \rightarrow \text{Ba}$ shown by their redox reactions with:
- (i) oxygen
 - (ii) water
 - (iii) dilute acids
- (c) the trend in reactivity in terms of the first and second ionisation energies of Group 2 elements down the group (see also 3.1.1 c)

Additional guidance

Reactions with acids will be limited to those producing a salt and hydrogen.

M3.1

Definition of second ionisation energy is **not** required, but learners should be able to write an equation for the change involved.

Reactions of Group 2 compounds

- (d) the action of water on Group 2 oxides and the approximate pH of any resulting solutions, including the trend of increasing alkalinity
- (e) uses of some Group 2 compounds as bases, including equations, for example (but not limited to):
- (i) $\text{Ca}(\text{OH})_2$ in agriculture to neutralise acid soils
 - (ii) $\text{Mg}(\text{OH})_2$ and CaCO_3 as 'antacids' in treating indigestion.

3.1.3 The halogens

Learning outcomes

Learners should be able to demonstrate and apply their knowledge and understanding of:

Additional guidance

Characteristic physical properties

- 2
- (a) existence of halogens as diatomic molecules and explanation of the trend in the boiling points of Cl_2 , Br_2 and I_2 , in terms of induced dipole–dipole interactions (London forces) (see also 2.2.2 k)

Redox reactions and reactivity of halogens and their compounds

- (b) the outer shell s^2p^5 electron configuration and the gaining of one electron in many redox reactions to form $1-$ ions
- (c) the trend in reactivity of the halogens Cl_2 , Br_2 and I_2 , illustrated by reaction with other halide ions
- (d) explanation of the trend in reactivity shown in (c), from the decreasing ease of forming $1-$ ions, in terms of attraction, atomic radius and electron shielding
- (e) explanation of the term *disproportionation* as oxidation and reduction of the same element, illustrated by:
- (i) the reaction of chlorine with water as used in water purification
 - (ii) the reaction of chlorine with cold, dilute aqueous sodium hydroxide, as used to form bleach
 - (iii) reactions analogous to those specified in (i) and (ii)
- (f) the benefits of chlorine use in water treatment (killing bacteria) contrasted with associated risks (e.g. hazards of toxic chlorine gas and possible risks from formation of chlorinated hydrocarbons)

Throughout this section, explanations of redox reactions should emphasise electron transfer and oxidation number changes and include full and ionic equations (see also 2.1.5 Redox).

Including colour change in aqueous and organic solutions.

HSW9,10,12 Decisions on whether or not to chlorinate water depend on balance of benefits and risks, and ethical considerations of people's right to choose. Consideration of other methods of purifying drinking water.

Characteristic reactions of halide ions

- (g) the precipitation reactions, including ionic equations, of the aqueous anions Cl^- , Br^- and I^- with aqueous silver ions, followed by aqueous ammonia, and their use as a test for different halide ions.

Complexes with ammonia are **not** required other than observations.

PAG4

HSW4 Qualitative analysis.

3.1.4 Qualitative analysis

| Learning outcomes | Additional guidance |
|---|---|
| <i>Learners should be able to demonstrate and apply their knowledge and understanding of:</i> | |
| Tests for ions | |
| (a) qualitative analysis of ions on a test-tube scale; processes and techniques needed to identify the following ions in an unknown compound: | |
| (i) anions: | Sequence of tests required is carbonate, sulfate then halide. (BaCO ₃ and Ag ₂ SO ₄ are both insoluble.) |
| • CO ₃ ²⁻ , by reaction with H ⁺ (aq) forming CO ₂ (g) (see 2.1.4 c) | PAG4 |
| • SO ₄ ²⁻ , by precipitation with Ba ²⁺ (aq) | HSW4 Qualitative analysis. |
| • Cl ⁻ , Br ⁻ , I ⁻ (see 3.1.3 g) | |
| (ii) cations: NH ₄ ⁺ , by reaction with warm NaOH(aq) forming NH ₃ . | |

3.2 Physical chemistry

This section introduces physical chemistry within the general theme of energy.

Learners first study the importance of enthalpy changes, their uses and determination from experimental results including enthalpy cycles.

This section then investigates the ways in which a change in conditions can affect the rate of a chemical reaction, in terms of activation energy, the Boltzmann distribution and catalysis.

Reversible reactions are then studied, including the dynamic nature of chemical equilibrium and the influence of conditions upon the position of equilibrium.

Finally, the integrated roles of enthalpy changes, rates, catalysts and equilibria are considered as a way of increasing yield and reducing energy demand, improving the sustainability of industrial processes.

3.2.1 Enthalpy changes

| Learning outcomes | Additional guidance |
|---|---------------------|
| <i>Learners should be able to demonstrate and apply their knowledge and understanding of:</i> | |
| Enthalpy changes: ΔH of reaction, formation, combustion and neutralisation | |
| (a) explanation that some chemical reactions are accompanied by enthalpy changes that are exothermic (ΔH , negative) or endothermic (ΔH , positive) | |
| (b) construction of enthalpy profile diagrams to show the difference in the enthalpy of reactants compared with products | M3.1 |

- (c) qualitative explanation of the term *activation energy*, including use of enthalpy profile diagrams
- (d) explanation and use of the terms:
- (i) *standard conditions* and *standard states* (physical states under standard conditions)
 - (ii) *enthalpy change of reaction* (enthalpy change associated with a stated equation, $\Delta_r H$)
 - (iii) *enthalpy change of formation* (formation of 1 mol of a compound from its elements, $\Delta_f H$)
 - (iv) *enthalpy change of combustion* (complete combustion of 1 mol of a substance, $\Delta_c H$)
 - (v) *enthalpy change of neutralisation* (formation of 1 mol of water from neutralisation, $\Delta_{\text{neut}} H$)
- (e) determination of enthalpy changes directly from appropriate experimental results, including use of the relationship: $q = mc\Delta T$

M3.1

Activation energy in terms of the minimum energy required for a reaction to take place.

Definitions required for enthalpy changes of formation, combustion and neutralisation only.

Standard conditions can be considered as 100 kPa and a stated temperature, 298 K.

M0.0, M0.2, M2.2, M2.3, M2.4

PAG3**Bond enthalpies**

- (f) (i) explanation of the term *average bond enthalpy* (breaking of 1 mol of bonds in gaseous molecules)
- (ii) explanation of exothermic and endothermic reactions in terms of enthalpy changes associated with the breaking and making of chemical bonds
- (iii) use of average bond enthalpies to calculate enthalpy changes and related quantities (see also 2.2.2 f)

M0.0, M0.2, M2.2, M2.3, M2.4

Definition of average bond enthalpy **not** required.

Learners are expected to understand that an actual bond enthalpy may differ from the average value.

Hess' law and enthalpy cycles

- (g) Hess' law for construction of enthalpy cycles and calculations to determine indirectly:
- (i) an enthalpy change of reaction from enthalpy changes of combustion
 - (ii) an enthalpy change of reaction from enthalpy changes of formation
 - (iii) enthalpy changes from unfamiliar enthalpy cycles
- (h) the techniques and procedures used to determine enthalpy changes directly and indirectly.

M0.0, M0.2, M1.1, M2.2, M2.3, M2.4, M3.1

Definition of Hess' law **not** required.
Unfamiliar enthalpy cycles will be provided.

HSW2 Application of the principle of conservation of energy to determine enthalpy changes.

M3.1, M3.2

PAG3

HSW4 Opportunities for carrying out experimental and investigative work.

3.2.2 Reaction rates

| Learning outcomes | Additional guidance |
|--|---|
| <i>Learners should be able to demonstrate and apply their knowledge and understanding of:</i> | |
| Simple collision theory | |
| (a) the effect of concentration, including the pressure of gases, on the rate of a reaction, in terms of frequency of collisions | |
| (b) calculation of reaction rate from the gradients of graphs measuring how a physical quantity changes with time | M3.1, M3.2, M3.5 Suitable physical quantities to monitor could include concentration, gas volume, mass, etc. |
| Catalysts | |
| (c) explanation of the role of a catalyst: | Details of processes are not required. |
| (i) in increasing reaction rate without being used up by the overall reaction | |
| (ii) in allowing a reaction to proceed via a different route with lower activation energy, as shown by enthalpy profile diagrams | |
| (d) (i) explanation of the terms <i>homogeneous</i> and <i>heterogeneous</i> catalysts | |
| (ii) explanation that catalysts have great economic importance and benefits for increased sustainability by lowering temperatures and reducing energy demand from combustion of fossil fuels with resulting reduction in CO ₂ emissions | HSW9,10 Benefits to the environment of improved sustainability weighed against toxicity of some catalysts. |
| (e) the techniques and procedures used to investigate reaction rates including the measurement of mass, gas volumes and time | PAG9 HSW4 Many opportunities to carry out experimental and investigative work. |
| The Boltzmann distribution | |
| (f) qualitative explanation of the Boltzmann distribution and its relationship with activation energy (see also 3.2.1 c) | M3.1 |
| (g) explanation, using Boltzmann distributions, of the qualitative effect on the proportion of molecules exceeding the activation energy and hence the reaction rate, for: | M3.1 |
| (i) temperature changes | |
| (ii) catalytic behaviour (see also 3.2.2 c). | HSW1,2,5 Use of Boltzmann distribution model to explain effect on reaction rates. |

3.2.3 Chemical equilibrium

Learning outcomes

Learners should be able to demonstrate and apply their knowledge and understanding of:

Additional guidance

Dynamic equilibrium and le Chatelier's principle

- 2**
- (a) explanation that a dynamic equilibrium exists in a closed system when the rate of the forward reaction is equal to the rate of the reverse reaction and the concentrations of reactants and products do not change
 - (b) le Chatelier's principle and its application for homogeneous equilibria to deduce qualitatively the effect of a change in temperature, pressure or concentration on the position of equilibrium
 - (c) explanation that a catalyst increases the rate of both forward and reverse reactions in an equilibrium by the same amount resulting in an unchanged position of equilibrium
 - (d) the techniques and procedures used to investigate changes to the position of equilibrium for changes in concentration and temperature.
 - (e) explanation of the importance to the chemical industry of a compromise between chemical equilibrium and reaction rate in deciding the operational conditions

Definition for le Chatelier's principle **not** required.

HSW1,2,5 Use of le Chatelier's principle to explain effect of factors on the position of equilibrium.

Qualitative effects only.

HSW4 Opportunities to carry out experimental and investigative work.

HSW6 Balancing the effects of equilibrium, rate, safety and economics to determine the conditions used in industrial reactions e.g. Haber process.

The equilibrium constant, K_c

- (f) expressions for the equilibrium constant, K_c , for homogeneous reactions and calculations of the equilibrium constant, K_c , from provided equilibrium concentrations
- (g) estimation of the position of equilibrium from the magnitude of K_c .

M0.2, M1.1, M2.3, M2.4

Learners will **not** need to determine the units for K_c .

M0.3

A qualitative estimation only is required.

Module 4: Core organic chemistry

This module introduces organic chemistry and its important applications to everyday life, including current environmental concerns associated with sustainability.

The module assumes knowledge and understanding of the chemical concepts developed in Module 2: Foundations in chemistry.

The module provides learners with a knowledge and understanding of the important chemical ideas that underpin the study of organic chemistry:

- nomenclature and formula representation, functional groups, organic reactions and isomerism
- aliphatic hydrocarbons
- alcohols and haloalkanes
- organic practical skills and organic synthesis
- instrumental analytical techniques to provide evidence of structural features in molecules.

This module also provides learners with an opportunity to develop important organic practical skills, including use of Quickfit apparatus for distillation, heating under reflux and purification of organic liquids.

4.1 Basic concepts and hydrocarbons

This section is fundamental to the study of organic chemistry.

This section introduces the various types of structures used routinely in organic chemistry, nomenclature, and the important concepts of homologous series,

In the context of this module, it is important that learners should appreciate the need to consider responsible use of organic chemicals in the environment. Current trends in this context include reducing demand for hydrocarbon fuels, processing plastic waste productively, and preventing use of ozone-depleting chemicals.

Synoptic assessment

This module provides a context for synoptic assessment and the subject content links strongly with the content encountered in Module 2: Foundations in chemistry.

- Atoms, moles and stoichiometry
- Acid and redox reactions
- Bonding and structure

Knowledge and understanding of Module 2 will be assumed and examination questions will be set that link its content with this module and other areas of chemistry.

functional groups, isomerism and reaction mechanisms using curly arrows.

The initial ideas are then developed within the context of the hydrocarbons: alkanes and alkenes.

4.1.1 Basic concepts of organic chemistry

Learning outcomes

Learners should be able to demonstrate and apply their knowledge and understanding of:

Naming and representing the formulae of organic compounds

- (a) application of IUPAC rules of nomenclature for systematically naming organic compounds

Additional guidance

Nomenclature will be limited to the functional groups within this specification.
E.g. $\text{CH}_3\text{CH}_2\text{CH}(\text{CH}_3)\text{CH}_2\text{OH}$ has the systematic name: 2-methylbutan-1-ol.
Learners will be expected to know the names of the first ten members of the alkanes homologous series and their corresponding alkyl groups.

HSW8 Use of systematic nomenclature to avoid ambiguity.

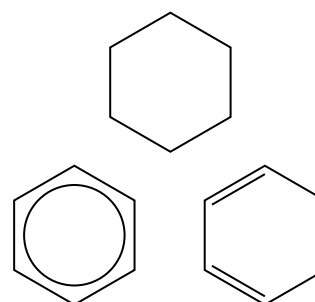
HSW11 The role of IUPAC in developing a systematic framework for chemical nomenclature.

M4.2

See also **2.1.3 b** for empirical formula and molecular formula.
Definitions **not** required.

In structural formulae, the carboxyl group will be represented as COOH and the ester group as COO .

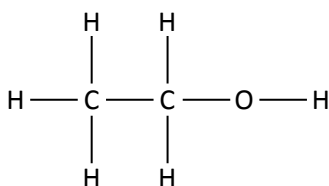
The symbols below will be used for cyclohexane and benzene:



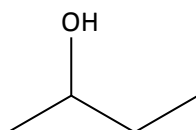
HSW8 Communication using organic chemical structures; selecting the appropriate type of formula for the context.

- (b) interpretation and use of the terms:

- (i) *general formula* (the simplest algebraic formula of a member of a homologous series) e.g. for an alkane: $\text{C}_n\text{H}_{2n+2}$
(ii) *structural formula* (the minimal detail that shows the arrangement of atoms in a molecule) e.g. for butane: $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3$ or $\text{CH}_3(\text{CH}_2)_2\text{CH}_3$
(iii) *displayed formula* (the relative positioning of atoms and the bonds between them) e.g. for ethanol:



- (iv) *skeletal formula* (the simplified organic formula, shown by removing hydrogen atoms from alkyl chains, leaving just a carbon skeleton and associated functional groups) e.g. for butan-2-ol:



Functional groups

- (c) interpretation and use of the terms:
- (i) *homologous series* (a series of organic compounds having the same functional group but with each successive member differing by CH_2)
 - (ii) *functional group* (a group of atoms responsible for the characteristic reactions of a compound)
 - (iii) *alkyl group* (of formula $\text{C}_n\text{H}_{2n+1}$)
 - (iv) *aliphatic* (a compound containing carbon and hydrogen joined together in straight chains, branched chains or non-aromatic rings)
 - (v) *alicyclic* (an aliphatic compound arranged in non-aromatic rings with or without side chains)
 - (vi) *aromatic* (a compound containing a benzene ring)
 - (vii) *saturated* (single carbon–carbon bonds only) and *unsaturated* (the presence of multiple carbon–carbon bonds, including $\text{C}=\text{C}$, $\text{C}\equiv\text{C}$ and aromatic rings)
- (d) use of the general formula of a homologous series to predict the formula of any member of the series

Definition required for homologous series only.

R may be used to represent alkyl groups, but also other fragments of organic compounds not involved in reactions.

The terms saturated and unsaturated will be used to indicate the presence of multiple carbon–carbon bonds as distinct from the wider term ‘degree of saturation’ used also for any multiple bonds and cyclic compounds.

Isomerism

- (e) explanation of the term *structural isomers* (compounds with the same molecular formula but different structural formulae) and determination of possible structural formulae of an organic molecule, given its molecular formula

M4.2

Reaction mechanisms

- (f) the different types of covalent bond fission:
- (i) homolytic fission (in terms of each bonding atom receiving one electron from the bonded pair, forming two radicals)
 - (ii) heterolytic fission (in terms of one bonding atom receiving both electrons from the bonded pair)

(g) the term *radical* (a species with an unpaired electron) and use of 'dots' to represent species that are radicals in mechanisms

(h) a 'curly arrow' described as the movement of an electron pair, showing either heterolytic fission or formation of a covalent bond

(i) reaction mechanisms, using diagrams, to show clearly the movement of an electron pair with 'curly arrows' and relevant dipoles.

Radical mechanisms will be represented by a sequence of equations.

Dots, •, are required in all instances where there is a single unpaired electron (e.g. $Cl\bullet$ and $CH_3\bullet$). Dots are not required for species that are diradicals (e.g. O).

'Half curly arrows' are **not** required, **see 4.1.2 f**.

HSW1,8 Use of the 'curly arrow' model to demonstrate electron flow in organic reactions.

Any relevant dipoles should be included. Curly arrows should start from a bond, a lone pair of electrons or a negative charge.

HSW1,2,8 Use of reaction mechanisms to explain organic reactions.

4.1.2 Alkanes

Learning outcomes

Learners should be able to demonstrate and apply their knowledge and understanding of:

Properties of alkanes

(a) alkanes as saturated hydrocarbons containing single C–C and C–H bonds as σ -bonds (overlap of orbitals directly between the bonding atoms); free rotation of the σ -bond

(b) explanation of the tetrahedral shape and bond angle around each carbon atom in alkanes in terms of electron pair repulsion (**see also 2.2.2 g–h**)

(c) explanation of the variations in boiling points of alkanes with different carbon-chain length and branching, in terms of induced dipole–dipole interactions (London forces) (**see also 2.2.2 k**)

Reactions of alkanes

(d) the low reactivity of alkanes with many reagents in terms of the high bond enthalpy and very low polarity of the σ -bonds present (**see also 2.2.2 j**)

(e) complete combustion of alkanes, as used in fuels, and the incomplete combustion of alkane fuels in a limited supply of oxygen with the resulting potential dangers from CO

Additional guidance

Hybridisation **not** required.

HSW1 Use of model of orbital overlap to explain covalent bonding in organic compounds.

M4.1, M4.2

Learners should be able to draw 3-D diagrams.

M3.1

HSW1 Use of ideas about enthalpy and polarity to explain macroscopic properties of alkanes.

- (f) the reaction of alkanes with chlorine and bromine by radical substitution using ultraviolet radiation, including a mechanism involving homolytic fission and radical reactions in terms of initiation, propagation and termination (**see also 4.1.1 f–g**)
- (g) the limitations of radical substitution in synthesis by the formation of a mixture of organic products, in terms of further substitution and reactions at different positions in a carbon chain.

Learners are **not** required to use 'half curly arrows' in this mechanism.

Equations should show which species are radicals using a single 'dot', •, to represent the unpaired electron.

4.1.3 Alkenes

| Learning outcomes | Additional guidance |
|--|---|
| <i>Learners should be able to demonstrate and apply their knowledge and understanding of:</i> | |
| Properties of alkenes | |
| (a) alkenes as unsaturated hydrocarbons containing a C=C bond comprising a π -bond (sideways overlap of adjacent p-orbitals above and below the bonding C atoms) and a σ -bond (overlap of orbitals directly between the bonding atoms) (see also 4.1.2 a); restricted rotation of the π -bond | Hybridisation is not required. HSW1 Use of model of orbital overlap to explain covalent bonding in organic compounds. |
| (b) explanation of the trigonal planar shape and bond angle around each carbon in the C=C of alkenes in terms of electron pair repulsion (see also 2.2.2 g–h, 4.1.2 b) | M4.1, M4.2 |

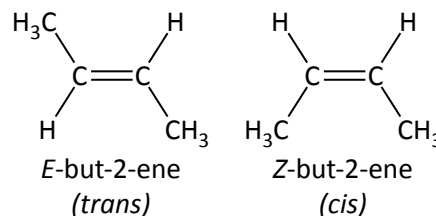
Stereoisomerism in alkenes

- (c) (i) explanation of the terms:
- *stereoisomers* (compounds with the same structural formula but with a different arrangement in space)
 - *E/Z isomerism* (an example of stereoisomerism, in terms of restricted rotation about a double bond and the requirement for two different groups to be attached to each carbon atom of the C=C group)
 - *cis–trans isomerism* (a special case of *E/Z isomerism* in which two of the substituent groups attached to each carbon atom of the C=C group are the same)
- (ii) use of Cahn–Ingold–Prelog (CIP) priority rules to identify the *E* and *Z* stereoisomers
- (d) determination of possible *E/Z* or *cis–trans* stereoisomers of an organic molecule, given its structural formula

Addition reactions of alkenes

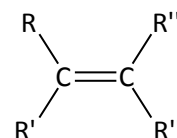
- (e) the reactivity of alkenes in terms of the relatively low bond enthalpy of the π -bond
- (f) addition reactions of alkenes with:
- hydrogen in the presence of a suitable catalyst, e.g. Ni, to form alkanes
 - halogens to form dihaloalkanes, including the use of bromine to detect the presence of a double C=C bond as a test for unsaturation in a carbon chain
 - hydrogen halides to form haloalkanes
 - steam in the presence of an acid catalyst, e.g. H_3PO_4 , to form alcohols
- (g) definition and use of the term *electrophile* (an electron pair acceptor)
- (h) the mechanism of electrophilic addition in alkenes by heterolytic fission (**see also 4.1.1 h–i**)

M4.2, M4.3



Use of *E* as equivalent to *trans* and *Z* as equivalent to *cis* is only consistently correct when there is an H on each carbon atom of the C=C bond.

Assigning CIP priorities to double or triple bonds within R groups is **not** required:



M4.2, M4.3

For the reaction with halogens, either a carbocation or a halonium ion intermediate is acceptable.

HSW1,2,8 Use of reaction mechanisms to explain organic reactions.

- (i) use of Markownikoff's rule to predict formation of a major organic product in addition reactions of H-X to unsymmetrical alkenes, e.g. H-Br to propene, in terms of the relative stabilities of carbocation intermediates in the mechanism

Limited to stabilities of primary, secondary and tertiary carbocations.
Explanation for relative stabilities of carbocations not required.

HSW1,2,5 Use of stability to explain products of organic reactions.

Polymers from alkenes

- (j) addition polymerisation of alkenes and substituted alkenes, including:
- (i) the repeat unit of an addition polymer deduced from a given monomer
 - (ii) identification of the monomer that would produce a given section of an addition polymer

Waste polymers and alternatives

- (k) the benefits for sustainability of processing waste polymers by:
- (i) combustion for energy production
 - (ii) use as an organic feedstock for the production of plastics and other organic chemicals
 - (iii) removal of toxic waste products, e.g. removal of HCl formed during disposal by combustion of halogenated plastics (e.g. PVC)
- (l) the benefits to the environment of development of biodegradable and photodegradable polymers.

HSW9,10 Benefits of cheap oil-derived plastics counteracted by problems for environment of landfill; the move to re-using waste, improving use of resources.

HSW9,10 Benefits of reduced dependency on finite resources and alleviating problems from disposal of persistent plastic waste.

4.2 Alcohols, haloalkanes and analysis

This section introduces two further functional groups: alcohols and haloalkanes, and considers the importance of polarity and bond enthalpy to organic reactions.

Throughout this section, there are many opportunities for developing organic practical skills, including preparation and purification of organic liquids.

Finally, the important techniques of infrared spectroscopy and mass spectrometry are used to illustrate instrumental analysis as a valuable tool for identifying organic compounds.

4.2.1 Alcohols

Learning outcomes

Learners should be able to demonstrate and apply their knowledge and understanding of:

Properties of alcohols

- (a) (i) the polarity of alcohols and an explanation, in terms of hydrogen bonding, of the water solubility and the relatively low volatility of alcohols compared with alkanes (**see also 2.2.2 I and 4.1.2 c**)
- (ii) classification of alcohols into primary, secondary and tertiary alcohols

Reactions of alcohols

- (b) combustion of alcohols
- (c) oxidation of alcohols by an oxidising agent, e.g. $\text{Cr}_2\text{O}_7^{2-}/\text{H}^+$ (i.e. $\text{K}_2\text{Cr}_2\text{O}_7/\text{H}_2\text{SO}_4$), including:
 - (i) the oxidation of primary alcohols to form aldehydes and carboxylic acids; the control of the oxidation product using different reaction conditions
 - (ii) the oxidation of secondary alcohols to form ketones
 - (iii) the resistance to oxidation of tertiary alcohols
- (d) elimination of H_2O from alcohols in the presence of an acid catalyst (e.g. H_3PO_4 or H_2SO_4) and heat to form alkenes
- (e) substitution with halide ions in the presence of acid (e.g. $\text{NaBr}/\text{H}_2\text{SO}_4$) to form haloalkanes.

Additional guidance

Equations should use [O] to represent the oxidising agent.

PAG7

Mechanism **not** required.

Mechanism **not** required.

4.2.2 Haloalkanes

| Learning outcomes | Additional guidance |
|---|---|
| <i>Learners should be able to demonstrate and apply their knowledge and understanding of:</i> | |
| Substitution reactions of haloalkanes | |
| (a) hydrolysis of haloalkanes in a substitution reaction: | PAG7 |
| (i) by aqueous alkali | |
| (ii) by water in the presence of AgNO ₃ and ethanol to compare experimentally the rates of hydrolysis of different carbon–halogen bonds | |
| (b) definition and use of the term <i>nucleophile</i> (an electron pair donor) | |
| (c) the mechanism of nucleophilic substitution in the hydrolysis of primary haloalkanes with aqueous alkali (see also 4.1.1 h–i) | HSW1,2 Use of reaction mechanisms to explain organic reactions. |
| (d) explanation of the trend in the rates of hydrolysis of primary haloalkanes in terms of the bond enthalpies of carbon–halogen bonds (C–F, C–Cl, C–Br and C–I) | |
| Environmental concerns from use of organohalogen compounds | |
| (e) production of halogen radicals by the action of ultraviolet (UV) radiation on CFCs in the upper atmosphere and the resulting catalysed breakdown of the Earth’s protective ozone layer, including equations to represent: | Simple equations of the breakdown process are required, e.g. |
| (i) the production of halogen radicals | $C_2F_2Cl_2 \rightarrow C_2F_2Cl\cdot + \cdot Cl$ |
| (ii) the catalysed breakdown of ozone by Cl• and other radicals e.g. •NO. | $\cdot Cl + O_3 \rightarrow \cdot ClO + O_2$ $\cdot ClO + O \rightarrow \cdot Cl + O_2$ |
| | Learners could be expected to construct similar equations for other stated radicals. |
| | HSW9,10,11,12 Benefits of CFCs; acceptance of scientific evidence explaining ozone depletion leading to government legislation against CFC use. |

4.2.3 Organic synthesis

Learning outcomes

Learners should be able to demonstrate and apply their knowledge and understanding of:

Practical skills

- (a)** the techniques and procedures for:
- (i)** use of Quickfit apparatus including for distillation and heating under reflux
 - (ii)** preparation and purification of an organic liquid including:
 - use of a separating funnel to remove an organic layer from an aqueous layer
 - drying with an anhydrous salt (e.g. MgSO_4 , CaCl_2)
 - redistillation

Synthetic routes

- (b)** for an organic molecule containing several functional groups:
- (i)** identification of individual functional groups
 - (ii)** prediction of properties and reactions
- (c)** two-stage synthetic routes for preparing organic compounds.

Additional guidance

PAG5

HSW4 Opportunities to carry out experimental and investigative work.

Learners will be expected to identify functional groups encountered in this specification: alkanes, alkenes, alcohols and haloalkanes.

HSW3 Development of synthetic routes.

Learners will be expected to be able to devise two-stage synthetic routes by applying transformations between all functional groups studied in this specification.

Extra information may be provided on exam papers to extend the learner's toolkit of organic reactions.

HSW3 Development of synthetic routes.

4.2.4 Analytical techniques

| Learning outcomes | Additional guidance |
|---|---|
| <i>Learners should be able to demonstrate and apply their knowledge and understanding of:</i> | |
| Infrared spectroscopy | |
| (a) infrared (IR) radiation causes covalent bonds to vibrate more and absorb energy | |
| (b) absorption of infrared radiation by atmospheric gases containing C=O, O–H and C–H bonds (e.g. H ₂ O, CO ₂ and CH ₄), the suspected link to global warming and resulting changes to energy usage | HSW9,10,11,12 Acceptance of scientific evidence explaining global warming has prompted governments towards policies to use renewable energy supplies. |
| (c) use of an infrared spectrum of an organic compound to identify: <ul style="list-style-type: none"> (i) an alcohol from an absorption peak of the O–H bond (ii) an aldehyde or ketone from an absorption peak of the C=O bond (iii) a carboxylic acid from an absorption peak of the C=O bond and a broad absorption peak of the O–H bond | <p>M3.1</p> <p>In examinations, infrared absorption data will be provided on the <i>Data Sheet</i>. Learners should be aware that most organic compounds produce a peak at approximately 3000 cm⁻¹ due to absorption by C–H bonds.</p> |
| (d) interpretations and predictions of an infrared spectrum of familiar or unfamiliar substances using supplied data | <p>M3.1</p> <p>Restricted to functional groups studied in this specification.</p> <p>HSW3,5 Analysis and interpretation of spectra.</p> |
| (e) use of infrared spectroscopy to monitor gases causing air pollution (e.g. CO and NO from car emissions) and in modern breathalysers to measure ethanol in the breath | HSW12 Use of analytical techniques to provide evidence for law courts, e.g. drink driving. |
| Mass spectrometry | |
| (f) use of a mass spectrum of an organic compound to identify the molecular ion peak and hence to determine molecular mass | <p>M3.1</p> <p>Limited to ions with single charges. Mass spectra limited to organic compounds containing C, H and O encountered in this specification.</p> <p>Learners should be aware that mass spectra may contain a small M+1 peak from the small proportion of carbon-13.</p> <p>HSW3,5 Analysis and interpretation of spectra.</p> |

- (g) analysis of fragmentation peaks in a mass spectrum to identify parts of structures

M3.1

Learners should be able to suggest the structures of fragment ions.

HSW3,5 Analysis and interpretation of spectra.

Combined techniques

- (h) deduction of the structures of organic compounds from different analytical data including:

M3.1

Limited to functional groups encountered in this specification.

- (i) elemental analysis (**see also 2.1.3 c**)

- (ii) mass spectra

- (iii) IR spectra.

Learners will **not** be expected to interpret mass spectra of organic halogen compounds.

HSW3,5,6 Analysis and interpretation of different analytical data.