

3.1.1 Atomic structure

3.1.1.1 Fundamental particles

Can you explain how our understanding of atomic structure has developed over time?



Can you state the relative charge and relative mass of a proton, neutron and electron?



3.1.1.2 Mass number and isotopes

Can you define mass number (A) and atomic (proton) number (Z)?



Can you work out the number of protons, neutrons and electrons in an atom or ion from A , Z and charge?



Can you explain the existence of isotopes?



Can you describe ionisation, acceleration, ion drift, detection and data analysis in a time of flight (TOF) mass spectrometer?



Can you explain how mass spectrometry gives relative isotopic masses and abundances, identifies elements and finds M_r ?



Can you interpret simple mass spectra of elements?



Can you calculate relative atomic mass from isotopic abundance?



3.1.1.3 Electron configuration

Can you write electron configurations of atoms and ions up to $Z = 36$ in terms of shells and sub-shells (s, p and d)?



Can you define first ionisation energy?



Can you write equations for first and successive ionisation energies?



Can you explain how ionisation energy trends in Period 3 (Na to Ar) and Group 2 (Be to Ba) give evidence for shells and sub-shells?



3.1.2 Amount of substance

3.1.2.1 Relative atomic mass and relative molecular mass

Can you define relative atomic mass (A_r) and relative molecular mass (M_r) relative to carbon-12?



Can you explain when the term relative formula mass is used?



3.1.2.2 The mole and the Avogadro constant

Can you explain that the Avogadro constant is the number of particles in one mole?	☐	☐	☐
Can you apply the mole to electrons, atoms, molecules, ions, formulas and equations?	☐	☐	☐
Can you carry out calculations using the Avogadro constant?	☐	☐	☐
Can you carry out calculations using mass, M_r and amount in moles?	☐	☐	☐
Can you carry out calculations using concentration (mol dm^{-3}), volume and amount of substance in solution?	☐	☐	☐

3.1.2.3 The ideal gas equation

Can you use $pV = nRT$ in calculations, with all variables in SI units?	☐	☐	☐
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3.1.2.4 Empirical and molecular formula

Can you define empirical formula and molecular formula and explain how they are related?	☐	☐	☐
Can you calculate an empirical formula from composition by mass or percentage by mass?	☐	☐	☐
Can you calculate a molecular formula from the empirical formula and M_r ?	☐	☐	☐

3.1.2.5 Balanced equations and associated calculations

Can you write balanced full equations and ionic equations for reactions studied?	☐	☐	☐
Can you balance unfamiliar equations when given the reactants and products?	☐	☐	☐
Can you use balanced equations to calculate masses, gas volumes and percentage yields?	☐	☐	☐
Can you calculate percentage atom economy and explain the benefits of high atom economy for society and industry?	☐	☐	☐
Can you use balanced equations to calculate concentrations and volumes for reactions in solution?	☐	☐	☐

3.1.3 Bonding**3.1.3.1 Ionic bonding**

Can you describe ionic bonding as electrostatic attraction between oppositely charged ions in a lattice?	☐	☐	☐
Can you recall the formulas of sulfate, hydroxide, nitrate, carbonate and ammonium ions?	☐	☐	☐

Can you predict the charge on a simple ion from the element's position in the Periodic Table?



Can you construct formulas for ionic compounds?



3.1.3.2 Nature of covalent and dative covalent bonds

Can you describe a single covalent bond and a multiple covalent bond as shared pairs of electrons?



Can you describe a co-ordinate (dative covalent) bond as a shared pair where both electrons come from one atom?



Can you represent a covalent bond with a line and a co-ordinate bond with an arrow?



3.1.3.3 Metallic bonding

Can you describe metallic bonding as attraction between delocalised electrons and positive ions in a lattice?



3.1.3.4 Bonding and physical properties

Can you describe the four types of crystal structure: ionic, metallic, macromolecular (giant covalent) and molecular?



Can you describe the structures of diamond, graphite, ice, iodine, magnesium and sodium chloride?



Can you relate melting point and conductivity to the type of structure and bonding?



Can you explain the energy changes associated with changes of state?



Can you draw diagrams to represent these structures with a specified number of particles?



3.1.3.5 Shapes of simple molecules and ions

Can you explain that bonding pairs and lone pairs act as charge clouds that repel and get as far apart as possible?



Can you state that lone pair-lone pair repulsion is greater than lone pair-bond pair, which is greater than bond pair-bond pair?



Can you explain the shapes of, and bond angles in, simple molecules and ions with up to six electron pairs around the central atom?



3.1.3.6 Bond polarity

Can you define electronegativity?



Can you explain how unequal sharing of electrons gives a polar bond and may give a molecule a permanent dipole?



Can you use partial charges to show that a bond is polar?



Can you explain why some molecules with polar bonds do not have a permanent dipole?



3.1.3.7 Forces between molecules

Can you describe permanent dipole-dipole forces, induced dipole-dipole (van der Waals) forces and hydrogen bonding?



Can you explain the existence of these forces between familiar and unfamiliar molecules?



Can you explain how intermolecular forces influence melting and boiling points?



Can you use hydrogen bonding to explain the low density of ice and the anomalous boiling points of some compounds?



3.1.4 Energetics

3.1.4.1 Enthalpy change

Can you define enthalpy change (ΔH) as the heat energy change at constant pressure?



Can you explain exothermic and endothermic reactions in terms of the sign of ΔH ?



Can you define standard enthalpy of combustion and standard enthalpy of formation, including standard conditions?



3.1.4.2 Calorimetry

Can you use $q = mc\Delta T$ to calculate the heat energy change in a reaction?



Can you use $q = mc\Delta T$ to calculate a molar enthalpy change and give it the correct sign?



3.1.4.3 Applications of Hess's law

Can you state Hess's law?



Can you use Hess's law to calculate enthalpy changes from enthalpies of formation and combustion?



Can you use Hess's law to calculate enthalpy changes that cannot be measured directly?



3.1.4.4 Bond enthalpies

Can you define mean bond enthalpy?



Can you use mean bond enthalpies to calculate an approximate value of ΔH for a gas-phase reaction?



Can you explain why values calculated from mean bond enthalpies differ from data book values?

**3.1.5 Kinetics****3.1.5.1 Collision theory**

Can you explain that reactions only happen when particles collide with energy at least equal to the activation energy?



Can you define activation energy?

**3.1.5.2 Maxwell-Boltzmann distribution**

Can you draw and explain the Maxwell-Boltzmann distribution of molecular energies in a gas?

**3.1.5.3 Effect of temperature on reaction rate**

Can you define the rate of a chemical reaction?



Can you use the Maxwell-Boltzmann distribution to explain why a small temperature increase gives a large increase in rate?

**3.1.5.4 Effect of concentration and pressure**

Can you explain qualitatively how increasing concentration or gas pressure increases the rate of reaction?

**3.1.5.5 Catalysts**

Can you explain that a catalyst increases rate without being changed and provides a route with lower activation energy?



Can you use a Maxwell-Boltzmann distribution to explain how a catalyst increases the rate of reaction?



3.1.6

Chemical equilibria, Le Chatelier's principle and K_c

3.1.6.1 Chemical equilibria and Le Chatelier's principle

- | | | | |
|--|-----------------------|-----------------------|-----------------------|
| Can you explain that many reactions are reversible and describe dynamic equilibrium? | ☐ | ☐ | ☐ |
| Can you use Le Chatelier's principle to predict the effects of changes in temperature, pressure and concentration on equilibrium position? | ☐ | ☐ | ☐ |
| Can you explain that a catalyst does not affect the position of equilibrium? | ☐ | ☐ | ☐ |
| Can you explain why a compromise temperature and pressure may be used in industrial processes? | ☐ | ☐ | ☐ |

3.1.6.2 Equilibrium constant K_c for homogeneous systems

- | | | | |
|---|-----------------------|-----------------------|-----------------------|
| Can you construct an expression for K_c for a homogeneous system at equilibrium? | ☐ | ☐ | ☐ |
| Can you calculate a value of K_c from equilibrium concentrations at constant temperature? | ☐ | ☐ | ☐ |
| Can you carry out calculations involving K_c ? | ☐ | ☐ | ☐ |
| Can you explain that K_c is not affected by changes in concentration or by a catalyst? | ☐ | ☐ | ☐ |
| Can you predict the qualitative effect of a change in temperature on the value of K_c ? | ☐ | ☐ | ☐ |

3.1.7

Oxidation, reduction and redox equations

3.1.7 Oxidation, reduction and redox equations

- | | | | |
|---|-----------------------|-----------------------|-----------------------|
| Can you define oxidation and reduction in terms of electrons, and oxidising and reducing agents? | ☐ | ☐ | ☐ |
| Can you apply the rules for assigning oxidation states? | ☐ | ☐ | ☐ |
| Can you work out the oxidation state of an element in a compound or ion from its formula? | ☐ | ☐ | ☐ |
| Can you write half-equations identifying the oxidation and reduction processes in a redox reaction? | ☐ | ☐ | ☐ |
| Can you combine half-equations to give an overall redox equation? | ☐ | ☐ | ☐ |

3.1.8 Thermodynamics

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3.1.8.1 Born-Haber cycles

Can you define lattice enthalpy as either lattice dissociation or lattice formation enthalpy?



Can you define enthalpy of formation, ionisation energy, enthalpy of atomisation, bond enthalpy and electron affinity?



Can you construct Born-Haber cycles to calculate lattice enthalpies and other enthalpy changes?



Can you compare Born-Haber lattice enthalpies with perfect ionic model values and explain evidence for covalent character?



Can you define enthalpy of hydration and enthalpy of solution?



Can you use cycles to calculate enthalpies of solution from lattice enthalpies and enthalpies of hydration?



3.1.8.2 Gibbs free-energy change and entropy change

Can you explain why ΔH alone does not determine whether a change is feasible?



Can you explain entropy as a measure of disorder, using physical and chemical changes as examples?



Can you calculate entropy changes from absolute entropy values?



Can you use $\Delta G = \Delta H - T\Delta S$ and explain that a reaction is feasible when ΔG is zero or negative?



Can you use $\Delta G = \Delta H - T\Delta S$ to find how ΔG varies with temperature?



Can you use $\Delta G = \Delta H - T\Delta S$ to find the temperature at which a reaction becomes feasible?



3.1.9 Rate equations

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3.1.9.1 Rate equations

Can you write a rate equation in the form $\text{rate} = k[A]^m[B]^n$?



Can you define order of reaction and rate constant?



Can you carry out calculations using a rate equation?



Can you explain qualitatively the effect of temperature on the rate constant k ?



Can you carry out calculations using the Arrhenius equation $k = Ae^{-E_a/RT}$?



Can you use $\ln k = -E_a/R \times 1/T + \ln A$ and plot a graph of $\ln k$ against $1/T$ to find E_a ?



3.1.9.2 Determination of rate equation

Can you use concentration-time graphs to deduce the rate of a reaction?



Can you use initial concentration-time data to deduce the initial rate?



Can you use rate-concentration data or graphs to deduce the order (0, 1 or 2) with respect to a reactant?



Can you derive the rate equation from the orders with respect to each reactant?



Can you use the orders to suggest the rate-determining step and a possible mechanism?



3.1.10

Equilibrium constant K_p for homogeneous systems

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3.1.10 Equilibrium constant K_p

Can you calculate partial pressures from mole fractions and total pressure?



Can you construct an expression for K_p for a homogeneous system at equilibrium?



Can you carry out calculations involving K_p ?



Can you predict the qualitative effects of changes in temperature and pressure on equilibrium position?



Can you predict the qualitative effect of a change in temperature on the value of K_p ?



Can you explain that a catalyst affects how fast equilibrium is reached but not the value of K_p ?



3.1.11

Electrode potentials and electrochemical cells

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3.1.11.1 Electrode potentials and cells

Can you use the IUPAC convention to write half-equations for electrode reactions?



Can you write and apply the conventional representation of a cell?



Can you describe how electrode potentials are measured using the standard hydrogen electrode?



Can you state the standard conditions for measuring electrode potentials (298 K, 100 kPa, 1.00 mol dm⁻³)?



Can you explain that standard electrode potentials can be listed as an electrochemical series?



Can you use $E^\ominus$ values to predict the direction of simple redox reactions?



Can you calculate the EMF of a cell?



3.1.11.2 Commercial applications of electrochemical cells

Can you describe non-rechargeable cells, rechargeable cells and fuel cells?



Can you use given electrode data to deduce the reactions in non-rechargeable and rechargeable cells, including lithium cells?



Can you deduce the EMF of a commercial cell?



Can you write the electrode reactions in an alkaline hydrogen-oxygen fuel cell?



Can you explain how the electrode reactions generate an electric current?



Can you discuss the benefits and risks to society of using these cells?



3.1.12 Acids and bases

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3.1.12.1 Bronsted-Lowry acid-base equilibria

Can you define an acid as a proton donor and a base as a proton acceptor?



Can you explain that acid-base equilibria involve the transfer of protons?



3.1.12.2 Definition and determination of pH

Can you define pH as $-\log_{10}[\text{H}^+]$?



Can you convert between $[\text{H}^+]$ and pH?



Can you calculate the pH of a strong acid from its concentration?



3.1.12.3 The ionic product of water, K_w

Can you derive $K_w = [\text{H}^+][\text{OH}^-]$ and explain that its value varies with temperature?



Can you use K_w to calculate the pH of a strong base from its concentration?



3.1.12.4 Weak acids and bases; K_a for weak acids

Can you explain that weak acids and weak bases dissociate only slightly in aqueous solution?



Can you construct an expression for K_a ?



Can you calculate the pH of a weak acid from its concentration and K_a ?



Can you convert between K_a and pK_a ?



3.1.12.5 pH curves, titrations and indicators

Can you carry out titration calculations from experimental results?



Can you sketch and explain the shapes of pH curves for all combinations of strong and weak monoprotic acids and bases?



Can you use pH curves to select an appropriate indicator?



3.1.12.6 Buffer action

Can you define a buffer solution?



Can you explain the composition of acidic and basic buffers?



Can you explain qualitatively how acidic and basic buffers work?



Can you calculate the pH of acidic buffer solutions?



Can you describe some applications of buffer solutions?



3.2.1 Periodicity

3.2.1.1 Classification

Can you classify an element as s, p, d or f block from its position in the Periodic Table?



3.2.1.2 Physical properties of Period 3 elements

Can you explain the trend in atomic radius across Period 3?



Can you explain the trend in first ionisation energy across Period 3?



Can you explain the melting points of Period 3 elements in terms of structure and bonding?



3.2.2 Group 2, the alkaline earth metals

3.2.2 Group 2

Can you explain the trends in atomic radius, first ionisation energy and melting point from Mg to Ba?



Can you describe the reactions of Mg to Ba with water?



Can you describe the use of magnesium in the extraction of titanium from TiCl_4 ?



Can you describe the relative solubilities of the Group 2 hydroxides?



Can you describe the uses of $\text{Mg}(\text{OH})_2$ in medicine and $\text{Ca}(\text{OH})_2$ in agriculture?



Can you describe the use of CaO or CaCO_3 to remove SO_2 from flue gases?



Can you describe the relative solubilities of the Group 2 sulfates?



Can you explain why acidified BaCl_2 solution is used to test for sulfate ions?



Can you describe the use of BaSO_4 in medicine?



3.2.3 Group 7(17), the halogens

3.2.3.1 Trends in properties

Can you explain the trend in electronegativity down Group 7?



Can you explain the trend in boiling points down Group 7 in terms of structure and bonding?



Can you explain the trend in oxidising ability, including displacement reactions of halide ions?



Can you explain the trend in reducing ability of halide ions, including reactions of solid sodium halides with concentrated sulfuric acid?



Can you use acidified silver nitrate to identify and distinguish between halide ions?



Can you describe the trend in solubility of the silver halides in ammonia?



Can you explain why silver nitrate is acidified and why ammonia is added in the halide test?



3.2.3.2 Uses of chlorine and chlorate(I)

Can you write equations for the reaction of chlorine with water to form chloride and chlorate(I) ions?



Can you write equations for the reaction of chlorine with water in sunlight to form chloride ions and oxygen?



Can you explain the use of chlorine in water treatment and weigh the health benefits against its toxic effects?



Can you describe the reaction of chlorine with cold, dilute NaOH and the uses of the solution formed?



3.2.4

Properties of Period 3 elements and their oxides

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3.2.4 Period 3 elements and oxides

Can you describe the reactions of Na and Mg with water?



Can you describe the reactions of Na, Mg, Al, Si, P and S with oxygen to form their oxides?



Can you explain the trend in melting points of the highest oxides of Na to S in terms of structure and bonding?



Can you describe the reactions of the Period 3 oxides with water and the pH of the solutions formed?



Can you explain the trends in these reactions in terms of the type of bonding?



Can you draw the structures of the acids and anions formed when P_4O_{10} , SO_2 and SO_3 react with water?



Can you write equations for the reactions of these oxides with given acids and bases?



3.2.5.1 General properties of transition metals

Can you explain that transition metal characteristics arise from an incomplete d sub-level?



Can you list complex formation, coloured ions, variable oxidation states and catalytic activity as characteristic properties?



Can you define ligand, complex and co-ordination number?

**3.2.5.2 Substitution reactions**

Can you describe H_2O , NH_3 and Cl^- as monodentate ligands?



Can you explain why exchange of NH_3 and H_2O occurs without a change in co-ordination number?



Can you explain why substitution by Cl^- can change the co-ordination number?



Can you describe bidentate ligands such as ethane-1,2-diamine and $\text{C}_2\text{O}_4^{2-}$ and multidentate ligands such as EDTA^{4-} ?



Can you describe haem as an iron(II) complex and explain why carbon monoxide is toxic?



Can you explain the chelate effect in terms of entropy and enthalpy changes?

**3.2.5.3 Shapes of complex ions**

Can you describe octahedral complexes and their cis-trans and optical isomerism?



Can you describe tetrahedral complexes formed with larger ligands such as Cl^- ?



Can you describe square planar complexes, including cis-trans isomerism and cisplatin?



Can you describe $[\text{Ag}(\text{NH}_3)_2]^+$ as a linear complex used in Tollens' reagent?

**3.2.5.4 Formation of coloured ions**

Can you explain how transition metal ions absorb visible light, promoting d electrons, using $\Delta E = h\nu = hc/\lambda$?



Can you explain how changes in oxidation state, co-ordination number and ligand change the colour?



Can you explain how a colorimeter is used to find the concentration of a coloured ion?



3.2.5.5 Variable oxidation states

Can you describe the reduction of vanadate(V) by zinc in acid to vanadium(IV), (III) and (II) and the colours seen?



Can you explain how pH and the ligand affect the redox potential of transition metal ions?



Can you describe the use of Tollens' reagent to distinguish aldehydes from ketones?



Can you carry out calculations for redox titrations of Fe^{2+} and $\text{C}_2\text{O}_4^{2-}$ with MnO_4^- ?



Can you carry out calculations for other redox titrations from given data?

**3.2.5.6 Catalysts**

Can you explain the importance of variable oxidation states in catalysis?



Can you explain how heterogeneous catalysts work at active sites, including support media and poisoning?



Can you explain, with equations, how V_2O_5 acts as a catalyst in the Contact process?



Can you describe the use of Fe in the Haber process?



Can you explain how homogeneous catalysts work through intermediate species?



Can you explain, with equations, how Fe^{2+} catalyses the reaction between I^- and $\text{S}_2\text{O}_8^{2-}$?



Can you explain, with equations, the autocatalysis by Mn^{2+} in the reaction between $\text{C}_2\text{O}_4^{2-}$ and MnO_4^- ?

**3.2.6****Reactions of ions in aqueous solution****A-LEVEL ONLY****3.2.6 Reactions of ions in aqueous solution**

Can you describe the metal-aqua ions $[\text{M}(\text{H}_2\text{O})_6]^{2+}$ (Fe, Cu) and $[\text{M}(\text{H}_2\text{O})_6]^{3+}$ (Al, Fe)?



Can you explain why 3+ metal-aqua ions are more acidic than 2+ ions in terms of charge/size ratio?



Can you describe amphoteric hydroxides, such as $\text{Al}(\text{OH})_3$?



Can you describe and explain the reactions of Fe^{2+} , Cu^{2+} , Al^{3+} and Fe^{3+} with OH^- and with NH_3 ?



Can you describe and explain the reactions of Fe^{2+} , Cu^{2+} , Al^{3+} and Fe^{3+} with CO_3^{2-} ?



3.3.1

Introduction to organic chemistry

3.3.1.1 Nomenclature

Can you represent organic compounds using empirical, molecular, general, structural, displayed and skeletal formulas?



Can you explain the meaning of a homologous series and a functional group?



Can you name and draw compounds using IUPAC rules for chains and rings of up to six carbon atoms?



3.3.1.2 Reaction mechanisms

Can you represent free-radical mechanisms with dots for unpaired electrons and equations for each step?



Can you use curly arrows to show the movement of electron pairs in mechanisms?



3.3.1.3 Isomerism

Can you describe chain, position and functional group structural isomers?



Can you explain that stereoisomers have the same structural formula but a different spatial arrangement?



Can you explain E-Z isomerism arising from restricted rotation about a C=C bond?



Can you use the CIP priority rules to name E and Z isomers?



Can you draw the structural isomers and stereoisomers of a given formula?



3.3.2

Alkanes

3.3.2.1 Fractional distillation of crude oil

Can you describe alkanes as saturated hydrocarbons and their use as fuels?



Can you explain how crude oil is separated by fractional distillation?



3.3.2.2 Modification of alkanes by cracking

Can you describe thermal cracking and catalytic cracking, including conditions and main products?



Can you explain the economic reasons for cracking?



3.3.2.3 Combustion of alkanes

Can you write equations for complete and incomplete combustion of alkanes?



Can you explain how internal combustion engines produce NO_x , CO, carbon and unburned hydrocarbons?



Can you explain how catalytic converters remove gaseous pollutants?



Can you explain how sulfur dioxide is removed from flue gases using calcium oxide or calcium carbonate?

**3.3.2.4 Chlorination of alkanes**

Can you describe the reaction of methane with chlorine in UV light?



Can you outline the free-radical substitution mechanism with initiation, propagation and termination steps?

**3.3.3 Halogenoalkanes****3.3.3.1 Nucleophilic substitution**

Can you explain why the polar C-X bond is attacked by nucleophiles?



Can you outline nucleophilic substitution mechanisms with OH^- , CN^- and NH_3 ?



Can you explain how carbon-halogen bond enthalpy affects the rate of substitution?

**3.3.3.2 Elimination**

Can you explain how halogenoalkanes undergo elimination with KOH in ethanol to form alkenes?



Can you outline the elimination mechanism and explain the role of the reagent as a base?



Can you explain how conditions favour substitution or elimination, using 2-bromopropane as an example?

**3.3.3.3 Ozone depletion**

Can you explain how UV light breaks C-Cl bonds in CFCs to form chlorine atoms?



Can you write equations showing chlorine atoms catalysing the decomposition of ozone?



Can you explain how scientific research led to legislation and the development of alternatives to CFCs?



3.3.4 Alkenes

3.3.4.1 Structure, bonding and reactivity

Can you describe alkenes as unsaturated hydrocarbons with a C=C bond of high electron density?



3.3.4.2 Addition reactions of alkenes

Can you outline electrophilic addition mechanisms with HBr, H₂SO₄ and Br₂?



Can you describe the bromine water test for unsaturation?



Can you explain the formation of major and minor products in terms of carbocation stability?



3.3.4.3 Addition polymers

Can you draw the repeating unit of an addition polymer from its monomer and vice versa?



Can you name addition polymers using IUPAC rules?



Can you explain why addition polymers are unreactive?



Can you explain how plasticisers change the properties of PVC?



Can you explain the properties of addition polymers in terms of intermolecular forces?



3.3.5 Alcohols

3.3.5.1 Alcohol production

Can you describe the industrial hydration of alkenes with an acid catalyst, including the mechanism?



Can you describe the fermentation of glucose to produce ethanol, including conditions?



Can you explain how ethanol is separated by fractional distillation?



Can you explain the meaning of carbon neutral for bioethanol and discuss the environmental and ethical issues?



3.3.5.2 Oxidation of alcohols

Can you classify alcohols as primary, secondary and tertiary?



Can you describe oxidation of primary alcohols to aldehydes and carboxylic acids with acidified potassium dichromate(VI)?



Can you describe oxidation of secondary alcohols to ketones and explain why tertiary alcohols are not easily oxidised?



Can you write equations for these oxidations using [O]?



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



3.3.5.3 Elimination

Can you describe the acid-catalysed dehydration of alcohols to form alkenes?



Can you outline the mechanism for the elimination of water from alcohols?



Can you explain how this route produces addition polymers without using monomers from crude oil?



3.3.6 Organic analysis

3.3.6.1 Identification of functional groups by test-tube reactions

Can you identify alcohols, aldehydes, alkenes and carboxylic acids using test-tube reactions?



3.3.6.2 Mass spectrometry

Can you use high resolution mass spectrometry precise masses to find the molecular formula of a compound?



3.3.6.3 Infrared spectroscopy

Can you explain that bonds absorb infrared radiation at characteristic wavenumbers?



Can you use IR spectra and data to identify functional groups?



Can you explain the use of the fingerprint region to identify a compound and detect impurities?



Can you explain the link between absorption of IR by CO₂, methane and water vapour and global warming?



3.3.7 Optical isomerism

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3.3.7 Optical isomerism

Can you identify a chiral centre (asymmetric carbon atom)?



Can you explain that enantiomers are non-superimposable mirror images?	☐	☐	☐
Can you explain that enantiomers rotate plane-polarised light in opposite directions?	☐	☐	☐
Can you explain why a racemic mixture is optically inactive?	☐	☐	☐
Can you draw the 3D structural formulas of the two enantiomers of a compound?	☐	☐	☐
Can you explain how a racemate forms in some reaction mechanisms?	☐	☐	☐

3.3.8 Aldehydes and ketones**A-LEVEL ONLY****3.3.8 Aldehydes and ketones**

Can you explain why the carbonyl group is attacked by nucleophiles?	☐	☐	☐
Can you describe the oxidation of aldehydes to carboxylic acids and tests to distinguish aldehydes from ketones?	☐	☐	☐
Can you describe the reduction of aldehydes and ketones using NaBH_4 ?	☐	☐	☐
Can you outline the nucleophilic addition mechanism for reduction by NaBH_4 ?	☐	☐	☐
Can you outline the nucleophilic addition mechanism with KCN followed by dilute acid to form hydroxynitriles?	☐	☐	☐
Can you explain why this reaction can form a racemic mixture?	☐	☐	☐
Can you explain the hazards of using KCN?	☐	☐	☐

3.3.9 Carboxylic acids and derivatives**A-LEVEL ONLY****3.3.9.1 Carboxylic acids and esters**

Can you name and draw carboxylic acids and esters?	☐	☐	☐
Can you explain why carboxylic acids are weak acids and describe their reaction with carbonates?	☐	☐	☐
Can you describe esterification with alcohols in the presence of an acid catalyst?	☐	☐	☐
Can you describe common uses of esters as solvents, plasticisers, perfumes and food flavourings?	☐	☐	☐
Can you describe vegetable oils and animal fats as esters of propane-1,2,3-triol (glycerol)?	☐	☐	☐
Can you describe the acid and alkaline hydrolysis of esters?	☐	☐	☐
Can you describe the alkaline hydrolysis of fats and oils to make soap and glycerol?	☐	☐	☐
Can you describe the production of biodiesel from vegetable oils and methanol?	☐	☐	☐

3.3.9.2 Acylation

Can you name and draw acid anhydrides, acyl chlorides and amides?

☐☐☐

Can you describe the reactions of acyl chlorides and acid anhydrides with water, alcohols, ammonia and primary amines?

☐☐☐

Can you outline the nucleophilic addition-elimination mechanism for these reactions of acyl chlorides?

☐☐☐

Can you explain the industrial advantages of ethanoic anhydride over ethanoyl chloride in making aspirin?

☐☐☐**3.3.10 Aromatic chemistry****A-LEVEL ONLY****3.3.10.1 Bonding**

Can you describe benzene as a planar molecule with delocalised electrons and equal bond lengths?

☐☐☐

Can you use enthalpies of hydrogenation to explain the extra stability of benzene?

☐☐☐

Can you explain why benzene undergoes substitution rather than addition?

☐☐☐**3.3.10.2 Electrophilic substitution**

Can you outline the mechanism of nitration of benzene, including formation of the NO_2^+ ion?

☐☐☐

Can you explain the importance of nitration in making explosives and amines?

☐☐☐

Can you outline the mechanism of Friedel-Crafts acylation using AlCl_3 ?

☐☐☐

Can you explain the importance of Friedel-Crafts acylation in synthesis?

☐☐☐**3.3.11 Amines****A-LEVEL ONLY****3.3.11.1 Preparation**

Can you describe the preparation of primary aliphatic amines from ammonia and halogenoalkanes?

☐☐☐

Can you describe the preparation of primary aliphatic amines by reduction of nitriles?

☐☐☐

Can you describe the preparation of aromatic amines by reduction of nitro compounds and their use in dyes?

☐☐☐

3.3.11.2 Base properties

Can you explain why amines are weak bases?



Can you explain the difference in base strength of ammonia, primary aliphatic amines and primary aromatic amines?

**3.3.11.3 Nucleophilic properties**

Can you explain why amines act as nucleophiles?



Can you outline the mechanisms forming primary, secondary and tertiary amines and quaternary ammonium salts?



Can you describe the use of quaternary ammonium salts as cationic surfactants?



Can you outline the addition-elimination mechanism for reactions of ammonia and amines with acyl chlorides and acid anhydrides?

**3.3.12 Polymers****A-LEVEL ONLY****3.3.12.1 Condensation polymers**

Can you describe how polyesters and polyamides form from dicarboxylic acids with diols, diamines and amino acids?



Can you draw the repeating units of Terylene, nylon 6,6 and Kevlar and describe their uses?



Can you draw a repeating unit from given monomers and deduce monomers from a section of polymer?



Can you explain the intermolecular forces between polymer chains?

**3.3.12.2 Biodegradability and disposal of polymers**

Can you explain why polyalkenes are chemically inert and non-biodegradable?



Can you explain why polyesters and polyamides can be hydrolysed?



Can you evaluate the advantages and disadvantages of different methods of polymer disposal, including recycling?

**3.3.13 Amino acids, proteins and DNA****A-LEVEL ONLY****3.3.13.1 Amino acids**

Can you explain why amino acids are amphoteric and form zwitterions?



Can you draw the structures of amino acids in acidic and alkaline solutions?



3.3.13.2 Proteins

Can you describe proteins as sequences of amino acids joined by peptide links?



Can you draw the structure of a peptide of up to three amino acids and its hydrolysis products?



Can you describe primary, secondary (alpha-helix and beta-pleated sheet) and tertiary structure?



Can you explain the roles of hydrogen bonding and sulfur-sulfur bonds in protein structure?



Can you describe how amino acids are separated and identified by thin-layer chromatography and calculate R_f values?



3.3.13.3 Enzymes

Can you explain how enzymes act as catalysts with a stereospecific active site?



Can you explain why a stereospecific active site binds only one enantiomer?



Can you explain how drugs act as enzyme inhibitors and how computer modelling helps design them?



3.3.13.4 DNA

Can you describe the structure of a nucleotide: phosphate, 2-deoxyribose and a base?



Can you describe how nucleotides join to form a single strand of DNA?



Can you explain how hydrogen bonding between base pairs leads to the double helix?



3.3.13.5 Action of anticancer drugs

Can you explain how cisplatin prevents DNA replication by binding to guanine?



Can you explain why cisplatin can have adverse effects and weigh up its benefits?



3.3.14

Organic synthesis

A-LEVEL ONLY

3.3.14 Organic synthesis

Can you explain why chemists aim for processes that are solvent-free, use non-hazardous materials, have few steps and high atom economy?



Can you recall the reagents and conditions for the reactions in the specification?



Can you devise synthesis routes of up to four steps between organic compounds?

**3.3.15**

Nuclear magnetic resonance spectroscopy

A-LEVEL ONLY

3.3.15 NMR spectroscopy

Can you explain how NMR gives information about the positions of ^{13}C or ^1H atoms in a molecule?



Can you explain that chemical shift depends on the molecular environment and is measured on the δ scale?



Can you explain why TMS is used as a standard?



Can you explain the use of deuterated solvents and CCl_4 when preparing samples?



Can you use ^{13}C NMR spectra and chemical shift data to suggest a structure?



Can you use integration data from ^1H NMR spectra to find relative numbers of equivalent protons?



Can you use the $n+1$ rule to explain doublets, triplets and quartets in ^1H NMR spectra?



Can you use ^1H NMR spectra and chemical shift data to suggest a structure?

**3.3.16**

Chromatography

A-LEVEL ONLY

3.3.16 Chromatography

Can you explain how chromatography separates components by balance between the mobile and stationary phases?



Can you describe thin-layer chromatography (TLC), column chromatography (CC) and gas chromatography (GC)?



Can you calculate R_f values from a chromatogram?



Can you compare retention times and R_f values with standards to identify substances?



Can you explain why gas chromatography is coupled with mass spectrometry?



The 12 required practical activities

1 Can you make up a volumetric solution and carry out a simple acid-base titration?	☐	☐	☐
2 Can you measure an enthalpy change?	☐	☐	☐
3 Can you investigate how the rate of a reaction changes with temperature?	☐	☐	☐
4 Can you carry out simple test-tube reactions to identify Group 2 and NH_4^+ cations and halide, OH^- , CO_3^{2-} and SO_4^{2-} anions?	☐	☐	☐
5 Can you distil a product from a reaction?	☐	☐	☐
6 Can you carry out tests for alcohol, aldehyde, alkene and carboxylic acid?	☐	☐	☐
7 Can you measure the rate of reaction by an initial rate method and a continuous monitoring method?	☐	☐	☐
8 Can you measure the EMF of an electrochemical cell?	☐	☐	☐
9 Can you investigate how pH changes when a weak acid reacts with a strong base and a strong acid with a weak base?	☐	☐	☐
10 Can you prepare a pure organic solid and test its purity, and prepare a pure organic liquid?	☐	☐	☐
11 Can you carry out simple test-tube reactions to identify transition metal ions in aqueous solution?	☐	☐	☐
12 Can you separate species by thin-layer chromatography?	☐	☐	☐