Theme 1: The Particulate Nature of Matter

Topics	Learning Objective	Knowledge Level
☐ Particulate nature of matter	☐ Define the terms: "elements", "compounds", and "mixtures", and distinguish between their properties. ☐ Distinguish the different states of matter, explain their interconversion, and use state symbols (s, l, and aq) in chemical equations. ☐ Interpret observable changes in physical properties and temperature during changes of state. Convert between values in Celsius and Kelvin scale.	Adequate Adequate Adequate
☐ The atom	☐ Describe the structure of atoms and use nuclear notation ($^{A}_{Z}X$) to deduce the number of protons, neutrons, and electrons in atoms and ions. ☐ Define isotopes and perform calculations involving non-integer relative atomic masses and abundance of isotopes from given data. Specific examples of isotopes need not be learned.	Adequate Adequate
☐ Electron configurations	☐ Understand emission spectra and qualitatively describe the relationship between color, frequency, wavelength, and energy across the electromagnetic spectrum. Distinguish between a continuous and line spectrum. ☐ Describe the emission spectrum of the hydrogen atom, including the relationship between the lines and energy transitions to the first, second, and third energy series. Ignore the names of the different series. ☐ Deduce the maximum number of electrons that can occupy each energy level, using the formula $2n^2$. ☐ Recognize the shape and orientation of an s atomic orbital and the three p atomic orbitals. ☐ Apply the Aufbau Principle, Hund's Rule, and the Pauli Exclusion Principle to deduce electron configurations for atoms and ions up to Z = 36. Recall full electron configurations, condensed electron configurations, and orbital diagrams of these elements. Recall the exceptions of Cr and Cu.	Adequate Adequate Adequate Adequate Adequate
☐ Further atoms (HL)	☐ Interpret mass spectra in terms of identity and relative abundance of isotopes.	Adequate
☐ Further electron configurations (HL)	☐ Explain the convergence limit and its association to ionization energy. Explain the trends and discontinuities in first ionization energy (IE) across a period and down a group. Calculate the value of the	Adequate

	first IE from spectral data that gives the wavelength or frequency of the convergence limit. ☐ Deduce the group of an element from its successive ionization data.	Adequate

Theme 2: Periodic Table and Trends

Corresponding pages in the Oxford Study Guide:

Topics	Learning Objective	Knowledge Level
☐ Periodic table and trends	☐ Identify the positions of metals, nonmetals, and metalloids in the periodic table. Identify the four blocks associated with the sublevels *s*, *p*, *d*, and *f*.	Adequate
	☐ Deduce the electron configuration of an atom up to Z = 36 from the element's position in the periodic table and vice versa. Recall the classifications of "alkali metals", "halogens", "transition metals", and "noble gases".	Adequate
	☐ Define periodicity as trends in properties of elements across a period and down a group. Explain the periodicity of atomic radius, ionic radius, ionization energy, electron affinity, and electronegativity.	Adequate
	☐ Describe and explain the reactions of group 1 metals with water, and of group 17 elements with halide ions.	Adequate
☐ Further periodic table (HL)	☐ Explain the discontinuities in the trend of increasing first ionization energy across a period with reference to the energy of the electron removed. Explain how these discontinuities provide evidence for the existence of energy sublevels.	Adequate
	☐ Recall that transition elements have incomplete d-sublevels. Recognize their key properties, including: variable oxidation state, high melting points, magnetic properties, catalytic properties, formation of colored compounds, and formation of complex ions with ligands.	Adequate
	☐ Explain the formation of variable oxidation states in transition elements. Deduce the electron configurations of ions of the first-row transition elements.	Adequate
	☐ Explain why transition element complexes are colored. Apply the color wheel to deduce the wavelengths and frequencies of light absorbed and/or observed.	Adequate

Theme 3: Moles and Stoichiometry

Corresponding pages in the Oxford Study Guide:

Topics	Learning Objective	Knowledge Level
☐ Moles	☐ Understand the concepts of the mole and its relation to Avogadro's constant. Convert the amount of substance, *n*, to the number of specified elementary entities. ☐ Determine relative formula masses, M_r, from relative atomic masses, A_r. ☐ Solve problems involving the relationships between the number of particles, the amount of substance in moles, and the mass in grams. ☐ Understand the concept of empirical and molecular formulae. Interconvert the percentage composition by mass and the empirical formula. Determine the molecular formula of a compound from its empirical formula and molar mass. ☐ Solve problems involving the molar concentration, amount of solute, and volume of a solution, including the use of square brackets to represent molar concentration. ☐ Solve problems involving the mole ratio of reactants and/or products and the volume of gases.	Adequate Adequate Adequate Adequate Adequate Adequate
☐ Ideal Gases	☐ Define ideal gases and recognize the key assumptions in the ideal gas model. ☐ Explain the limitations of the ideal gas model. ☐ Investigate the relationship between temperature, pressure, and volume for a fixed mass of an ideal gas and analyze graphs relating these variables. The names of specific gas laws will not be assessed. ☐ Solve problems relating to the ideal gas equation: $PV = nRT$, including the use of the combined gas law $P_1V_1/T_1 = P_2V_2/T_2$	Adequate Adequate Adequate Adequate
☐ Amount of chemical change	☐ Deduce chemical equations when reactants and products are specified, including the use of state symbols. ☐ Use the mole ratio of an equation to calculate: the masses, volumes, and concentrations of reactants and products. Use Avogadro's law and definitions of molar concentration. ☐ Understand how the limiting reactant determines the theoretical yield. Identify the limiting and excess reactants from given data. Distinguish between the theoretical yield and the experimental yield. ☐ Solve problems involving reacting quantities,	Adequate Adequate Adequate Adequate

	limiting and excess reactants, theoretical, experimental, and percentage yields. ☐ Understand that atom economy is a measure of efficiency in green chemistry. Calculate the atom economy from the stoichiometry of a reaction. Understand the inverse relationship between atom economy and wastage in industrial processes.	Adequate

Theme 4: Models of Bonding and Structure

Corresponding pages in the Oxford Study Guide:

Topics	Learning Objective	Knowledge Level
☐ Ionic bonds and structure	☐ Predict the charge of an ion from the electron configuration of the atom, including transition elements. ☐ Define an ionic bond and deduce the formula and name of an ionic compound from its component ions, including polyatomic ions. Interconvert names and formulas of binary ionic compounds. Recall the following polyatomic ions by name and formula: ammonium (NH_4^+), hydroxide (OH^-), nitrate (NO_3^-), hydrogen carbonate (HCO_3^-), carbonate (CO_3^{2-}) sulfate (SO_4^{2-}), and phosphate (PO_4^{3-}) ☐ Describe the structure of ionic compounds and explain their physical properties, including: volatility, electrical conductivity, and solubility. Describe lattice enthalpy as a measure of the strength of the ionic bond in different compounds, influenced by ion radius and charge.	Adequate Adequate Adequate
☐ Covalent bonding and forces	☐ Define a covalent bond and deduce the Lewis formula of molecules and ions for up to four electron pairs on each atom. Understand and use the octet rule in molecules containing atoms with fewer than an octet of electrons, in both organic and inorganic examples. ☐ Define single, double, and triple bonds and explain the relationship between the number of bonds, bond length, and bond strength. ☐ Define a coordination bond and identify coordination bonds in compounds, including transition element complexes. ☐ Understand the valence shell electron pair repulsion (VSEPR) model and predict the electron domain geometry and the molecular geometry for species with up to four electron domains. Recall how	Adequate Adequate Adequate Adequate

	non-bonding pairs and multiple bonds affect bond angles. ☐ Deduce the polar nature of a covalent bond from electronegativity values. ☐ Recall bond polarity and molecular geometry as the factors governing molecular polarity, and deduce the net dipole moment of a molecule or ion. ☐ Describe the structures and explain the properties of silicon, silicon dioxide, and carbon's allotropes (diamond, graphite, fullerene, and graphene). ☐ Understand the key intermolecular forces, including: London dispersion, dipole-induced dipole, dipole-dipole, and hydrogen bonding. Deduce the types of intermolecular forces present from the structural features of covalent molecules. Understand the term "van der Waals forces" as an inclusive term to include dipole-diploe, dipole-induced dipole, and London dispersion forces. Explain the occurrence of hydrogen bonds. ☐ Compare the relative strengths of intermolecular forces. Explain the physical properties of covalent substances to include: volatility, electrical conductivity, and solubility in terms of their structure. ☐ Understand chromatography as a technique used to separate the components of a mixture based on their relative attractions involving intermolecular forces to mobile and stationary phases. Explain, calculate, and interpret the retention factor values, R_f.	Adequate Adequate Adequate Adequate Adequate Adequate
☐ Metallic bonds	☐ Define a metallic bond. Explain the electrical conductivity, thermal conductivity, and malleability of metals. Relate characteristic properties of metals to their experimental uses. ☐ Understand that the strength of a metallic bond depends on the charge of the ions and the radius of the metal ion. Explain trends in melting points of *s* and *p* block metals.	Adequate Adequate
☐ Further covalent bonding (HL)	☐ Understand the occurrence of resonance structures. Deduce resonance structures of molecules and ions, including use of the term "delocalization". ☐ Discuss the structure of benzene from physical and chemical evidence. ☐ Understand that atoms can form molecules in which they have an expanded octet of electrons. Visually represent Lewis formulas for species with 5 and6 electron domains around the central atom. Deduce the electron domain geometry and the molecular geometry for species with 5 and 6 electron domains. ☐ Apply formal charge to determine a preferred Lewis formula from different Lewis formulas for a species.	Adequate Adequate Adequate Adequate

	☐ Define sigma bonds (σ) and pi bonds (π). Deduce the presence of sigma bonds and pi bonds in molecules and ions through both organic and inorganic examples. ☐ Define hybridization as the concept of mixing atomic orbitals to form new hybrid orbitals for bonding. Analyze the hybridization and bond formation in molecules and ions, Identify the relationships between Lewis formulas, electron domains, molecular geometry, and type of hybridization. Predict the geometry around an atom from its hybridization, and vice versa.	Adequate Adequate
☐ Further metallic bonding (HL)	☐ Understand that the transition elements have delocalized d-electrons. Explain the high melting point and electrical conductivity of transition elements.	Adequate

Theme 5: From Models to Materials

Topics	Learning Objective	Knowledge Level
☐ Models to materials	☐ Understand that bonding is best described as a continuum between the ionic, covalent, and metallic models, and can be represented by a bonding triangle. Use bonding models to explain the properties of a material. ☐ Understand the position of a compound in the bonding triangle is determined by the relative contributions of the three bonding types to the overall bond. Determine the position of a compound in the bonding triangle from electronegativity data. Predict the properties of a compound based on its position in the bonding triangle. Calculations of percentage ionic character are not required. ☐ Define alloys as mixtures of a metal and other metals or non-metals. Explain the properties of alloys in terms of non-directional bonding, including the common examples: bronze, brass, and stainless steel. ☐ Define polymers as large macromolecules, made from repeating subunits called monomers. Describe the common properties of plastics in terms of their structure. ☐ Understand the formation of addition polymers. Represent the repeating unit of an addition polymer from given monomer structures.	Adequate Adequate Adequate Adequate Adequate
☐ Functional groups	☐ Use of the chemical formula: empirical, molecular, structural (full and condensed), stereochemical, and	Adequate

	skeletal. Interconvert molecular, skeletal, and structural formulas. Construct 3D models (real or virtual) of organic molecules. ☐ Understand the classification of organic compounds according to the functional groups. Identify the following functional groups by name and structure: halogeno, hydroxyl, carbonyl, carboxyl, alkoxy, amino, amido, ester, phenyl. Understand and use the terms “saturated” and “unsaturated”. ☐ Define a homologous series as a family of compounds in which successive members differ by a common structural unit, and that can be described by a general formula. Identify the following homologous series: alkanes, alkenes, alkynes, halogenoalkanes, alcohols, aldehydes, ketones, carboxylic acids, ethers, amines, amides, and esters. ☐ Describe and explain the trend in melting and boiling points of members of a homologous series. ☐ Apply IUPAC nomenclature to saturated or mono-unsaturated compounds that have up to six carbon atoms in the parent chain and contain one type of the following functional groups: halogeno, hydroxyl, carbonyl, carboxyl. Name straight-chain and branched-chain isomers. ☐ Define structural isomers as molecules that have the same molecular formula but different connectivities. Recognize isomers, including branched, straight-chain, position, and functional group isomers, and primary, secondary, and tertiary alcohols.	Adequate Adequate Adequate Adequate Adequate
☐ Condensation polymers (HL)	☐ Understand the reactions involved in the formation of condensation polymers. Represent the repeating unit of polyamides and polyesters from given monomer structures.	Adequate
☐ Further functional groups (HL)	☐ Define stereoisomers as species with the same constitution (atom identities, connectivities, and bond multiplicities), but different spatial arrangements of atoms. Describe and explain the features that give rise to *cis-trans* isomerism and recognize it in non-cyclic alkenes and C3 and C4 cycloalkanes. Nomenclature using the *E-Z* system will not be assessed. Draw stereochemical formulas showing the tetrahedral arrangement around a chiral carbon. Describe and explain a chiral carbon atom giving rise to stereoisomers with different optical properties. Recognize a pair of enantiomers as non-superimposable mirror images from 3D modeling (real or virtual). Understand and use the terms: “chiral”, “optical activity”, “enantiomer”, and “racemic” mixture. ☐ Deduce information about the structural features of	Adequate Adequate

	a compound from specific MS fragmentation patterns. ☐ Interpret the functional group region of an IR spectrum, using a table of characteristic frequencies (wavenumber/cm^{-1}). Understand the absorption of IR radiation by greenhouse gases. ☐ Interpret ^1H NMR spectra to deduce the structures of organic molecules from the number of signals, the chemical shifts, and the relative areas under signals (integration traces). ☐ Interpret ^1H NMR spectra from splitting patterns showing singlets, doublets, triplets, and quartets to deduce greater structural detail. ☐ Interpret a variety of data, including analytical spectra, to determine the structure of a molecule.	Adequate Adequate Adequate Adequate

Theme 6: Energetics

Corresponding pages in the Oxford Study Guide:

Topics	Learning Objective	Knowledge Level
☐ Enthalpy	☐ Understand that chemical reactions involve a transfer of energy. Understand the difference between heat and temperature. ☐ Recall the classification of reactions as endothermic or exothermic. Understand the temperature change (decrease or increase) that accompanies endothermic and exothermic reactions, respectively. ☐ Sketch and interpret energy profiles for endothermic and exothermic reactions. ☐ Understand the standard enthalpy change for a chemical reaction, $\Delta H^{\ominus}$. Apply the equations q =mc and ΔH = -q in the calculation of the enthalpy change of a reaction.	Adequate Adequate Adequate Adequate
☐ Cycles of energy	☐ Recall that bond-breaking absorbs and bond-forming releases energy. Calculate the enthalpy change of a reaction from given average bond enthalpy data. Include explanation of why bond enthalpy data are average values and may differ from those measured experimentally. ☐ Define Hess's law. Apply Hess's law to calculate enthalpy changes in multistep reactions.	Adequate Adequate
☐ Further energy cycles (HL)	☐ Understand standard enthalpy changes of combustion, $\Delta H_c^{\ominus}$, and formation, $\Delta H_f^{\ominus}$. Deduce equations and solutions to problems involving these	Adequate

	terms. ☐ Calculate enthalpy changes of a reaction using $\Delta H_f^\ominus$ data or $\Delta H_c^\ominus$ data: $\Delta H^\ominus = \Sigma \Delta H_f^\ominus$products - $\Sigma \Delta H_f^\ominus$reactants $\Delta H^\ominus = \Sigma \Delta H_c^\ominus$reactants - $\Sigma \Delta H_c^\ominus$products ☐ Understand a Born-Haber cycle for an ionic compound. Interpret and determine values from a Born-Haber cycle for compounds composed of univalent and divalent ions, including: ionization energies, enthalpy of atomization, electron affinities, lattice enthalpy, enthalpy of formation. The construction of a complete Born-Haber cycle will not be assessed.	Adequate Adequate
☐ Entropy and Spontaneity (HL)	☐ Define entropy, S, as a measure of the dispersal or distribution of matter and/or energy in a system. Predict whether a physical or chemical change will result in an increase or decrease in entropy of a system. Calculate standard entropy changes, $\Delta S^\ominus$, from standard entropy values, $S^\ominus$. ☐ Understand the change in Gibbs energy, ΔG, relates the energy that can be obtained from a chemical reaction to the change in enthalpy, ΔH, change in entropy, ΔS, and absolute temperature, T. Apply the equation $\Delta G^\ominus = \Delta H^\ominus - T\Delta S^\ominus$ to calculate unknown values of these terms. ☐ Interpret the sign of ΔG calculated from thermodynamic data. Determine the temperature at which a reaction becomes spontaneous.	Adequate Adequate Adequate

Theme 7: Redox

Corresponding pages in the Oxford Study Guide:

Topics	Learning Objective	Knowledge Level
☐ Electron transfer	☐ Understand the concept of oxidation states and explain why the oxidation state of an element is zero. Deduce the oxidation states of an atom in an ion or a compound, including the examples of hydrogen in metal hydrides (-1) and oxygen in peroxides (-1). Utilize oxidation numbers in the naming of compounds. Understand and use the terms: “oxidation number” and “oxidation state”. ☐ Explain that oxidation and reduction can be described in terms of electron transfer, change in oxidation state, oxygen gain/loss or hydrogen loss/gain. Identify the oxidized and reduced species and the oxidizing and reducing agents in a chemical	Adequate Adequate

	reaction.	
	☐ Deduce redox half-equations and equations in acidic or neutral solutions.	Adequate
	☐ Predict the relative ease of oxidation of metals. Predict the relative ease of reduction of halogens. Interpret data regarding metal and metal ion reactions.	Adequate
	☐ Recall that oxidation occur at the anode and reduction occurs at the cathode in electrochemical cells. Identify electrodes as anode and cathode, and identify their signs/polarities in voltaic cells and electrolytic cells, based on the type of reaction occurring at the electrode.	Adequate
	☐ Recall that a primary (voltaic) cell is an electrochemical cell that converts energy from spontaneous redox reactions to electrical energy. Explain the direction of electron flow from anode to cathode in the external circuit, and ion movement across the salt bridge. Construction of primary cells including: half-cells containing metal/metal ion, anode, cathode, electric circuit, salt bridge.	Adequate
	☐ Understand that secondary (rechargeable) cells involve redox reactions that can be reversed using electrical energy. Deduce the reactions of the charging process from given electrode reactions for discharge, and vice versa.	Adequate
	☐ Recall that an electrolytic cell is an electrochemical cell that converts electrical energy to chemical energy by bringing about non-spontaneous reactions. Explain how current is conducted in an electrolytic cell. Deduce the products of the electrolysis of a molten salt. Construct electrolytic cells including: a DC power source, an anode, a cathode, and the electrolyte.	Adequate
	☐ Deduce equations to show changes in the functional groups during oxidation of primary and secondary alcohols, including the two-step reaction in the oxidation of primary alcohols. Explain the experimental set-up for distillation and reflux. The names and formulas of specific oxidizing agents, and the mechanisms of oxidation, will not be assessed.	Adequate
	☐ Deduce equations to show reduction of carboxylic acids to primary alcohols via the aldehyde, and reduction of ketones to secondary alcohols. Include the role of hydride ions in the reduction reaction. The names and formulas of specific reducing agents, and the mechanisms of reduction, will not be assessed.	Adequate
	☐ Recall that the reduction of unsaturated compounds by the addition of hydrogen lowers the degree of unsaturation. Deduce the products of the reactions of hydrogen with alkenes and alkynes.	Adequate

☐ Further electron transfer (HL)	☐ Recall that the hydrogen half-cell $H^+(aq) + e^- \rightleftharpoons \frac{1}{2} H_2(g)$ is assigned a standard electrode potential of zero by convention. Interpret standard electrode potential data in terms of ease of oxidation/reduction. ☐ Recall that a standard cell potential $E^\ominus_{cell}$, can be calculated from standard electrode potentials and has a positive value for a spontaneous reaction. Predict whether a reaction is spontaneous in the forward or reverse direction from $E^\ominus$ data. ☐ Understand that the equation $\Delta G^\ominus = -nFE^\ominus_{cell}$ shows the relationship between standard change in Gibbs energy and standard cell potential for a reaction. Determine the value for $\Delta G^\ominus$ from $E^\ominus$ data. ☐ Understand that during electrolysis of aqueous solutions, competing reactions can occur at the anode and cathode. Deduce from standard electrode potentials the products of the electrolysis of aqueous solutions. Explain the effects of concentration and the nature of the electrode for electrolysis of $NaCl(aq)$ and $CuSO_4(aq)$. ☐ Recall that electroplating involves the electrolytic coating of an object with a metallic thin layer. Deduce equations for the electrode reactions during electroplating.	Adequate Adequate Adequate Adequate Adequate

Theme 8: Fuels

Topics	Learning Objective	Knowledge Level
☐ Fuels	☐ Deduce equations for reactions of combustion, including hydrocarbons and alcohols. ☐ Deduce equations for the incomplete combustion of hydrocarbons and alcohols. ☐ Recall common fossil fuels as: coal, crude oil, and natural gas. Evaluate the amount of carbon dioxide added to the atmosphere when different fuels burn. Understand the link between carbon dioxide levels and the greenhouse effect. ☐ Understand the production of biofuels from the biological fixation of carbon through photosynthesis. Understand the difference between renewable and non-renewable energy sources. Consider the advantages and disadvantages of biofuels. ☐ State advantages and disadvantages of fuel cells, primary cells, and secondary cells. ☐ Deduce half-equations for the electrode reactions in a fuel cell, including hydrogen and methanol as fuels.	Adequate Adequate Adequate Adequate Adequate Adequate

Theme 9: Kinetics

Corresponding pages in the Oxford Study Guide:

Topics	Learning Objective	Knowledge Level
☐ Rate of change	☐ Define the rate of reaction as the change in concentration of a particular reactant/product per unit time. Determine rates of reaction. Calculation of reaction rates from tangents of graphs of concentration, volume, or mass against time. ☐ Explain the relationship between the kinetic energy of the particles and the temperature in Kelvin, and the role of collision geometry. ☐ Recall the factors that influence the rate of a reaction, including: pressure, concentration, surface area, temperature, and the presence of a catalyst. Predict and explain the effects of changing conditions on the rate of a reaction. ☐ Define activation energy, E_a, as the minimum energy that colliding particles need for a successful collision leading to a reaction. Construct Maxwell-Boltzmann energy distribution curves to explain the effect of temperature on the probability of successful collisions. ☐ Recall that catalysts increase the rate of reaction by providing an alternative reaction pathway with lower E_a. Sketch and explain energy profiles with and without catalysts for endothermic and exothermic reactions. Construct Maxwell-Boltzmann energy distribution curves to explain the effect of different values for E_a on the probability of successful collisions.	Adequate Adequate Adequate Adequate Adequate
☐ Further rate of change (HL)	☐ Evaluate proposed reaction mechanisms and recognize reaction intermediates. Distinguish between intermediates and transition states, and recognize both in energy profiles of reactions. ☐ Construct and interpret energy profiles from kinetic data. ☐ Define the molecularity of an elementary step as the number of reacting particles taking part in that step. Interpret the terms “unimolecular”, “bimolecular”, and “termolecular”. ☐ Deduce the rate equation for a reaction from experimental data. ☐ Recall that the order of a reaction with respect to a reactant is the exponent to which the concentration of the reactant is raised in the rate equation.	Adequate Adequate Adequate Adequate Adequate

	Understand that the overall reaction order is the sum of the orders with respect to each reactant. ☐ Sketch, identify, and analyze graphical representations of zero, first, and second order reactions. ☐ Recall that the rate constant, *k*, is temperature dependent and its units are determined from the overall order of the reaction. Solve problems involving the rate equation. ☐ Understand and use the Arrhenius equation. Describe the qualitative relationship between temperature and the rate constant. Analyze graphical representations of the Arrhenius equation, including its linear form. ☐ Determine the activation energy and the Arrhenius factor from experimental data.	Adequate Adequate Adequate Adequate

Theme 10: Equilibrium

Corresponding pages in the Oxford Study Guide:

Topics	Learning Objective	Knowledge Level
☐ Extent of change	☐ Recall that a state of dynamic equilibrium is reached in a closed system when the rates of forward and reverse reactions are equal. Describe the characteristics of a physical and chemical system at equilibrium. ☐ Recall the equilibrium law. Deduce the equilibrium constant expression from an equation for a homogeneous reaction. ☐ Understand that the magnitude of the equilibrium constant indicates the extent of a reaction at equilibrium and is temperature dependent. Determine the relationships between *K* values for reactions that are the reverse of each other at the same temperature. Include the extent of reaction for: $K<<1$, $K<1$, $K=1$, $K>1$, and $K>>1$. ☐ Apply Le Châtelier's principle to predict and explain responses to changes of systems at equilibrium. Recall the effects on the value of *K* and on the equilibrium composition.	Adequate Adequate Adequate Adequate
☐ Further extent of change (HL)	☐ Understand the reaction quotient, *Q*, as a non-equilibrium expression of the ratio of reactants and products. Calculate the reaction quotient *Q* from the concentrations of reactants and products at a particular time, and determine the direction in which the reaction will proceed to reach equilibrium. ☐ Understand that as a reaction approaches	Adequate

	equilibrium, ΔG becomes less negative and finally reaches zero. Perform calculations using the equation $\Delta G = \Delta G^{\ominus} + RT \ln Q$ and its application to a system at equilibrium $\Delta G^{\ominus} = -RT\ln K$. ☐ Understand how the equilibrium constant and Gibbs energy change ΔG, can both be used to measure the position of an equilibrium reaction. Perform calculations using the equation $\Delta G^{\ominus} = -RT\ln K$. ☐ Solve problems involving values of K and initial and equilibrium concentrations of the components of an equilibrium mixture. Understand the approximation that $[\text{reactant}]_{initial} \approx [\text{reactant}]_{eqm}$ when K is very small.	Adequate Adequate Adequate

Theme 11: Acids and Bases

Corresponding pages in the Oxford Study Guide:

☐ Proton transfer	☐ Recall that acids react with reactive metals to release hydrogen. Deduce equations for reactions of reactive metals with dilute HCl and H_2SO_4. ☐ Deduce equations for the reactions with water of the oxides of group 1 and group 2 metals, carbon, and sulfur. Recall the formation of acid rain by gaseous non-metal oxides, and the acidification of oceans by increasing CO_2 levels. ☐ Define a Brønsted-Lowry acid as a proton donor and a Brønsted-Lowry base as a proton acceptor. Deduce the Brønsted-Lowry acid and base in a reaction. Distinguish between the terms "base" and "alkali". ☐ Define a pair of species differing by a single proton as a conjugate acid-base pair. Deduce the formula of the conjugate acid or base of any Brønsted-Lowry base or acid. ☐ Understand that some species can act as both Brønsted-Lowry acids and bases. Interpret and formulate equations to show acid-base reactions of these species. ☐ Define the pH scale as $pH = -\log[H^+]$ and $[H^+] = 10^{-pH}$. Perform calculations involving the logarithmic relationship between pH and $[H^+]$. Estimate the pH using a universal indicator, and precisely measure pH using a pH meter/probe. ☐ Explain how strong and weak acids and bases differ in the extent of ionization. Recognize that acid-base equilibria lie in the direction of the weaker conjugate. Recall that HCl, HBr, HNO_3, and H_2SO_4 are strong acids, and group 1 hydroxides are strong bases. Distinguish between strong and weak acids or	Adequate Adequate Adequate Adequate Adequate Adequate Adequate

	bases and concentrated and dilute reagents. ☐ Recall that acids react with bases in neutralization reactions. Formulate equations for the reactions between acids and metal oxides, metal hydroxides, hydrogen carbonates, and carbonates. Identify the parent acid and base of different salts. ☐ Recognize, sketch, and interpret pH curves of neutralization reactions involving strong acids and bases. Identify appropriate intercepts with the pH axis and equivalence point.	Adequate Adequate
☐ Further proton transfer (HL)	☐ Understand that the pOH scale describes the $[OH^-]$ of a solution and can be defined as: $pOH = -\log[OH^-]$ and $[OH^-] = 10^{-pOH}$. Interconvert $[H^+]$, $[OH^-]$, pH, and pOH values. ☐ Define a Lewis acid as an electron-pair acceptor and a Lewis base is an electron-pair donor. Apply Lewis acid-base theory to inorganic and organic chemistry to identify the role of the reacting species. ☐ Understand that when a Lewis base reacts with a Lewis acid, a coordination bond is formed. Recall that nucleophiles are Lewis bases and electrophiles are Lewis acids. Draw and interpret Lewis formulas of reactants and products to show coordination bond formation in Lewis acid-base reactions. ☐ Interpret the strengths of weak acids and bases as described by their K_a, K_b, pK_a, or pK_b values. ☐ Recall that, for a conjugate acid-base pair, the relationship $K_a \times K_b = K_w$ can be derived from the expressions for K_a and K_b. Solve problems involving these values. ☐ Understand that the pH of a salt solution depends on the relative strengths of the parent acid and base. Construct equations for the hydrolysis of ions in a salt, and predict the effect of each ion on the pH of the salt solution. Recall the examples of the ammonium ion NH_4^+, the carboxylate ion $RCOO^-$, the carbonate ion CO_3^{2-}, and the hydrogen carbonate ion HCO_3^-. ☐ Interpret the general shapes of pH curves for all four combinations of strong and weak acids and bases including: intercept with the pH axis, equivalence point, buffer region, and points where $pH = pK_a$ or $pOH = pK_b$. ☐ Recall that acid-base indicators are weak acids, where the components of the conjugate acid-base pair have different colors. Construct equilibria expressions to show why the color of an indicator changes with pH. Recall universal indicator as a mixture of many indicators with a wide pH range of color change. ☐ Identify an appropriate indicator for a titration from	Adequate Adequate Adequate Adequate Adequate Adequate Adequate Adequate

	the identity of the salt and the pH range of the indicator. Distinguish between the terms “end point” and “equivalence point”. ☐ Define a buffer solution as one that resists change in pH on the addition of small amounts of acid or alkali. Describe the composition of acidic and basic buffers and explain their actions. ☐ Recall that the pH of a buffer solution depends on both: the pK_a or pK_b of its acid or base, and the ratio of the concentration of acid or base to the concentration of the conjugate base or acid. Solve problems involving the composition and pH of a buffer solution, using the equilibrium constant. Explain the effect of dilution of a buffer.	Adequate Adequate Adequate

Theme 12: Electron sharing reactions (organic mechanisms)

Corresponding pages in the Oxford Study Guide:

Topics	Learning Objective	Knowledge Level
☐ Electron sharing	☐ Define a radical as a molecular entity that has an unpaired electron and understand that radicals are highly reactive. Identify and represent radicals. ☐ Recall that radicals are produced by homolytic fission in the presence of ultraviolet (UV) light or heat. Explain, including with equations, the homolytic fission of halogens, known as the initiation step in a chain reaction. ☐ Recall that radicals take part in substitution reactions with alkanes, producing a mixture of products. Explain, using equations, the propagation and termination steps in the reactions between alkanes and halogens. Explain the stability of alkanes due to the strengths of the C-C and C-H bonds and their essentially non-polar nature.	Adequate Adequate Adequate
☐ Electron-pair sharing	☐ Define a nucleophile as a reactant that forms a bond to its reaction partner (the electrophile) by donating both bonding electrons. Recognize nucleophiles in chemical reactions, including neutral and negatively charged species. ☐ Deduce equations with descriptions and explanations of the movement of electron pairs in nucleophilic substitution reactions. ☐ Define heterolytic fission as the breakage of a covalent bond when both bonding electrons remain with one of the two fragments formed. Explain, with	Adequate Adequate Adequate

	equations, the formation of ions by heterolytic fission. ☐ Define an electrophile as a reactant that forms a bond to its reaction partner (the nucleophile) by accepting both bonding electrons from that reaction partner. Recognize electrophiles in chemical reactions, including neutral and positively-charged species. ☐ Explain why alkenes are susceptible to electrophilic attack. Deduce equations for the reactions of alkenes with water, halogens, and hydrogen halides.	Adequate Adequate
☐ Further electron-pair sharing (HL)	☐ Recall that coordination bonds are formed when ligands donate an electron pair to transition element cations, forming complex ions. Deduce the charge on a complex ion, given the formula of the ion and ligands present. ☐ Describe and explain the mechanism of the reactions of primary and tertiary halogenoalkanes with nucleophiles. Distinguish between the one-step S_N2 reaction of primary halogenolakanes and the two-step S_N1 reaction of tertiary halogenoalkanes. Understand the stereospecificity of S_N2 reactions. ☐ Predict and explain the relative rates of the substitution reactions for different halogenoalkanes. The roles of the solvent and the reaction mechanism will not be assessed. ☐ Describe and explain the mechanisms of the reactions between symmetrical alkenes and halogens, water and hydrogen halides. ☐ Predict and explain the major product of a reaction between an unsymmetrical alkene and a hydrogen halide or water. ☐ Recall that electrophilic substitution reactions include the reactions of benzene with electrophiles. Describe and explain the mechanism of the reaction between benzene and a charged electrophile, E^+. The formation of the electrophile will not be assessed.	Adequate Adequate Adequate Adequate Adequate Adequate