

1.1.1 Planning

Can you design an experiment, choosing suitable apparatus, techniques and methods?

☐ ☐ ☐

Can you identify the variables that must be controlled in an experiment, and explain how?

☐ ☐ ☐

Can you evaluate whether an experimental method is appropriate for meeting the expected outcomes?

☐ ☐ ☐**1.1.2 Implementing**

Can you describe how to use a wide range of practical apparatus and techniques correctly?

☐ ☐ ☐

Can you use appropriate units for measurements?

☐ ☐ ☐

Can you present observations and data in a suitable format, such as tables with correct headings and units?

☐ ☐ ☐**1.1.3 Analysis**

Can you process, analyse and interpret qualitative and quantitative experimental results?

☐ ☐ ☐

Can you use appropriate mathematical skills to analyse quantitative data?

☐ ☐ ☐

Can you give answers to an appropriate number of significant figures?

☐ ☐ ☐

Can you plot and interpret graphs, including finding gradients and intercepts?

☐ ☐ ☐**1.1.4 Evaluation**

Can you evaluate results and draw valid conclusions from them?

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Can you identify anomalies in experimental measurements?

☐ ☐ ☐

Can you identify the limitations in experimental procedures?

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Can you identify and calculate uncertainties, including percentage uncertainties, and comment on precision and accuracy?

☐ ☐ ☐

Can you suggest improvements to procedures and apparatus?

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1.2.1 Practical skills

Can you apply investigative approaches and methods when using instruments and equipment?	☐	☐	☐
Can you use a wide range of apparatus and techniques safely and correctly?	☐	☐	☐
Can you follow written procedures accurately?	☐	☐	☐
Can you make and record observations and measurements with precision?	☐	☐	☐
Can you keep appropriate records of experimental activities?	☐	☐	☐
Can you present information and data in a scientific way?	☐	☐	☐
Can you use software and tools to process data and carry out research?	☐	☐	☐
Can you use online and offline research skills, including websites, textbooks and other sources?	☐	☐	☐
Can you correctly cite sources of information?	☐	☐	☐
Can you use a range of practical instruments, equipment and techniques appropriate to chemistry?	☐	☐	☐

1.2.2 Use of apparatus and techniques

Can you use appropriate apparatus to measure mass, time, volume of liquids and gases, and temperature?	☐	☐	☐
Can you heat substances safely using a water bath, electric heater or sand bath?	☐	☐	☐
Can you measure pH using a pH chart or pH meter, or a pH probe on a data logger?	☐	☐	☐
Can you carry out titration, distillation, heating under reflux, qualitative tests for ions and organic functional groups, and filtration including under reduced pressure?	☐	☐	☐
Can you use a volumetric flask, including accurate technique for making a standard solution?	☐	☐	☐
Can you use acid-base indicators in titrations of weak and strong acids with weak and strong alkalis?	☐	☐	☐
Can you purify a solid product by recrystallisation and use a separating funnel to purify a liquid?	☐	☐	☐
Can you use melting point apparatus to check the purity of a solid?	☐	☐	☐
Can you use thin layer or paper chromatography?	☐	☐	☐
Can you set up electrochemical cells and measure voltages?	☐	☐	☐
Can you safely and carefully handle solids and liquids, including corrosive, irritant, flammable and toxic substances?	☐	☐	☐

Can you measure the rate of a reaction by at least two different methods, such as an initial rate method and a continuous monitoring method?



EL1

Formulae, equations and amount of substance

Formulae, equations and amount of substance

Can you define atomic number, mass number and isotopes?



Can you explain the Avogadro constant and the mole, and define relative atomic mass, relative isotopic mass, relative molecular mass and relative formula mass?



Can you calculate amounts in moles from masses, and use reacting masses in calculations?



Can you calculate empirical and molecular formulae, and percentage composition by mass?



Can you calculate percentage yield and the formula of a hydrated salt (water of crystallisation)?



Can you carry out mole calculations involving concentrations of solutions in mol dm^{-3} and g dm^{-3} ?



Can you make up a standard solution, dilute solutions accurately and carry out acid-base titrations and their calculations?



Can you write and balance full and ionic equations, including state symbols?



EL2

Atomic structure

Atomic structure

Can you use the electrons-in-boxes model to show how electrons fill orbitals and sub-shells?



Can you describe the shapes of s and p orbitals?



Can you write electron configurations, using sub-shells, for atoms from H to Kr and for s- and p-block ions in Periods 1 to 4?



Can you describe how models of atomic structure developed, including the Geiger-Marsden experiment and evidence for shells from ionisation enthalpies and spectra?



Can you describe nuclear fusion, where light nuclei join under very high temperature and pressure to form heavier elements in stars?



Can you write balanced nuclear equations for fusion reactions?



EL3

Bonding and structure

Bonding and structure

Can you describe chemical bonding as electrostatic attraction, and draw dot-and-cross diagrams for ionic, covalent and dative covalent bonds?



Can you describe giant lattice (metallic, ionic, covalent network) and simple molecular structures?



Can you relate the melting points, solubility and electrical conductivity of substances to their structure and bonding?



Can you use electron pair repulsion theory to predict and name the shapes of molecules and ions and their bond angles, e.g. BeCl_2 , BF_3 , CH_4 , NH_4^+ , SF_6 ?



Can you explain how lone pairs reduce bond angles, e.g. in NH_3 and H_2O ?



Can you describe the structure of an ionic lattice such as sodium chloride?



EL4

Inorganic chemistry and the periodic table

Inorganic chemistry and the periodic table

Can you describe how the periodic table is arranged by proton number into groups and periods, and divided into s-, p- and d-blocks?



Can you use the periodic table to predict the properties of elements from their position?



Can you describe and explain the trends in melting point across Periods 2 and 3 in terms of structure and bonding?



Can you relate the charge on s- and p-block ions to their position in the periodic table?



Can you recall the names and formulae of common ions (e.g. NO_3^- , SO_4^{2-} , CO_3^{2-} , OH^- , NH_4^+ , HCO_3^- , PO_4^{3-}) and use them to write formulae of compounds?



Can you describe the reactions of Group 2 elements (Mg to Ba) with water and with oxygen?



Can you describe the trends in thermal stability of Group 2 carbonates and in the solubility of Group 2 hydroxides and carbonates?



Can you define first ionisation enthalpy and write equations for successive ionisation enthalpies?



Can you explain the trends in ionisation enthalpy across a period and down a group, and use them to explain the reactivity of metals?



Can you explain the trend in thermal stability of Group 2 carbonates in terms of the charge density of the Group 2 ion?



Can you predict the solubility of compounds of common ions and give the colours of common precipitates?



Can you describe tests for ions, e.g. Ba^{2+} to test for SO_4^{2-} , and identify an unknown salt from a sequence of test-tube results?



EL5

Acids, spectra and mass spectrometry

Equilibria (acid-base)

Can you define the terms acid, base, alkali and neutralisation, and recall the formulae of HCl , HNO_3 and H_2SO_4 ?



Can you describe how to prepare soluble salts and insoluble salts?



Can you describe the basic character of Group 2 (Mg to Ba) oxides and hydroxides, including their reactions with water and acids?



Energy and matter

Can you place infrared, visible and ultraviolet radiation in order of frequency, energy and wavelength in the electromagnetic spectrum?



Can you explain how atomic absorption and emission spectra arise from electron transitions between energy levels?



Can you use $\Delta E = h\nu$ and $c = \nu\lambda$ in calculations?



Can you recall the flame colours of Li^+ , Na^+ , K^+ , Ca^{2+} , Ba^{2+} and Cu^{2+} ions?



Modern analytical techniques

Can you use data from a mass spectrum to find isotopic abundances and calculate the relative atomic mass of an element?



DF1

Gas calculations and organic bonding

Formulae, equations and amount of substance

Can you use the ideal gas equation $pV = nRT$ and molar gas volume in calculations?



Can you calculate reacting volumes of gases and enthalpy changes from amounts?



Can you measure the volume of a gas produced in a reaction?



Bonding and structure

Can you describe the bonding in organic compounds in terms of σ and π bonds?



Can you relate molecular shape to structural formulae and use wedges and dashes to show 3D shape?



DF2

Energetics

Energetics

Can you explain the terms exothermic, endothermic, enthalpy change and standard conditions?



Can you define standard enthalpy changes of reaction, combustion, formation and neutralisation (per mole of water formed)?



Can you explain average bond enthalpy and relate it to bond length and bond strength?



Can you explain that bond breaking is endothermic and bond making is exothermic, and use this to explain the overall enthalpy change of a reaction?



Can you describe how to measure enthalpy changes for reactions in solution and for burning liquids?



Can you calculate enthalpy changes from experimental results using $q = mc\Delta T$?



Can you use Hess cycles and enthalpy level diagrams to calculate enthalpy changes from formation, combustion and bond enthalpy data?



Can you describe experiments to find enthalpy changes indirectly using Hess's law?



DF3

Catalysts, cracking and pollutants

Kinetics

Can you define catalyst, catalysis, catalyst poison and heterogeneous catalysis?



Can you describe a simple model of heterogeneous catalysis (adsorption, weakening of bonds, reaction and desorption)?



Can you describe the cracking of hydrocarbons over heated catalysts and how to carry it out and test the products in the lab?



Inorganic chemistry and the periodic table

Can you describe the sources of particulates, unburnt hydrocarbons, CO, CO₂, NO_x and SO_x from burning fuels?



Can you explain the environmental effects of these pollutants?



Can you describe ways of reducing pollutants, such as catalytic converters?



DF4

Alkanes, alkenes and alcohols

Organic functional groups

Can you define aliphatic, aromatic, arene, saturated, unsaturated, functional group and homologous series?



Can you name and draw formulae for alkanes, cycloalkanes, alkenes and alcohols with up to ten carbon atoms?



Organic reactions

Can you write balanced equations for the complete and incomplete combustion of alkanes, cycloalkanes, alkenes and alcohols?



Can you describe the addition reactions of alkenes with bromine, hydrogen bromide, hydrogen and water, giving conditions?



Can you explain why C=C is more reactive than C-C and use bromine water as a test for unsaturation?



Polymers

Can you describe addition polymerisation and convert between the structural formula of a monomer and its addition polymer?



Organic mechanisms

Can you draw the electrophilic addition mechanism for alkenes, using curly arrows, via a carbocation or bromonium ion?



Can you explain how products formed with other anions present (e.g. Cl⁻ in bromine water) provide evidence for the mechanism?



Isomerism

Can you draw and interpret full, shortened and skeletal structural formulae?



Can you identify and draw structural isomers?



Can you explain E/Z isomerism as arising from restricted rotation about a C=C bond, and name E and Z isomers?



Can you identify cis/trans isomers where each carbon of the C=C has an H atom?

**Sustainability**

Can you compare the benefits and risks of fossil fuels with alternatives such as biofuels and hydrogen?



Can you discuss the decisions involved in developing a sustainable energy supply?



ES1

Atom economy and redox

Formulae, equations and amount of substance

Can you calculate atom economy and use it to judge how efficiently a reaction uses atoms?



Redox

Can you explain, given information, the chemical processes used to extract halogens from minerals in the sea?



Can you predict the products of electrolysis of aqueous solutions and write half-equations at the anode (oxygen or halogen) and cathode (hydrogen or metal)?



Can you describe redox reactions of s-, p- and d-block elements in terms of electron transfer using half-equations?



Can you define oxidation and reduction as loss and gain of electrons, and identify oxidising and reducing agents?



Can you assign oxidation states to atoms in formulae and ions, and use them to identify what is oxidised and reduced?



Can you use oxidation states to balance redox equations that do not involve acid-base reactions?



Can you carry out iodine-thiosulfate titrations and the associated calculations?



Can you use systematic names for inorganic compounds, e.g. copper(I) sulfide, sodium chlorate(I)?



ES2

The halogens

Inorganic chemistry and the periodic table

Can you describe the appearance, physical state at room temperature and volatility of the halogens?



Can you describe the solubility of the halogens in water and organic solvents, and the colours of their solutions?



Can you explain the relative reactivity of the halogens in terms of their ability to gain electrons?



Can you describe the displacement reactions of chlorine, bromine and iodine with halide ions, writing equations and half-equations?



Can you describe the precipitation reactions of Cl^- , Br^- and I^- with Ag^+ and give the colours of the precipitates?



Can you describe the solubility of the silver halides in ammonia and use it to identify halide ions?



Can you describe how to prepare HCl, HBr and HI, including using phosphoric acid for HBr and HI?



Can you describe and explain the different reactions of concentrated sulfuric acid with chlorides, bromides and iodides?



Can you compare the thermal stabilities of the hydrogen halides?



Can you describe the reactions of hydrogen halides with ammonia and their acidity in water?



Can you weigh the risks of storing and transporting chlorine against its benefits, such as sterilising water and bleaching?

**ES3**

Equilibria

Equilibria

Can you describe the characteristics of a dynamic equilibrium?



Can you write expressions for K_c for homogeneous equilibria?



Can you calculate K_c and equilibrium concentrations, and relate the position of equilibrium to the size of K_c ?



Can you use K_c to explain how changing concentration affects the position of a homogeneous equilibrium?



Can you predict the effects of changing temperature and pressure on the position of equilibrium?



OZ1

Polarity and intermolecular bonds

Bonding and structure

Can you define electronegativity and use electronegativity values to predict bond polarity?



Can you use molecular shape and bond polarity to predict whether a molecule is polar?



Can you describe instantaneous dipole-induced dipole and permanent dipole-permanent dipole bonds?



Can you explain how chain length, branching and relative molecular mass affect the strength of intermolecular bonds?



Can you explain the formation of hydrogen bonds, including in water and ice and the unusual properties they cause?



Can you relate boiling points of substances, including the halogens, to the strength of their intermolecular bonds?



OZ2

Rates, catalysts and gas composition

Kinetics

Can you define activation enthalpy and draw enthalpy profiles for reactions?



Can you use collision theory to explain the effects of concentration and pressure on rate?



Can you use the Boltzmann distribution and activation enthalpy to explain the effects of temperature and catalysts on rate?



Can you explain how a catalyst provides an alternative route with a lower activation enthalpy?



Can you define homogeneous catalysis and intermediate, e.g. chlorine radicals catalysing ozone breakdown?



Inorganic chemistry and the periodic table

Can you calculate the composition of a gas mixture as a percentage by volume and in parts per million (ppm)?



Organic functional groups

Can you recognise, name systematically and write formulae for haloalkanes and amines?

**Organic reactions**

Can you compare the boiling points of fluoro-, chloro-, bromo- and iodoalkanes?



Can you describe nucleophilic substitution of haloalkanes with water and hydroxide ions to form alcohols, and with ammonia to form amines?

**Reaction mechanisms**

Can you define the terms substitution and nucleophile?



Can you draw the $\text{S}_{\text{N}}2$ mechanism for nucleophilic substitution of haloalkanes using curly arrows and partial charges?



Can you use experimental evidence to decide whether bond enthalpy or bond polarity better explains the reactivity of haloalkanes?



Can you define homolytic and heterolytic fission?



Can you describe radicals and radical chain reactions in terms of initiation, propagation and termination, e.g. alkanes with halogens, using half curly arrows?



Can you explain how haloalkanes cause ozone depletion in the stratosphere?



Can you relate the ease of photodissociation of fluoro- to iodoalkanes to their bond enthalpies?

**Sustainability**

Can you describe the formation and destruction of ozone in the stratosphere and troposphere?



Can you explain the role of stratospheric ozone in absorbing UV, and the harmful effects of tropospheric ozone in photochemical smog?

**Energy and matter**

Can you place the radiation from the Sun and the Earth (infrared, visible, ultraviolet) on the electromagnetic spectrum?



Can you explain how UV and visible radiation can promote electrons to higher energy levels?



Can you explain how absorbed radiation can break bonds (photodissociation)?



Can you calculate frequency, wavelength and energy of electromagnetic radiation using $E = h\nu$ and $c = \nu\lambda$?



WM1

Functional groups and reactions

Organic functional groups

Can you recognise and write formulae for carboxylic acids, phenols, acid anhydrides, esters, aldehydes, ketones and ethers?



Can you classify alcohols as primary, secondary or tertiary from their structures?



Organic reactions

Can you describe the acidity of phenols, including reaction with alkalis but not carbonates?



Can you describe the test for phenols with neutral iron(III) chloride (purple colour) and the formation of esters from phenols with acid anhydrides?



Can you describe esterification of alcohols with carboxylic acids and acid anhydrides?



Can you describe the oxidation of primary and secondary alcohols to aldehydes, ketones and carboxylic acids, explaining when to use reflux or distillation?



Can you describe the dehydration of alcohols to alkenes and the substitution of alcohols to form haloalkanes?



Can you plan two-step syntheses using the reactions in the specification?



Can you prepare a solid organic product such as aspirin and purify it by filtration under reduced pressure and recrystallisation?



Can you use melting point determination and thin layer chromatography to check purity?



Can you prepare and purify a liquid organic product such as a chloroalkane using heating under reflux, a separating funnel and distillation?



Can you apply the principles of green chemistry to industrial processes from given information?



Reaction mechanisms

Can you define elimination, e.g. the formation of alkenes from alcohols?



WM2

Mass spectrometry and IR spectroscopy

Modern analytical techniques

Can you use the M^+ peak in a mass spectrum to find the relative molecular mass of a compound?



Can you interpret and predict fragment ion peaks in a mass spectrum?



Can you explain the M+1 peak as being caused by ^{13}C ?



Can you interpret and predict infrared spectra, linking absorptions to the functional groups present?



CI1 Rates of reaction

Kinetics

Can you define rate of reaction, rate constant, and overall and individual orders of reaction?



Can you use the rate equation $\text{rate} = k[A]^m[B]^n$ in calculations and work out the units of k ?



Can you calculate half-lives from given data and use constant half-life to identify a first order reaction?



Can you describe experiments to follow the rate of a reaction by continuous monitoring and by initial rates?



Can you use concentration-time graphs, tangents and half-lives to find rates and orders?



Can you use rate-concentration data or graphs to find orders, rate constants and the rate equation?



Can you use the Arrhenius equation, $k = Ae^{-E_a/RT}$, to determine the activation energy and pre-exponential factor from rate constants at different temperatures?



Can you relate the rate-determining step to the orders in the rate equation and to a possible mechanism?



CI2 Equilibrium in industry

Equilibrium

Can you explain how changing temperature affects the value of K_c , and why pressure and catalysts do not?



Can you explain that a catalyst does not shift the position of equilibrium but speeds up how quickly it is reached?



Can you use rate and equilibrium principles to decide the most economical operating conditions for an industrial process?



Can you calculate K_c , with units, from initial and equilibrium concentrations?



Can you describe experiments to determine K_c ?



CI3 Nitrogen chemistry and industrial processes

Inorganic chemistry and the periodic table

Can you use given information about the reactions in an industrial process?



Can you describe the bonding in N_2 , NH_3 and NH_4^+ ?



Can you describe the oxides of nitrogen N_2O , NO and NO_2 and their sources?



Can you describe the interconversion of nitrate(V), nitrate(III), ammonium ions and nitrogen oxides, including oxidation states?



Can you describe tests for nitrate(V) ions and ammonium ions?



Sustainability

Can you assess the costs of an industrial process, including raw materials, energy, plant, co-products and by-products?



Can you weigh the benefits of an industrial process against its health, safety and environmental hazards?



PL1

Proteins, nucleic acids and drugs

Structure and bonding

Can you draw the general structure of an amino acid and describe proteins as condensation polymers linked by peptide bonds?	☐	☐	☐
Can you describe the formation and acid hydrolysis of peptide links, and use paper chromatography to identify amino acids?	☐	☐	☐
Can you explain the primary, secondary and tertiary structure of proteins?	☐	☐	☐
Can you explain how intermolecular bonds and covalent bonds between side chains determine secondary and tertiary structure?	☐	☐	☐
Can you describe DNA and RNA as condensation polymers of nucleotides made from a phosphate, a sugar and a base?	☐	☐	☐
Can you describe how the sugar-phosphate backbone forms and how bases join to make the DNA double helix?	☐	☐	☐
Can you explain the role of hydrogen bonding in base pairing and in DNA replication?	☐	☐	☐
Can you explain how DNA encodes RNA, which codes for the sequence of amino acids in a protein?	☐	☐	☐
Can you describe the molecular recognition of a drug by a receptor in terms of its pharmacophore, 3D shape and bonding?	☐	☐	☐
Can you explain how modifying groups on a drug molecule can change its activity?	☐	☐	☐

PL2

Enzymes

Kinetics

Can you describe the rate-substrate concentration curve for an enzyme reaction, first order at low and zero order at high substrate concentration?	☐	☐	☐
Can you describe experiments to investigate enzyme kinetics?	☐	☐	☐
Can you explain enzyme specificity in terms of the 3D active site?	☐	☐	☐
Can you explain the effects of temperature and pH on enzyme activity?	☐	☐	☐
Can you explain competitive inhibition of enzymes?	☐	☐	☐

PL3

Acids, amines and amides

Equilibria (acid-base)

Can you describe the acidity of carboxylic acids and their reactions with metals, alkalis and carbonates?



Can you explain the acid-base properties of amino acids and the formation of zwitterions?



Can you explain the basicity of amines in terms of the nitrogen lone pair accepting a proton, and describe their reactions with acids to form salts?



Organic functional groups

Can you recognise and name compounds in the homologous series studied, including amino acids, amines, amides and acyl chlorides?



Can you name nylon-6,6, nylon-6,10 and nylon-6 and explain what the numbers mean?



Can you write formulae for primary and secondary amide groups?



Organic reactions

Can you describe the acid and alkaline hydrolysis of esters and amides, including polyesters and nylon, and the salts formed?



Can you describe the reactions of acyl chlorides with amines to form amides and with alcohols to form esters?



PL4

Condensation polymers and optical isomerism

Polymers

Can you distinguish between addition and condensation polymerisation?



Can you work out the structure of a condensation polymer from its monomers, and the monomers from a polymer?



Isomerism

Can you identify chiral centres and explain optical isomerism with diagrams?



Can you describe enantiomers as non-superimposable mirror images?



Modern analytical techniques

Can you use the high-resolution M^+ peak to determine a molecular formula?



Can you use differences between peaks in a mass spectrum to identify groups lost on fragmentation?



Can you interpret carbon-13 NMR spectra to identify the number and type of carbon environments?



Can you interpret proton NMR spectra, including chemical shift, relative peak areas and $n+1$ splitting up to quartets?



Can you combine evidence from mass spectrometry, IR and NMR to determine the structure of an organic compound?



01 Solubility and lattice enthalpy

Energetics

Can you explain the factors that determine whether a solute dissolves in water or a non-aqueous solvent, including ion-dipole bonds and ionic bonds?



Can you define enthalpy change of solution, lattice enthalpy and enthalpy change of hydration, and describe hydrated ions?



Can you construct enthalpy cycles linking lattice enthalpy, hydration enthalpies and enthalpy of solution, and calculate unknown values?



Can you describe how to measure the enthalpy change of solution experimentally?



Can you explain how the charge density of ions affects lattice enthalpy and hydration enthalpy?



02 Entropy and solubility product

Energetics

Can you describe entropy qualitatively as the number of ways molecules and their energy quanta can be arranged?



Can you predict the sign of the entropy change of a system from changes of state and changes in the number of gas particles?



Can you use $\Delta S_{\text{total}} = \Delta S_{\text{sys}} + \Delta S_{\text{surr}}$ and $\Delta S_{\text{surr}} = -\Delta H/T$ in calculations?



Can you explain that a reaction is feasible when ΔS_{total} is positive, and how temperature affects feasibility?



Can you calculate ΔS_{sys} from standard entropies of reactants and products?



Can you write expressions for the solubility product K_{sp} , use it in calculations and describe how to determine it?



03 Acids, pH, buffers and the greenhouse effect

Equilibria (acid-base)

Can you use Brønsted-Lowry theory to describe acids as proton donors and bases as proton acceptors, and identify conjugate acid-base pairs?



Can you write ionisation equations for strong acids and strong bases in water?



Can you write equations for the ionisation of weak acids and expressions for K_{a} , and convert between K_{a} and $\text{p}K_{\text{a}}$?



Can you describe how to measure pH using a pH meter?



Can you calculate the pH of strong acids and of strong bases using K_w ?



Can you calculate the pH of weak acids, stating the approximations made?



Can you explain how a buffer made from a weak acid and its salt resists changes in pH?



Can you calculate the pH of buffer solutions and the concentrations needed to make a buffer of given pH?



Energy and matter

Can you explain the greenhouse effect in terms of the Earth absorbing UV and visible radiation and emitting infrared?



Can you explain how greenhouse gases such as CO_2 , methane and water vapour absorb IR, and how increased concentrations cause enhanced warming?



Formulae, equations and amount of substance

Can you carry out manganate(VII) titrations and the associated calculations?



Can you carry out unstructured titration calculations?

**Bonding and structure**

Can you define coordination number and describe the shapes and bond angles of square planar, tetrahedral and octahedral complexes?

**Redox**

Can you balance redox half-equations and full equations that include acid-base steps, using oxidation states or other methods?



Can you set up simple cells from metal/metal ion half-cells and from half-cells containing different oxidation states of an element with an inert electrode?



Can you explain how a cell works using half-equations, electron flow in the external circuit and ion flow in the salt bridge?



Can you define standard electrode potential and describe how it is measured using a standard hydrogen electrode?



Can you use standard electrode potentials to calculate cell potentials and predict whether a redox reaction is feasible?



Can you explain rusting and its prevention using electrode potentials?

**Inorganic chemistry and the periodic table**

Can you define a transition metal as a d-block element forming at least one stable ion with an incomplete d sub-shell?



Can you recall the common oxidation states of iron and copper and the colours of their aqueous ions?



Can you write electron configurations for first-row d-block atoms and ions, including Cr and Cu?



Can you explain variable oxidation states in terms of the stability of d-electron arrangements?



Can you define ligand and complex ion and describe ligand substitution reactions of iron and copper complexes?



Can you describe dative bonding between ligands and metal ions, and write equations for ligand substitution?



Can you describe bidentate and polydentate ligands such as ethanedioate and EDTA?



Can you describe the colour changes and write ionic equations for the reactions of Fe^{2+} , Fe^{3+} and Cu^{2+} with sodium hydroxide solution?



Can you describe the reactions of Cu^{2+} with excess ammonia solution, and explain that iron hydroxides do not form ammonia complexes?



Can you explain homogeneous catalysis by transition metal ions in terms of changing oxidation states?



Can you explain heterogeneous catalysis by transition metals in terms of d and s electrons forming weak bonds with reactants on the surface?



Can you explain the colour of transition metal complexes in terms of d-orbital splitting by ligands and electron transitions between levels?



Energy and matter

Can you use a colorimeter or visible spectrophotometer to determine the concentration of a coloured solution?



Bonding and structure

Can you explain how dyes attach to fibres by intermolecular bonds, ionic bonds and covalent bonds?



Can you identify the chromophore in a dye and the groups that modify colour, increase solubility and bond to fibres?

**Organic functional groups**

Can you describe fats and oils as esters of propane-1,2,3-triol with varying degrees of unsaturation?



Can you write formulae for arenes and their derivatives and explain how delocalisation arises in benzene?



Can you explain why arenes undergo substitution rather than addition reactions?



Can you compare the Kekulé and delocalised models of benzene and use evidence such as enthalpy of hydrogenation and bond lengths to support the delocalised model?



Can you identify and name functional groups in polyfunctional molecules and predict their properties?



Can you describe tests for functional groups using reactions in the specification?

**Organic reactions**

Can you describe electrophilic substitution reactions of arenes: halogenation, nitration and sulfonation, giving reagents and conditions?



Can you describe Friedel-Crafts alkylation and acylation of arenes?



Can you draw the mechanism for the nitration of benzene?



Can you describe the formation of diazonium compounds and their coupling reactions to form azo dyes, giving conditions?



Can you describe the oxidation of aldehydes with acidified dichromate under reflux?



Can you use Fehling's solution and Tollens' reagent to distinguish aldehydes from ketones?



Can you describe the reaction of carbonyl compounds with hydrogen cyanide or cyanide ions to form hydroxynitriles (cyanohydrins)?



Can you propose and explain multi-step synthetic routes using reactions and conditions from the specification?



Reaction mechanisms

Can you draw the nucleophilic addition mechanism of CN^- with a carbonyl compound, using curly arrows and partial charges?



Can you classify organic reactions as addition, condensation, elimination, substitution, oxidation, reduction or hydrolysis?



Can you describe and explain unfamiliar mechanisms from given information?

**CD3**

Colour and chromatography

Energy and matter

Can you explain the origin of colour and UV absorption in organic molecules in terms of electronic transitions?



Can you relate the colour of an organic compound to the extent of delocalisation in its chromophore?



Modern analytical techniques

Can you describe gas-liquid chromatography, including the carrier gas, the stationary phase of high boiling liquid on a solid support, and detection (including by mass spectrometry)?



Can you use retention times to identify compounds in GLC and interpret chromatograms?



Practical activity groups

PAG1 Can you determine the amount of a substance in moles experimentally, e.g. by mass loss or gas volume measurement?



PAG2 Can you carry out an acid-base titration, including making a standard solution, and calculate an unknown concentration?



PAG3 Can you determine an enthalpy change experimentally, e.g. combustion of an alcohol or a reaction in solution?



PAG4 Can you carry out qualitative tests to identify cations and anions in an unknown salt?



PAG5 Can you synthesise and purify an organic liquid, such as a chloroalkane, using reflux, a separating funnel and distillation?



PAG6 Can you synthesise and purify an organic solid, such as aspirin, and check its purity by melting point?



PAG7 Can you carry out qualitative tests to identify organic functional groups?



PAG8 Can you set up electrochemical cells and measure cell potentials?



PAG9 Can you determine the rate or order of a reaction using a continuous monitoring method?



PAG10 Can you determine the order of a reaction using an initial rates method, e.g. a clock reaction?



PAG11 Can you measure pH, e.g. of weak acids, buffers or during a titration, using a pH meter?



PAG12 Can you carry out a research skills task, using and citing a range of sources?

