BIS - IB Chemistry Syllabus

Curriculum Overview:
SL students will study Topics 1-11
HL students will study Topics 1-20
Both SL and HL students will study 2 out of the 7 Options (the class and the instructor must agree on which 2 Options to study)
Both SL and HL students must complete the Group 4 Project

IB learner profile

The aim of all IB programmes is to develop internationally minded people who, recognizing their common humanity and shared guardianship of the planet, help to create a better and more peaceful world. IB learners strive to be:

Inquirers (Inq) They develop their natural curiosity. They acquire the skills necessary to conduct inquiry and research and show independence in learning. They actively enjoy learning and this love of learning will be sustained throughout their lives.

Knowledgeable (Kno) They explore concepts, ideas and issues that have local and global significance. In so doing, they acquire in-depth knowledge and develop understanding across a broad and balanced range of disciplines.

Thinkers (Thk) They exercise initiative in applying thinking skills critically and creatively to recognize and approach complex problems, and make reasoned, ethical decisions.

Communicators (Com) They understand and express ideas and information confidently and creatively in more than one language and in a variety of modes of communication. They work effectively and willingly in collaboration with others.

Principled (Pri) They act with integrity and honesty, with a strong sense of fairness, justice and respect for the dignity of the individual, groups and communities. They take responsibility for their own actions and the consequences that accompany them.

Open-minded (Opn) They understand and appreciate their own cultures and personal histories, and are open to the perspectives, values and traditions of other individuals and communities. They are accustomed to seeking and evaluating a range of points of view, and are willing to grow from the experience.

Caring (Car) They show empathy, compassion and respect towards the needs and feelings of others. They have a personal commitment to service, and act to make a positive difference to the lives of others and to the environment.

Risk-takers (Rsk) They approach unfamiliar situations and uncertainty with courage and forethought, and have the independence of spirit to explore new roles, ideas and strategies. They are brave and articulate in defending their beliefs.

Balanced (Bal) They understand the importance of intellectual, physical and emotional balance to achieve personal well-being for themselves and others.

Reflective (Ref) They give thoughtful consideration to their own learning and experience. They are able to assess and understand their strengths and limitations in order to support their learning and personal development.

Topic 1: Quantitative chemistry   (12.5 hours)

1.1 The mole concept and Avogadro's constant   **2 hours**

TOK: Assigning numbers to the masses of the chemical elements allowed chemistry to develop into a physical science and use mathematics to express relationships between reactants and products.

Assessment statement	Teacher's notes
Apply the mole concept to substances.	The mole concept applies to all kinds of particles: atoms, molecules, ions, electrons, formula units, and so on. The amount of substance is measured in moles (mol). The approximate value of Avogadro's constant (L), 6.02×10^{23} mol^{-1}, should be known. **TOK:** Chemistry deals with enormous differences in scale. The magnitude of Avogadro's constant is beyond the scale of our everyday experience.
Determine the number of particles and the amount of substance (in moles).	Convert between the amount of substance (in moles) and the number of atoms, molecules, ions, electrons and formula units.

1.2 Formulas   **3 hours**

Assessment statement	Teacher's notes
Define the terms *relative atomic mass* (A_r) and *relative molecular mass* (M_r).	
Calculate the mass of one mole of a species from its formula.	The term molar mass (in g mol^{-1}) will be used.
Solve problems involving the relationship between the amount of substance in moles, mass and molar mass.	
Distinguish between the terms *empirical formula* and *molecular formula*.	
Determine the empirical formula from the percentage composition or from other experimental data.	**Aim 7:** Virtual experiments can be used to demonstrate this.
Determine the molecular formula when given both the empirical formula and experimental data.	

1.3 Chemical equations   **1 hour**

Assessment statement	Teacher's notes
Deduce chemical equations when all reactants and products are given.	Students should be aware of the difference between coefficients and subscripts.
Identify the mole ratio of any two species in a chemical equation.	
Apply the state symbols (s), (l), (g) and (aq).	**TOK:** When are these symbols necessary in aiding understanding and when are they redundant?

1.4 Mass and gaseous volume relationships in chemical reactions   4.5 hours

Assessment statement	Teacher's notes
Calculate theoretical yields from chemical equations.	Given a chemical equation and the mass or amount (in moles) of one species, calculate the mass or amount of another species.
Determine the limiting reactant and the reactant in excess when quantities of reacting substances are given.	**Aim 7:** Virtual experiments can be used here.
Solve problems involving theoretical, experimental and percentage yield.	
Apply Avogadro's law to calculate reacting volumes of gases.	
Apply the concept of molar volume at standard temperature and pressure in calculations.	The molar volume of an ideal gas under standard conditions is 2.24×10^{-2} m^3 mol^{-1} (22.4 dm^3 mol^{-1}).
Solve problems involving the relationship between temperature, pressure and volume for a fixed mass of an ideal gas.	**Aim 7:** Simulations can be used to demonstrate this.
Solve problems using the ideal gas equation, $PV = nRT$	**TOK:** The distinction between the Celsius and Kelvin scales as an example of an artificial and natural scale could be discussed.
Analyse graphs relating to the ideal gas equation.	

1.5 Solutions   2 hours

Assessment statement	Teacher's notes
Distinguish between the terms *solute*, *solvent*, *solution* and *concentration* (g dm^{-3} and mol dm^{-3}).	Concentration in mol dm^{-3} is often represented by square brackets around the substance under consideration, for example, [HCl].
Solve problems involving concentration, amount of solute and volume of solution.	

Topic 2: Atomic structure (4 hours)

2.1 The atom   **1 hour**

TOK: What is the significance of the model of the atom in the different areas of knowledge? Are the models and theories that scientists create accurate descriptions of the natural world, or are they primarily useful interpretations for prediction, explanation and control of the natural world?

Assessment statement	Teacher's notes
State the position of protons, neutrons and electrons in the atom.	**TOK:** None of these particles can be (or will be) directly observed. Which ways of knowing do we use to interpret indirect evidence gained through the use of technology? Do we believe or know of their existence?
State the relative masses and relative charges of protons, neutrons and electrons.	The accepted values are: Relative mass relative charge proton 1 +1 neutron 1 0 electron 5×10^{-4} −1
Define the terms *mass number* (*A*), *atomic number* (*Z*) and *isotopes of an element.*	
Deduce the symbol for an isotope given its mass number and atomic number.	The following notation should be used: $_Z^A X$, for example, $_6^{12}C$
Calculate the number of protons, neutrons and electrons in atoms and ions from the mass number, atomic number and charge.	
Compare the properties of the isotopes of an element.	
Discuss the uses of radioisotopes	Examples should include ^{14}C in radiocarbon dating, ^{60}Co in radiotherapy, and ^{131}I and ^{125}I as medical tracers. **Aim 8:** Students should be aware of the dangers to living things of radioisotopes but also justify their usefulness with the examples above.

2.2 The mass spectrometer   **1 hour**

Assessment statement	Teacher's notes
Describe and explain the operation of a mass spectrometer.	A simple diagram of a single beam mass spectrometer is required. The following stages of operation should be considered: vaporization, ionization, acceleration, deflection and detection. **Aim 7:** Simulations can be used to illustrate the operation of a mass spectrometer.
Describe how the mass spectrometer may be used to determine relative atomic mass using the ^{12}C scale.	
Calculate non-integer relative atomic masses and abundance of isotopes from given data.	

2.3 Electron arrangement

2 hours

Assessment statement	Teacher's notes
Describe the electromagnetic spectrum.	Students should be able to identify the ultraviolet, visible and infrared regions, and to describe the variation in wavelength, frequency and energy across the spectrum. **TOK:** Infrared and ultraviolet spectroscopy are dependent on technology for their existence. What are the knowledge implications of this?
Distinguish between a *continuous spectrum* and a *line spectrum*.	
Explain how the lines in the emission spectrum of hydrogen are related to electron energy levels.	Students should be able to draw an energy level diagram, show transitions between different energy levels and recognize that the lines in a line spectrum are directly related to these differences. An understanding of convergence is expected. Series should be considered in the ultraviolet, visible and infrared regions of the spectrum. Calculations, knowledge of quantum numbers and historical references will not be assessed. **Aim 7:** Interactive simulations modelling the behaviour of electrons in the hydrogen atom can be used.
Deduce the electron arrangement for atoms and ions up to $Z = 20$.	For example, 2.8.7 or 2,8,7 for $Z = 17$. **TOK:** In drawing an atom, we have an image of an invisible world. Which ways of knowing allow us access to the microscopic world?

Topic 3: Periodicity   (6 hours)

TOK: The early discoverers of the elements allowed chemistry to make great steps with limited apparatus, often derived from the pseudoscience of alchemy. Lavoisier's work with oxygen, which overturned the phlogiston theory of heat, could be discussed as an example of a paradigm shift.
Int: The discovery of the elements and the arrangement of them is a story that exemplifies how scientific progress is made across national boundaries by the sharing of information.

3.1 The periodic table   **1 hour**

Assessment statement	Teacher's notes
Describe the arrangement of elements in the periodic table in order of increasing atomic number.	Names and symbols of the elements are given in the *Chemistry data booklet*. The history of the periodic table will not be assessed. **TOK:** The predictive power of Mendeleev's periodic table could be emphasized. He is an example of a "scientist" as a "risk taker".
Distinguish between the terms *group* and *period*.	The numbering system for groups in the periodic table is shown in the *Chemistry data booklet*. Students should also be aware of the position of the transition elements in the periodic table.
Apply the relationship between the electron arrangement of elements and their position in the periodic table up to $Z = 20$.	
Apply the relationship between the number of electrons in the highest occupied energy level for an element and its position in the periodic table.	

3.2 Physical properties   **2 hours**

Assessment statement	Teacher's notes
Define the terms *first ionization energy* and *electronegativity*.	
Describe and explain the trends in atomic radii, ionic radii, first ionization energies, electronegativities and melting points for the alkali metals (Li $\rightarrow$ Cs) and the halogens (F $\rightarrow$ I).	Data for all these properties is listed in the *Chemistry data booklet*. Explanations for the first four trends should be given in terms of the balance between the attraction of the nucleus for the electrons and the repulsion between electrons. Explanations based on effective nuclear charge are not required.
Describe and explain the trends in atomic radii, ionic radii, first ionization energies and electronegativities for elements across period 3.	**Aim 7:** Databases and simulations can be used here.
Compare the relative electronegativity values of two or more elements based on their positions in the periodic table.	

3.3 Chemical properties

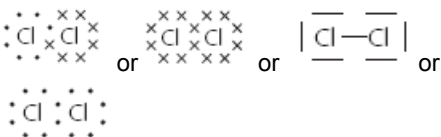| Assessment statement	Teacher's notes
Discuss the similarities and differences in the chemical properties of elements in the same group.	The following reactions should be covered. • Alkali metals (Li, Na and K) with water • Alkali metals (Li, Na and K) with halogens (Cl_2, Br_2 and I_2) • Halogens (Cl_2, Br_2 and I_2) with halide ions (Cl^-, Br^- and I^-)
Discuss the changes in nature, from ionic to covalent and from basic to acidic, of the oxides across period 3.	Equations are required for the reactions of Na_2O, MgO, P_4O_{10} and SO_3 with water. **Aim 8:** Non-metal oxides are produced by many large-scale industrial processes and the combustion engine. These acidic gases cause largescale pollution to lakes and forests, and localized pollution in cities.

Topic 4: Bonding (12.5 hours)

4.1 Ionic bonding

2 hours

Assessment statement	Teacher's notes
Describe the ionic bond as the electrostatic attraction between oppositely charged ions.	
Describe how ions can be formed as a result of electron transfer.	
Deduce which ions will be formed when elements in groups 1, 2 and 3 lose electrons.	
Deduce which ions will be formed when elements in groups 5, 6 and 7 gain electrons.	
State that transition elements can form more than one ion.	Include examples such as Fe^{2+} and Fe^{3+}.
Predict whether a compound of two elements would be ionic from the position of the elements in the periodic table or from their electronegativity values.	
State the formula of common polyatomic ions formed by nonmetals in periods 2 and 3.	Examples include NO_3^-, OH^-, SO_4^{2-}, CO_3^{2-}, PO_4^{3-}, NH_4^+, HCO_3^-.
Describe the lattice structure of ionic compounds.	Students should be able to describe the structure of sodium chloride as an example of an ionic lattice.

4.2 Covalent bonding

6 hours

Assessment statement	Teacher's notes
Describe the covalent bond as the electrostatic attraction between a pair of electrons and positively charged nuclei.	Single and multiple bonds should be considered. Examples should include O_2, N_2, CO_2, HCN, C_2H_4 (ethene) and C_2H_2 (ethyne).
Describe how the covalent bond is formed as a result of electron sharing.	Dative covalent bonds are required. Examples include CO, NH_4^+ and H_3O^+.
Deduce the Lewis (electron dot) structures of molecules and ions for up to four electron pairs on each atom.	A pair of electrons can be represented by dots, crosses, a combination of dots and crosses or by a line. For example, chlorine can be shown as: or or or Note: Cl–Cl is not a Lewis structure.
State and explain the relationship between the number of bonds, bond length and bond strength.	The comparison should include the bond lengths and bond strengths of: • two carbon atoms joined by single, double and triple bonds • the carbon atom and the two oxygen atoms in the carboxyl group of a carboxylic acid.

Predict whether a compound of two elements would be covalent from the position of the elements in the periodic table or from their electronegativity values.	
Predict the relative polarity of bonds from electronegativity values	**Aim 7:** Simulations may be used here.
Predict the shape and bond angles for species with four, three and two negative charge centres on the central atom using the valence shell electron pair repulsion theory (VSEPR).	Examples should include CH_4, NH_3, H_2O, NH_4^+, H_3O^+, BF_3, C_2H_4, SO_2, C_2H_2 and CO_2. **Aim 7:** Simulations are available to study the three dimensional structures of these and the structures in 4.2.9(diamond, graphite and C_{60} fullerene) and 4.2.10 (silicon and silicon dioxide).
Predict whether or not a molecule is polar from its molecular shape and bond polarities.	
Describe and compare the structure and bonding in the three allotropes of carbon (diamond, graphite and C_{60} fullerene).	
Describe the structure of and bonding in silicon and silicon dioxide.	

4.3 Intermolecular forces   2 hours

Assessment statement	Teacher's notes
Describe the types of intermolecular forces (attractions between molecules that have temporary dipoles, permanent dipoles or hydrogen bonding) and explain how they arise from the structural features of molecules.	The term van der Waals' forces can be used to describe the interaction between non-polar molecules.
Describe and explain how intermolecular forces affect the boiling points of substances.	The presence of hydrogen bonding can be illustrated by comparing: • HF and HCl • H_2O and H_2S • NH_3 and PH_3 • CH_3OCH_3 and CH_3CH_2OH • $CH_3CH_2CH_3$, CH_3CHO and CH_3CH_2OH.

4.4 Metallic bonding   0.5 hours

Assessment statement	Teacher's notes
Describe the metallic bond as the electrostatic attraction between a lattice of positive ions and delocalized electrons.	
Explain the electrical conductivity and malleability of metals.	**Aim 8:** Students should appreciate the economic importance of these properties and the impact that the large-scale production of iron and other metals has made on the world.

4.5 Physical properties

2 hours

Assessment statement	Teacher's notes
Compare and explain the properties of substances resulting from different types of bonding.	Examples should include melting and boiling points, volatility, electrical conductivity and solubility in non-polar and polar solvents.

Topic 5: Energetics   (8 hours)

5.1 Exothermic and endothermic reactions   **1 hour**

Assessment statement	Teacher's notes
Define the terms *exothermic reaction*, *endothermic reaction* and *standard enthalpy change of reaction* $(\Delta H^{\ominus})$.	Standard enthalpy change is the heat energy transferred under standard conditions—pressure 101.3 kPa, temperature 298 K. Only ΔH can be measured, not H for the initial or final state of a system.
State that combustion and neutralization are exothermic processes.	
Apply the relationship between temperature change, enthalpy change and the classification of a reaction as endothermic or exothermic.	
Deduce, from an enthalpy level diagram, the relative stabilities of reactants and products, and the sign of the enthalpy change for the reaction.	

5.2 Calculation of enthalpy changes   **3 hours**

Assessment statement	Teacher's notes
Calculate the heat energy change when the temperature of a pure substance is changed.	Students should be able to calculate the heat energy change for a substance given the mass, specific heat capacity and temperature change using $q = mc\Delta T$.
Design suitable experimental procedures for measuring the heat energy changes of reactions.	Students should consider reactions in aqueous solution and combustion reactions. Use of the bomb calorimeter and calibration of calorimeters will not be assessed. **Aim 7:** Data loggers and databases can be used here.
Calculate the enthalpy change for a reaction using experimental data on temperature changes, quantities of reactants and mass of water.	
Evaluate the results of experiments to determine enthalpy changes.	Students should be aware of the assumptions made and errors due to heat loss. **TOK:** What criteria do we use in judging whether discrepancies between experimental and theoretical values are due to experimental limitations or theoretical assumptions?

5.3 Hess's law   **2 hours**

Assessment statement	Teacher's notes

Determine the enthalpy change of a reaction that is the sum of two or three reactions with known enthalpy changes.	Students should be able to use simple enthalpy cycles and enthalpy level diagrams and to manipulate equations. Students will not be required to state Hess's law. **TOK:** As an example of the conservation of energy, this illustrates the unification of ideas from different areas of science.

5.4 Bond enthalpies

2 hours

Assessment statement	Teacher's notes
Define the term *average bond enthalpy.*	
Explain, in terms of average bond enthalpies, why some reactions are exothermic and others are endothermic.	

Topic 6: Kinetics (5 hours)

6.1 Rates of reaction   **2 hours**

Assessment statement	Teacher's notes
Define the term *rate of reaction*.	
Describe suitable experimental procedures for measuring rates of reactions.	**Aim 7:** Data loggers can be used to collect data and produce graphs. **TOK:** The empirical nature of the topic should be emphasized. Experimental results can support the theory but cannot prove it.
Analyse data from rate experiments	Students should be familiar with graphs of changes in concentration, volume and mass against time.

6.2 Collision theory   **3 hours**

Assessment statement	Teacher's notes
Describe the kinetic theory in terms of the movement of particles whose average energy is proportional to temperature in kelvins.	
Define the term *activation energy*, E_a.	
Describe the collision theory.	Students should know that reaction rate depends on: • collision frequency • number of particles with $E \geq E_a$ • appropriate collision geometry or orientation.
Predict and explain, using the collision theory, the qualitative effects of particle size, temperature, concentration and pressure on the rate of a reaction.	**Aim 7:** Interactive simulations can be used to demonstrate this.
Sketch and explain qualitatively the Maxwell–Boltzmann energy distribution curve for a fixed amount of gas at different temperatures and its consequences for changes in reaction rate.	Students should be able to explain why the area under the curve is constant and does not change with temperature. **Aim 7:** Interactive simulations can be used to demonstrate this.
Describe the effect of a catalyst on a chemical reaction.	
Sketch and explain Maxwell–Boltzmann curves for reactions with and without catalysts.	

Topic 7: Equilibrium (5 hours)

7.1 Dynamic equilibrium
<div align="right">**1 hour**</div>

Assessment statement	Teacher's notes
Outline the characteristics of chemical and physical systems in a state of equilibrium.	**Aim 7:** Spreadsheets and simulations can be used here.

7.2 The position of equilibrium
<div align="right">**4 hours**</div>

Assessment statement	Teacher's notes
Deduce the equilibrium constant expression (K_c) from the equation for a homogeneous reaction.	Consider gases, liquids and aqueous solutions.
Deduce the extent of a reaction from the magnitude of the equilibrium constant.	When $K_c \gg 1$, the reaction goes almost to completion. When $K_c \ll 1$, the reaction hardly proceeds.
Apply Le Chatelier's principle to predict the qualitative effects of changes of temperature, pressure and concentration on the position of equilibrium and on the value of the equilibrium constant.	Students will not be required to state Le Chatelier's principle. **Aim 7:** Simulations are available that model the behaviour of equilibrium systems.
State and explain the effect of a catalyst on an equilibrium reaction.	
Apply the concepts of kinetics and equilibrium to industrial processes.	Suitable examples include the Haber and Contact processes. **Aim 8:** A case study of Fritz Haber could be included to debate the role of scientists in society.

Topic 8: Acids and bases   (6 hours)

8.1 Theories of acids and bases   **2 hours**

Assessment statement	Teacher's notes
Define *acids* and *bases* according to the Brønsted–Lowry and Lewis theories.	**TOK:** Discuss the value of using different theories to explain the same phenomenon. What is the relationship between depth and simplicity?
Deduce whether or not a species could act as a Brønsted–Lowry and/or a Lewis acid or base.	
Deduce the formula of the conjugate acid (or base) of any Brønsted–Lowry base (or acid).	Students should make clear the location of the proton transferred, for example, CH_3COOH/CH_3COO- rather than $C_2H_4O_2/C_2H_3O_2^-$.

8.2 Properties of acids and bases   **1 hour**

Assessment statement	Teacher's notes
Outline the characteristic properties of acids and bases in aqueous solution.	Bases that are not hydroxides, such as ammonia, soluble carbonates and hydrogencarbonates, should be included. Alkalis are bases that dissolve in water. Students should consider the effects on indicators and the reactions of acids with bases, metals andcarbonates.

8.3 Strong and weak acids and bases   **2 hours**

Assessment statement	Teacher's notes
Distinguish between *strong* and *weak* acids and bases in terms of the extent of dissociation, reaction with water and electrical conductivity.	**Aim 8:** Although weakly acidic solutions are relatively safe, they still cause damage over long periods of time. Students could consider the effects of acid deposition on limestone buildings and living things.
State whether a given acid or base is strong or weak.	Students should consider hydrochloric acid, nitric acid and sulfuric acid as examples of strong acids, and carboxylic acids and carbonic acid (aqueous carbon dioxide) as weak acids. Students should consider all group 1 hydroxides and barium hydroxide as strong bases, and ammonia and amines as weak bases.
Distinguish between *strong* and *weak* acids and bases, and determine the relative strengths of acids and bases, using experimental data.	

8.4 The pH scale   **1 hour**

Assessment statement	Teacher's notes
Distinguish between aqueous solutions that are *acidic*, *neutral* or *alkaline* using the pH scale.	
Identify which of two or more aqueous solutions is more acidic or alkaline using pH values.	Students should be familiar with the use of a pH meter and universal indicator.
State that each change of one pH unit represents a 10-fold change in the hydrogen ion concentration [H+(aq)].	Relate integral values of pH to $[H^+(aq)]$ expressed as powers of 10. Calculation of pH from $[H^+(aq)]$ is not required. **TOK:** The distinction between artificial and natural sales could be discussed.
Deduce changes in $[H^+(aq)]$ when the pH of a solution changes by more than one pH unit.	**Aim 8:** A study of the effects of small pH changes in natural environments could be included.

Topic 9: Oxidation and reduction   (7 hours)

Aim 8: The Industrial Revolution was the consequence of the mass production of iron by a reduction process. However, iron spontaneously reverts back to an oxidized form. What price do we continue to pay in terms of energy and waste for choosing a metal so prone to oxidation and why was it chosen?

9.1 Introduction to oxidation and reduction   **2 hours**

Assessment statement	Teacher's notes
Define *oxidation* and *reduction* in terms of electron loss and gain.	
Deduce the oxidation number of an element in a compound.	Oxidation numbers should be shown by a sign (+ or –) and a number, for example, +7 for Mn in $KMnO_4$. **TOK:** Are oxidation numbers "real"?
State the names of compounds using oxidation numbers.	Oxidation numbers in names of compounds are represented by Roman numerals, for example, iron(II) oxide, iron(III) oxide. **TOK:** Chemistry has developed a systematic language that has resulted in older names becoming obsolete. What has been gained and lost in this process?
Deduce whether an element undergoes oxidation or reduction in reactions using oxidation numbers.	

9.2 Redox equations   **1 hour**

Assessment statement	Teacher's notes
Deduce simple oxidation and reduction half-equations given the species involved in a redox reaction.	
Deduce redox equations using half equations.	H^+ and H_2O should be used where necessary to balance half-equations in acid solution. The balancing of equations for reactions in alkaline solution will not be assessed.
Define the terms *oxidizing agent* and *reducing agent*.	
Identify the oxidizing and reducing agents in redox equations.	

9.3 Reactivity   **1 hour**

Assessment statement	Teacher's notes
Deduce a reactivity series based on the chemical behaviour of a group of oxidizing and reducing agents.	Examples include displacement reactions of metals and halogens. Standard electrode potentials will not be assessed.
Deduce the feasibility of a redox reaction from a given reactivity series.	Students are not expected to recall a specific reactivity series.

9.4 Voltaic cells

1 hour

Assessment statement	Teacher's notes
Explain how a redox reaction is used to produce electricity in a voltaic cell.	This should include a diagram to show how two half-cells can be connected by a salt bridge. Examples of half-cells are Mg, Zn, Fe and Cu in solutions of their ions.
State that oxidation occurs at the negative electrode (anode) and reduction occurs at the positive electrode (cathode).	

9.5 Electrolytic cells

2 hours

Assessment statement	Teacher's notes
Describe, using a diagram, the essential components of an electrolytic cell.	The diagram should include the source of electric current and conductors, positive and negative electrodes, and the electrolyte.
State that oxidation occurs at the positive electrode (anode) and reduction occurs at the negative electrode (cathode).	
Describe how current is conducted in an electrolytic cell.	
Deduce the products of the electrolysis of a molten salt.	Half-equations showing the formation of products at each electrode will be assessed. **Aim 8:** This process (which required the discovery of electricity) has made it possible to obtain reactive metals such as aluminium from their ores. This in turn has enabled subsequent steps in engineering and technology that increase our quality of life. Unlike iron, aluminium is not prone to corrosion and is one material that is replacing iron in many of its applications.

Topic 10: Organic chemistry   (12 hours)

10.1 Introduction   **4 hours**

Assessment statement	Teacher's notes
Describe the features of homologous series.	Include the same general formula, neighbouring members differing by CH_2, similar chemical properties and gradation in physical properties.
Predict and explain the trends in boiling points of members of a homologous series.	
Distinguish between *empirical*, *molecular* and *structural* formulas.	A structural formula is one that shows unambiguously how the atoms are arranged together. A full structural formula (sometimes called a graphic formula or displayed formula) shows every atom and bond, for example, for hexane: A condensed structural formula can omit bonds between atoms and can show identical groups bracketed together, for example, for hexane: $CH_3CH_2CH_2CH_2CH_2CH_3$ or $CH_3(CH_2)_4CH_3$. The use of R to represent an alkyl group and to represent the benzene ring can be used in condensed structural formulas. Although skeletal formulas are used for more complex structures in the *Chemistry data booklet*, such formulas will not be accepted in examination answers. **TOK:** The use of the different formulas illustrates the value of different models with different depths of detail.
Describe structural isomers as compounds with the same molecular formula but with different arrangements of atoms.	No distinction need be made between different types of structural isomerism, such as chain and position isomerism and functional group isomerism. Knowledge of stereoisomerism is not required in the core.
Deduce structural formulas for the isomers of the non-cyclic alkanes up to C_6.	Include both straight-chain and branched-chain isomers.
Apply IUPAC rules for naming the isomers of the non-cyclic alkanes up to C_6.	**TOK:** This could be discussed as an example of the use of the language of chemistry as a tool to classify and distinguish between different structures.
Deduce structural formulas for the isomers of the straight-chain alkenes up to C_6.	
Apply IUPAC rules for naming the isomers of the straight-chain alkenes up to C_6.	The distinction between *cis* and *trans* isomers is not required.
Deduce structural formulas for compounds containing up to six carbon atoms with one of the following functional groups: alcohol,	Condensed structural formulas can use OH, CHO, CO, COOH and F/Cl/Br/I.

Assessment statement	Teacher's notes
aldehyde, ketone, carboxylic acid and halide.	
Apply IUPAC rules for naming compounds containing up to six carbon atoms with one of the following functional groups: alcohol, aldehyde, ketone, carboxylic acid and halide.	
Identify the following functional groups when present in structural formulas: amino (NH_2), benzene ring (⬡) and esters (RCOOR).	
Identify primary, secondary and tertiary carbon atoms in alcohols and halogenoalkanes.	The terms primary, secondary and tertiary can also be applied to the molecules containing these carbon atoms.
Discuss the volatility and solubility in water of compounds containing the functional groups: alcohol, aldehyde, ketone, carboxylic acid and halide.	

10.2 Alkanes

2 hours

Assessment statement	Teacher's notes
Explain the low reactivity of alkanes in terms of bond enthalpies and bond polarity.	
Describe, using equations, the complete and incomplete combustion of alkanes.	
Describe, using equations, the reactions of methane and ethane with chlorine and bromine.	
Explain the reactions of methane and ethane with chlorine and bromine in terms of a free-radical mechanism.	Reference should be made to homolytic fission and the reaction steps of initiation, propagation and termination. The use of the half-arrow to represent the movement of a single electron is not required. The formulas of free radicals should include the radical symbol, for example, Cl• .

10.3 Alkenes

2 hours

Assessment statement	Teacher's notes
Describe, using equations, the reactions of alkenes with hydrogen and halogens.	
Describe, using equations, the reactions of symmetrical alkenes with hydrogen halides and water.	
Distinguish between *alkanes* and *alkenes* using bromine water.	
Outline the polymerization of alkenes.	Include the formation of poly(ethene), poly(chloroethene) and poly(propene) as examples of addition polymers. Include the identification of the repeating unit, for example,

	$-(-CH_2-CH_2-)_n-$ for poly(ethene).
Outline the economic importance of the reactions of alkenes.	**Aim 8:** Include the hydrogenation of vegetable oils in the manufacture of margarine, the hydration of ethene in the manufacture of ethanol, and polymerization in the manufacture of plastics.

10.4 Alcohols

<div align="right">1 hour</div>

Assessment statement	Teacher's notes
Describe, using equations, the complete combustion of alcohols.	
Describe, using equations, the oxidation reactions of alcohols.	A suitable oxidizing agent is acidified potassium dichromate(VI). Equations may be balanced using the symbol [O] to represent oxygen supplied by the oxidizing agent. Include the different conditions needed to obtain good yields of different products, that is, an aldehyde by distilling off the product as it is formed, and a carboxylic acid by heating under reflux.
Determine the products formed by the oxidation of primary and secondary alcohols.	Assume that tertiary alcohols are not oxidized by potassium dichromate(VI).

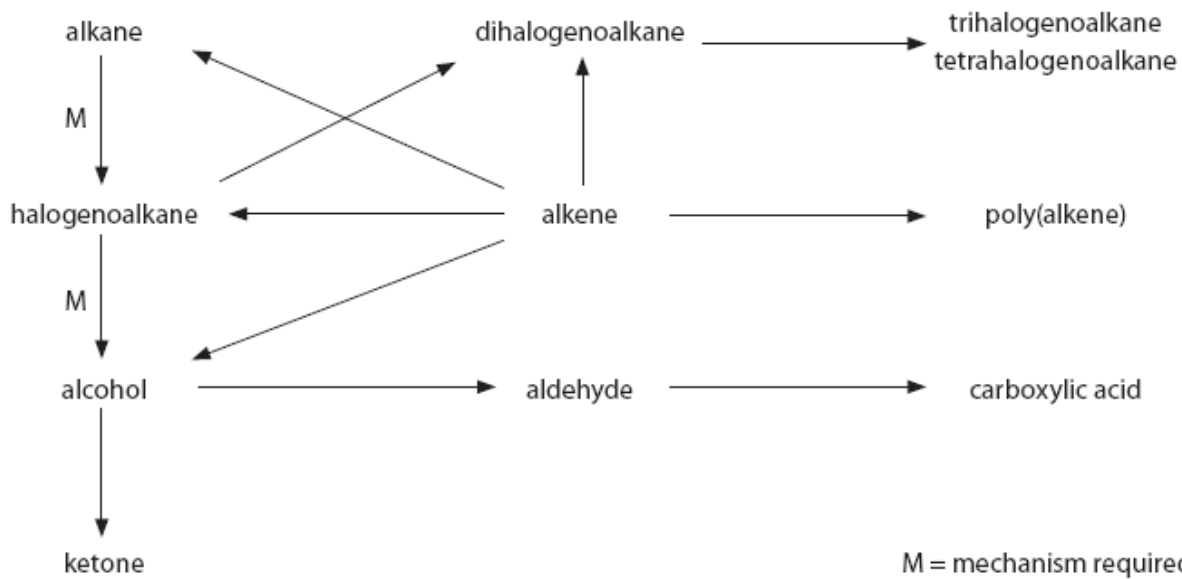# 10.5 Halogenoalkanes

<div align="right">2 hours</div>

Assessment statement	Teacher's notes
Describe, using equations, the substitution reactions of halogenoalkanes with sodium hydroxide.	**Aim 7:** Simulations are available for this.
Explain the substitution reactions of halogenoalkanes with sodium hydroxide in terms of S_N1 and S_N2 mechanisms.	Reference should be made to heterolytic fission. Curly arrows should be used to represent the movement of electron pairs. For tertiary halogenoalkanes the predominant mechanism is S_N1, and for primary halogenoalkanes it is S_N2. Both mechanisms occur for secondary halogenoalkanes.

10.6 Reaction pathways

<div align="right">1 hour</div>

Assessment statement	Teacher's notes
Deduce reaction pathways given the starting materials and the product.	Conversions with more than two stages will not be assessed. Reagents, conditions and equations should be included. For example, the conversion of but-2-ene to butanone can be done in two stages: but-2-ene can be heated with steam and a catalyst to form butan-2-ol, which can then be oxidized by heating with acidified potassium dichromate(VI) to form butanone.

The compound and reaction types in this topic are summarized in the following scheme:

alkane   dihalogenoalkane   trihalogenoalkane
tetrahalogenoalkane

M

halogenoalkane   alkene   poly(alkene)

M

alcohol   aldehyde   carboxylic acid

ketone   M = mechanism required

Topic 11: Measurement and data processing   (2 hours)

11.1 Uncertainty and error in measurement

Assessment statement	Teacher's notes
Describe and give examples of random uncertainties and systematic errors.	
Distinguish between *precision* and *accuracy*.	It is possible for a measurement to have great precision yet be inaccurate (for example, if the top of a meniscus is read in a pipette or a measuring cylinder).
Describe how the effects of random uncertainties may be reduced.	Students should be aware that random uncertainties, but not systematic errors, are reduced by repeating readings.
State random uncertainty as an uncertainty range (±).	
State the results of calculations to the appropriate number of significant figures.	

11.2 Uncertainties in calculated results

Assessment statement	Teacher's notes
State uncertainties as absolute and percentage uncertainties.	
Determine the uncertainties in results.	Only a simple treatment is required. For functions such as addition and subtraction, absolute uncertainties can be added. For multiplication, division and powers, percentage uncertainties can be added. If one uncertainty is much larger than others, the approximate uncertainty in the calculated result can be taken as due to that quantity alone.

11.3 Graphical techniques

TOK: Why are graphs helpful in providing powerful interpretations of reality?

Assessment statement	Teacher's notes
Sketch graphs to represent dependences and interpret graph behaviour.	Students should be able to give a qualitative physical interpretation of a particular graph, for example, the variables are proportional or inversely proportional.
Construct graphs from experimental data.	This involves the choice of axes and scale, and the plotting of points. **Aim 7:** Software graphing packages could be used.
Draw best-fit lines through data points on a graph.	These can be curves or straight lines.
Determine the values of physical quantities from graphs.	Include measuring and interpreting the slope (gradient), and stating the units for these quantities.

Option B: Human biochemistry   (15/22 hours)

The aim of this option is to give students an understanding of the chemistry of important molecules found in the human body, and the need for a balanced and healthy diet. Although the role that these molecules play in the body should be appreciated, the emphasis is placed on their chemistry, and students who have not followed a course in biology will not be at a disadvantage. Students will not be required to memorize complex structures, but they will be expected to recognize functional groups and types of bonding within and between molecules. Structures of some important biological molecules are given in the *Chemistry data booklet*. Teachers are encouraged to foster students' awareness of local and global issues.

Core material: B1–B6 are core material for SL and HL (15 hours).
Extension material: B7–B9 are extension material for HL only (7 hours).

B1 Energy   0.5 hours

Assessment statement	Teacher's notes	Suggested Resources
Calculate the energy value of a food from enthalpy of combustion data.		Lab: Calorimetry of foods (Rsk, Pri)

B2 Proteins   3 hours

Assessment statement	Teacher's notes	Suggested Resources
Draw the general formula of 2-amino acids.		Chem 233 notes
Describe the characteristic properties of 2-amino acids	Properties should include isoelectric point, formation of a zwitterion and buffer action.	Chem 233 notes
Describe the condensation reaction of 2-amino acids to form polypeptides.	Reactions involving up to three amino acids will be assessed.	Chem 233 notes
Describe and explain the primary, secondary (α-helix and β-pleated sheets), tertiary and quaternary structure of proteins.	Include all bonds and interactions (both intramolecular and intermolecular) responsible for the protein structure.	Chem 233 notes Animations, videos
Explain how proteins can be analysed by chromatography and electrophoresis.		Lab: Electrophoresis of proteins Lab: Biuret test on foods (Inq, Pri)
List the major functions of proteins in the body.	Include structural proteins (for example, collagen), enzymes, hormones (for example, insulin), immunoproteins (antibodies), transport proteins (for example, hemoglobin) and as an energy source.	Green/Damji text (Com)

B3 Carbohydrates   3 hours

Assessment statement	Teacher's notes
Describe the structural features of monosaccharides.	Monosaccharides contain a carbonyl group (C=O) and at least two –OH groups, and have the empirical formula CH2O.
Draw the straight-chain and ring	Students should be made aware of the

structural formulas of glucose and fructose.	structural difference between α and β isomers.
Describe the condensation of monosaccharides to form disaccharides and polysaccharides.	Examples include: • disaccharides—lactose, maltose and sucrose • polysaccharides—starch (α glucose), glycogen (α glucose) and cellulose (β glucose).
List the major functions of carbohydrates in the human body.	Include energy source (glucose), energy reserves (glycogen) and precursors for other biologically important molecules.
Compare the structural properties of starch and cellulose, and explain why humans can digest starch but not cellulose.	Both are polymers of glucose units. Starch has two forms: amylose, which is a straight-chain polymer (α 1,4 linkage), and amylopectin, which is a branched structure with both α 1,4 and α 1,6 linkages. Cellulose has a β 1,4 linkage; this can be hydrolysed by the enzyme cellulase, which is absent in most animals, including mammals.
State what is meant by the term dietary fibre.	Dietary fibre is mainly plant material that is not hydrolysed by enzymes secreted by the human digestive tract but may be digested by microflora in the gut. Examples include cellulose, hemicellulose, lignin and pectin.
Describe the importance of a diet high in dietary fibre.	**Aim 8:** Dietary fibre may be helpful in the prevention of conditions such as diverticulosis, irritable bowel syndrome, constipation, obesity, Crohn's disease, hemorrhoids and diabetes mellitus.

B4 Lipids

3.5 hours

Assessment statement	Teacher's notes
Compare the composition of the three types of lipids found in the human body.	Examples include triglycerides (fats and oils), phospholipid (lecithin) and steroids (cholesterol).
Outline the difference between HDL and LDL cholesterol and outline its importance.	
Describe the difference in structure between saturated and unsaturated fatty acids.	Most naturally occurring fats contain a mixture of saturated, mono-unsaturated and poly-unsaturated fatty acids and are classified according to the predominant type of unsaturation present.
Compare the structures of the two essential fatty acids linoleic (omega–6 fatty acid) and linolenic (omega–3 fatty acid) and state their importance.	

Define the term *iodine number* and calculate the number of C=C double bonds in an unsaturated fat/oil using addition reactions.	The number of moles of I2 reacting with one mole of fat/oil indicates the number of double bonds present in the fat/oil molecule.
Describe the condensation of glycerol and three fatty acid molecules to make a triglyceride.	
Describe the enzyme-catalysed hydrolysis of triglycerides during digestion.	
Explain the higher energy value of fats as compared to carbohydrates.	
Describe the important roles of lipids in the body and the negative effects that they can have on health.	Important roles include: • energy storage • insulation and protection of organs • steroid hormones • structural component of cell membrane • omega-3 poly-unsaturated fatty acids reduce the risk of heart disease • poly-unsaturated fats may lower levels of LDL cholesterol. Negative effects include: • increased risk of heart disease from elevated levels of LDL cholesterol and *trans* fatty acids; the major source of LDL cholesterol is saturated fats, in particular lauric (C12), myristic (C14) and palmitic (C16) acids • obesity.

B5 Micronutrients and macronutrients

2 hours

Assessment statement	Teacher's notes
Outline the difference between micronutrients and macronutrients.	Micronutrients are substances required in very small amounts (mg or μg) and that mainly function as a co-factor of enzymes (<0.005% body weight). Examples include vitamins and trace minerals (Fe, Cu, F, Zn, I, Se, Mn, Mo, Cr, Co and B). Macronutrients are chemical substances that are required in relatively large amounts (>0.005% body weight). Examples include proteins, fats, carbohydrates and minerals (Na, Mg, K, Ca, P, S and Cl).
Compare the structures of retinol (vitamin A), calciferol (vitamin D) and ascorbic acid (vitamin C).	
Deduce whether a vitamin is water- or fat-soluble from its structure.	Examples include: • water-soluble—vitamins B and C • fat-soluble—vitamins A, D, E and K.

Discuss the causes and effects of nutrient deficiencies in different countries and suggest solutions.	Micronutrient deficiencies include: • iron—anemia • iodine—goitre • retinol (vitamin A)—xerophthalmia, night blindness • niacin (vitamin B3)—pellagra • thiamin (vitamin B1)—beriberi • ascorbic acid (vitamin C)—scurvy • calciferol (vitamin D)—rickets. Macronutrient deficiencies include: • protein—marasmus and kwashiorkor. Some causes of malnutrition may be discussed here. Solutions include: • providing food rations that are composed of fresh and vitamin- and mineral-rich foods • adding nutrients missing in commonly consumed foods • genetic modification of food • providing nutritional supplements • providing selenium supplements to people eating foods grown in selenium-poor soil.

B6 Hormones   **3 hours**

Assessment statement	Teacher's notes
Outline the production and function of hormones in the body.	Hormones are chemical messengers. They are secreted directly into the blood by endocrine glands. Examples include ADH, aldosterone, estrogen, progesterone and testosterone, insulin, epinephrine (adrenaline) and thyroxine.
Compare the structures of cholesterol and the sex hormones.	Stress the common steroid backbone but the difference in functional groups.
Describe the mode of action of oral contraceptives.	**Aim 8**
Outline the use and abuse of steroids.	**Aim 8**

Group 4 Project   (10 hours)

Summary of the group 4 project

The group 4 project is a collaborative activity where students from different group 4 subjects work together on a scientific or technological topic, allowing for concepts and perceptions from across the disciplines to be shared in line with aim 10—that is, to "encourage an understanding of the relationships between scientific disciplines and the overarching nature of the scientific method". The project can be practically or theoretically based. Collaboration between schools in different regions is encouraged.

The group 4 project allows students to appreciate the environmental, social and ethical implications of science and technology. It may also allow them to understand the limitations of scientific study, for example, the shortage of appropriate data and/or the lack of resources. The emphasis is on interdisciplinary cooperation and the processes involved in scientific investigation, rather than the products of such investigation.

The choice of scientific or technological topic is open but the project should clearly address aims 7, 8 and 10 of the group 4 subject guides.

Ideally, the project should involve students collaborating with those from other group 4 subjects at all stages. To this end, it is not necessary for the topic chosen to have clearly identifiable separate subject components. However, for logistical reasons some schools may prefer a separate subject "action" phase (see the following "Project stages" section).

The Group 4 Project addresses ALL 10 aspects of the IB Learner Profile: Inq, Kno, Thk, Com, Pri, Opn, Car, Rsk, Bal, Ref