

Mapping grid showing how the AQA A A2 Level Chemistry specification (for first teaching in 2009) is covered by Boardworks A2 Chemistry

Unit 4. Kinetics, Equilibria and Organic Chemistry

Topic	Boardworks A2 Chemistry presentation title
3.4.1 Kinetics: Simple rate reactions; Determination of rate equation	<ul style="list-style-type: none"> Kinetics
3.4.2 Equilibria: Equilibrium constant K_c for homogenous systems; Qualitative effects of changes of temperature and concentration	<ul style="list-style-type: none"> Equilibria
3.4.3 Acids and Bases: Brønsted–Lowry acid-base equilibria in aqueous solution; Definition and determination of pH; The ionic product of water, K_w ; Weak acids and bases; K_a for weak acids; pH curves, titrations and indicators; Buffer action	<ul style="list-style-type: none"> Acids and Bases
3.4.4 Nomenclature and Isomerism in Organic Chemistry: Naming organic compounds; Isomerism	<ul style="list-style-type: none"> Carbonyl Compounds Acyl Compounds Aromatic Compounds Amines Polymers and Amino Acids
3.4.5 Compounds Containing the Carbonyl Group: Aldehydes and ketones; Carboxylic acids and esters; Acylation	<ul style="list-style-type: none"> Carbonyl Compounds Acyl Compounds
3.4.6 Aromatic Chemistry: Bonding; Delocalisation stability; Electrophilic substitution; Nitration; Friedel–Crafts acylation reactions	<ul style="list-style-type: none"> Aromatic Compounds
3.4.7 Amines: Base properties (Brønsted–Lowry); Nucleophilic properties; Preparation	<ul style="list-style-type: none"> Amines
3.4.8 Amino Acids: Acid and base properties; Proteins	<ul style="list-style-type: none"> Polymers and Amino Acids
3.4.9 Polymers: Addition polymers; Condensation polymers; Biodegradability and disposal of polymers	<ul style="list-style-type: none"> Polymers and Amino Acids
3.4.10 Organic Synthesis and Analysis: Applications	<ul style="list-style-type: none"> Organic Synthesis

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3.4.11 Structure Determination: Data sources; Mass spectrometry; Infra-red spectroscopy; Nuclear magnetic resonance spectroscopy; Chromatography	<ul style="list-style-type: none"> • Structure Determination
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Unit 5. Energetics, Redox and Inorganic Chemistry

Topic	Boardworks A2 Chemistry presentation title
3.5.1 Thermodynamics: Enthalpy change (ΔH); Free-energy change (ΔG) and entropy change (ΔS)	<ul style="list-style-type: none"> • Thermodynamics
3.5.2 Periodicity: Study of the reactions of Period 3 elements Na–Ar to illustrate periodic trends; A survey of the acid-base properties of the oxides of Period 3 elements	<ul style="list-style-type: none"> • Periodicity in Period 3
3.5.3 Redox Equilibria: Redox equations; Electrode potentials; Electrochemical series; Electrochemical cells	<ul style="list-style-type: none"> • Redox Reactions and Electrode Potentials • Applications of Redox Reactions
3.5.4 Transition Metals: General properties of transition metals; Complex formation; Shapes of complex ions; Formation of coloured ions; Variable oxidation states; Catalysis; Heterogeneous; Homogeneous; Other applications of transition metal complexes	<ul style="list-style-type: none"> • Introducing Transition Metals • Transition Metals: Colours and Reactions • Uses of Transition Metals
3.5.5 Reactions of Inorganic Compounds in Aqueous Solution: Lewis acids and bases; Metal-aqua ions; Acidity or hydrolysis reactions; Substitution reactions	<ul style="list-style-type: none"> • Transition Metals: Colours and Reactions

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Unit 4. General Principles of Chemistry II – Rates, Equilibria and Further Organic Chemistry

4.3 How Fast? – rates	Boardworks A2 Chemistry presentation title
a. demonstrate and understanding of the terms ‘rate of reaction’, ‘rate equation’, ‘order of reaction’, ‘rate constant’, ‘half-life’, ‘rate-determining step’, ‘activation energy’, ‘heterogeneous and homogenous catalyst’	<ul style="list-style-type: none"> • Uses of Transition Metals
b. select and describe a suitable experimental technique to obtain rate data for a given reaction, eg colorimetry, mass change and volume of gas evolved	<ul style="list-style-type: none"> • Kinetics
c. investigate reactions which produce data that can be used to calculate the rate of the reaction, its half-life from concentration or volume against time graphs, eg a clock reaction	<ul style="list-style-type: none"> • Kinetics
d. present and interpret the results of kinetic measurements in graphical form, including concentration-time and rate-concentration graphs	<ul style="list-style-type: none"> • Kinetics
e. investigate the reaction of iodine with propanone in acid to obtain data for the order with respect to the reactants and the hydrogen ion and make predictions about molecules/ions involved in the rate-determining step and possible mechanism (details of the actual mechanism can be discussed at a later stage in this topic)	<ul style="list-style-type: none"> • Kinetics
f. deduce from experimental data for reactions with zero, first and second order kinetics: <ol style="list-style-type: none"> <i>i.</i> half-life (the relationship between half-life and rate constant will be given if required) <i>ii.</i> order of reaction <i>iii.</i> rate of reaction <i>iv.</i> rate-determining step related to reaction mechanisms <i>v.</i> v. activation energy (by graphical methods only; the Arrhenius equation will be given if needed) 	<ul style="list-style-type: none"> • Kinetics
g. investigate the activation energy of a reaction, eg oxidation of iodide ions by iodate(V)	

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<p>h. apply a knowledge of the rate equations for the hydrolysis of halogenoalkanes to deduce the mechanisms for primary and tertiary halogenoalkane hydrolysis and to deduce the mechanism for the reaction between propanone and iodine</p>	
<p>i. demonstrate that the mechanisms proposed for the hydrolysis of halogenoalkanes are consistent with the experimentally determined orders of reactions, and that a proposed mechanism for the reaction between propanone and iodine is consistent with the data from the experiment in 4.3e</p>	
<p>j. use kinetic data as evidence for S_N1 or S_N2 mechanisms in the nucleophilic substitution reactions of halogenoalkanes.</p>	<ul style="list-style-type: none"> • Kinetics

4.4 How far? – entropy	Boardworks A2 Chemistry presentation title
<p>a. demonstrate an understanding that, since endothermic reactions can occur spontaneously at room temperature, enthalpy changes alone do not control whether reactions occur</p>	<ul style="list-style-type: none"> • Thermodynamics
<p>b. demonstrate an understanding of entropy in terms of the random dispersal of molecules and of energy quanta between molecules</p>	<ul style="list-style-type: none"> • Thermodynamics
<p>c. demonstrate an understanding that the entropy of a substance increases with temperature, that entropy increases as solid + liquid + gas and that perfect crystals at zero kelvin have zero entropy</p>	<ul style="list-style-type: none"> • Thermodynamics
<p>d. demonstrate an understanding that the standard entropy of a substance depends mainly on its physical state but also on its complexity</p>	<ul style="list-style-type: none"> • Thermodynamics
<p>e. demonstrate an understanding that reactions occur due to chance collisions, and that one possible ordered arrangement, eg in a crystalline solid, can be rearranged into many possible disordered arrangements, eg in a solution, so the probability of disorder is greater than order</p>	<ul style="list-style-type: none"> • Thermodynamics

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<p>f. interpret the natural direction of change as being in the direction of increasing total entropy (positive entropy change), eg gases spread spontaneously through a room and define the term enthalpy of hydration of an ion and use it and lattice energy to calculate the enthalpy of solution of an ionic compound</p>	<ul style="list-style-type: none"> • Thermodynamics • Transition Metals: Colours and Reactions
<p>g. carry out experiments and relate the results to disorder and enthalpy changes including:</p> <p>i. dissolving a solid, eg adding ammonium nitrate crystals to water</p> <p>ii. gas evolution, eg reacting ethanoic acid with ammonium carbonate</p> <p>iii. exothermic reaction producing a solid, eg burning magnesium ribbon in air</p> <p>iv. endothermic reaction of two solids, eg mixing solid barium hydroxide, $\text{Ba}(\text{OH})_2 \cdot 8\text{H}_2\text{O}$ with solid ammonium chloride</p>	
<p>h. demonstrate an understanding that the entropy change in any reaction is made up of the entropy change in the system added to the entropy change in the surroundings, summarised by the expression: $\Delta S_{total} = \Delta S_{system} + \Delta S_{surroundings}$</p>	<ul style="list-style-type: none"> • Thermodynamics
<p>i. calculate the entropy change in the system for a reaction, ΔS_{system}, given entropy data</p>	<ul style="list-style-type: none"> • Thermodynamics
<p>j. use the expression $\Delta S_{surroundings} = -\Delta H / T$ to calculate the entropy change in the surroundings and hence ΔS_{total}</p>	<ul style="list-style-type: none"> • Thermodynamics
<p>k. demonstrate an understanding that the feasibility of a reaction depends on the balance between ΔS_{system} and $\Delta S_{surroundings}$, and that at higher temperatures the magnitude of $\Delta S_{surroundings}$ decreases and its contribution to ΔS_{total} is less. Reactions can occur as long as ΔS_{total} is positive even if one of the other entropy changes is negative</p>	<ul style="list-style-type: none"> • Thermodynamics
<p>l. demonstrate an understanding of and distinguish between the concepts of thermodynamic stability and kinetic inertness</p>	<ul style="list-style-type: none"> • Thermodynamics
<p>m. calculate ΔS_{system} and $\Delta S_{surroundings}$ for the reactions in 4.49g to show that endothermic reactions can occur spontaneously at room temperature</p>	

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n. define the term enthalpy of hydration of an ion and use it and lattice energy to calculate the enthalpy of solution of an ionic compound	<ul style="list-style-type: none"> • Thermodynamics
o. demonstrate an understanding of the factors that affect the values of enthalpy of hydration and the lattice energy of an ionic compound	<ul style="list-style-type: none"> • Thermodynamics
p. use entropy and enthalpy of solution values to predict the solubility of ionic compounds.	

4.5 Equilibria	Boardworks A2 Chemistry presentation title
a. demonstrate an understanding of the term 'dynamic equilibrium' as applied to states of matter, solutions and chemical reactions	<ul style="list-style-type: none"> • Equilibria
b. recall that many important industrial reactions are reversible	<ul style="list-style-type: none"> • Equilibria
c. use practical data to establish the idea that a relationship exists between the equilibrium concentrations of reactants and products which produces the equilibrium constant for a particular reaction, eg data on the hydrogen-iodine equilibrium	<ul style="list-style-type: none"> • Equilibria
d. calculate a value for the equilibrium constant for a reaction based on data from experiment, eg the reaction of ethanol and ethanoic acid (this can be used as an example of the use of ICT to present and analyse data), the equilibrium $\text{Fe}^{2+}(\text{aq}) + \text{Ag}^+(\text{aq}) \leftrightarrow \text{Fe}^{3+}(\text{aq}) + \text{Ag}(\text{s})$ or the distribution of ammonia or iodine between two immiscible solvents	<ul style="list-style-type: none"> • Equilibria
e. construct expressions for K_c and K_p for homogeneous and heterogeneous systems, in terms of equilibrium concentrations or equilibrium partial pressures, perform simple calculations on K_c and K_p and work out the units of the equilibrium constants	<ul style="list-style-type: none"> • Equilibria
f. demonstrate an understanding that when ΔS_{total} increases the magnitude of the equilibrium constant increases since $\Delta S = R \ln K$	
g. apply knowledge of the value of equilibrium constants to predict the extent to which a reaction takes place	<ul style="list-style-type: none"> • Equilibria
h. relate the effect of a change in temperature on the value of ΔS_{total}	<ul style="list-style-type: none"> • Thermodynamics

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4.6 Application of rates and equilibrium	Boardworks A2 Chemistry presentation title
<p>a. demonstrate an understanding of how, if at all, and why a change in temperature, pressure or the presence of a catalyst affects the equilibrium constant and the equilibrium composition and recall the effects of changes of temperature and pressure on rate, eg the thermal decomposition of ammonium chloride, or the effect of temperature and pressure changes in the system $2\text{NO}_2 \leftrightarrow \text{N}_2\text{O}_4$</p>	<ul style="list-style-type: none"> • Equilibria
<p>b. use information on enthalpy change and entropy to justify the conditions used to obtain economic yields in industrial processes, and understand that in reality industrial processes cannot be in equilibrium since the products are removed, eg in the Haber process temperature affects the equilibrium yield and rate whereas pressure affects only the equilibrium yield (knowledge of industrial conditions are not required)</p>	
<p>c. demonstrate an understanding of the steps taken in industry to maximise the atom economy of the process, eg recycling unreacted reagents or using an alternative reaction</p>	<ul style="list-style-type: none"> • Equilibria
<p>d. demonstrate an understanding of the importance of being able to control reactions, through knowledge of equilibrium constants and entropy changes, the importance of controlling reactions to produce adequate yields under safe, economically viable conditions and why some reactions 'go' and some will never occur.</p>	<ul style="list-style-type: none"> • Equilibria • Thermodynamics

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4.7 Acid/base equilibria	Boardworks A2 Chemistry presentation title
<p>a. demonstrate an understanding that the theory about acidity developed in the 19th and 20th centuries from a substance with a sour taste to a substance which produces an excess of hydrogen ions in solution (Arrhenius theory) to the Brønsted–Lowry theory</p>	<ul style="list-style-type: none"> • Acids and Bases
<p>b. demonstrate an understanding that a Brønsted–Lowry acid is a proton donor and a base a proton acceptor and that acid-base equilibria involve transfer of protons</p>	<ul style="list-style-type: none"> • Acids and Bases
<p>c. demonstrate understanding of the Brønsted–Lowry theory of acid-base behaviour, and use it to identify conjugate acid-base pairs</p>	<ul style="list-style-type: none"> • Acids and Bases
<p>d. define the terms pH, K_a and K_w, pK_a and pK_w, and be able to carry out calculations relating the pH of strong acids and bases to their concentrations in mol dm⁻³</p>	<ul style="list-style-type: none"> • Acids and Bases
<p>e. demonstrate an understanding that weak acids and bases are only slightly dissociated in aqueous solution, and apply the equilibrium law to deduce the expressions for the equilibrium constants K_a and K_w</p>	<ul style="list-style-type: none"> • Acids and Bases
<p>f. analyse the results obtained from the following experiments:</p> <ul style="list-style-type: none"> <i>i.</i> measuring the pH of a variety of substances, eg equimolar solutions of strong and weak acids, strong and weak bases and salts <i>ii.</i> comparing the pH of a strong acid and a weak acid after dilution 10, 100 and 1000 times 	
<p>g. analyse and evaluate the results obtained from experiments to determine K_a for a weak acid by measuring the pH of a solution containing a known mass of acid, and discuss the assumptions made in this calculation</p>	
<p>h. calculate the pH of a solution of a weak acid based on data for concentration and K_a, and discuss the assumptions made in this calculation</p>	<ul style="list-style-type: none"> • Acids and Bases

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i. measure the pH change during titrations and draw titration curves using different combinations of strong and weak monobasic acids and bases	<ul style="list-style-type: none"> Acids and Bases
j. use data about indicators, together with titration curves, to select a suitable indicator and the use of titrations in analysis	<ul style="list-style-type: none"> Acids and Bases
k. explain the action of buffer solutions and carry out calculations on the pH of buffer solutions, eg making buffer solutions and comparing the effect of adding acid or alkali on the pH of the buffer	<ul style="list-style-type: none"> Acids and Bases
l. use titration curves to show the buffer action and to determine K_a from the pH at the point where half the acid is neutralised	<ul style="list-style-type: none"> Acids and Bases
m. explain the importance of buffer solutions in biological environments, eg buffers in cells and in blood (H_2CO_3/HCO_3^-) and in foods to prevent deterioration due to pH change (caused by bacterial or fungal activity).	<ul style="list-style-type: none"> Acids and Bases

4.8 Further organic chemistry 1. Chirality 2. Carbonyl compounds 3. Carboxylic acids 4. Carboxylic acid derivatives	Boardworks A2 Chemistry presentation title
1a. recall the meaning of structural and E-Z isomerism (geometric/cis-trans isomerism) object and non-superimposable mirror images	<ul style="list-style-type: none"> Organic Synthesis
1b. demonstrate an understanding of the existence of optical isomerism resulting from chiral centre(s) in a molecule with asymmetric carbon atom(s) and understand optical isomers as object and non-superimposable mirror images	<ul style="list-style-type: none"> Organic Synthesis
1c. recall optical activity as the ability of a single optical isomer to rotate the plane of polarization of plane-polarized monochromatic light in molecules containing a single chiral centre and understand the nature of a racemic mixture	<ul style="list-style-type: none"> Organic Synthesis
1d. use data on optical activity of reactants and products as evidence for proposed mechanisms, as in S_N1 and S_N2 and addition to carbonyl compounds.	

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<p>2a. give examples of molecules that contain the aldehyde or ketone compounds functional group</p>	<ul style="list-style-type: none"> • Carbonyl Compounds
<p>2b. explain the physical properties of aldehydes and ketones relating this to the lack of hydrogen bonding between molecules and their solubility in water in terms of hydrogen bonding with the water</p>	<ul style="list-style-type: none"> • Carbonyl Compounds
<p>2c. describe and carry out, where appropriate, the reactions of carbonyl compounds. This will be limited to:</p> <ul style="list-style-type: none"> <i>i.</i> oxidation with Fehling's or Benedict's solution, Tollens' reagent and acidified dichromate(VI) ions <i>ii.</i> reduction with lithium tetrahydridoaluminate (lithium aluminium hydride) in dry ether <i>iii.</i> nucleophilic addition of HCN in the presence of KCN, using curly arrows, relevant lone pairs, dipoles and evidence of optical activity to show the mechanism <i>iv.</i> the reaction with 2,4-dinitrophenylhydrazine and its use to detect the presence of a carbonyl group and to identify a carbonyl compound given data of the melting temperatures of derivatives <i>v.</i> iodine in the presence of alkali. 	<ul style="list-style-type: none"> • Carbonyl Compounds
<p>3a. give some examples of molecules that contain the carboxylic acid functional group</p>	<ul style="list-style-type: none"> • Carbonyl Compounds
<p>3b. explain the physical properties of carboxylic acids in relation to their boiling temperatures and solubility due to hydrogen bonding</p>	<ul style="list-style-type: none"> • Carbonyl Compounds
<p>3c. describe the preparation of carboxylic acids to include oxidation of alcohols and carbonyl compounds and the hydrolysis of nitriles</p>	<ul style="list-style-type: none"> • Carbonyl Compounds
<p>3d. describe and carry out, where appropriate, the reactions of carboxylic acids. This will be limited to:</p> <ul style="list-style-type: none"> <i>i.</i> reduction with lithium tetrahydridoaluminate (lithium aluminium hydride) in dry ether (ethoxyethane) <i>ii.</i> neutralization to produce salts, eg to determine the amount of citric acid in fruit <i>iii.</i> phosphorus(V) chloride (phosphorus pentachloride) <i>iv.</i> reactions with alcohols in the presence of an acid catalyst, eg the preparation of ethyl ethanoate as a solvent or as pineapple flavouring. 	

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<p>4a. demonstrate an understanding that these include acyl chlorides and esters and recognise their respective functional groups, giving examples of molecules containing these functional groups</p>	<ul style="list-style-type: none"> • Acyl Compounds
<p>4b. describe and carry out, where appropriate, the reactions of acyl chlorides limited to their reaction with:</p> <ul style="list-style-type: none"> <i>i.</i> water <i>ii.</i> alcohols <i>iii.</i> concentrated ammonia <i>iv.</i> amines 	<ul style="list-style-type: none"> • Acyl Compounds
<p>4c. describe and carry out, where appropriate, the reactions of esters. This will be limited to:</p> <ul style="list-style-type: none"> <i>i.</i> their hydrolysis with an acid <i>ii.</i> their hydrolysis with a base, eg to form soaps <i>iii.</i> their reaction with alcohols and acids to explain the process of trans-esterification and recall how it is applied to the manufacture of bio-diesel (as a potentially greener fuel) and low-fat spreads (replacing the hydrogenation of vegetable oils to produce margarine) 	<ul style="list-style-type: none"> • Acyl Compounds
<p>4d. demonstrate an understanding of the importance of the formation of polyesters and describe their formation by condensation polymerization of ethane-1,2-diol and benzene-1,4-dicarboxylic acid.</p>	

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4.9 Spectroscopy and chromatography	Boardworks A2 Chemistry presentation title
<p>a. explain the effect of different types of radiation on molecules and how the principles of this are used in chemical analysis and in reactions, limited to:</p> <ul style="list-style-type: none"> <i>i.</i> infrared in analysis <i>ii.</i> microwaves for heating <i>iii.</i> radio waves in nmr <i>iv.</i> ultraviolet in initiation of reactions 	
<p>b. explain the use of high resolution nmr spectra to identify the structure of a molecule:</p> <ul style="list-style-type: none"> <i>i.</i> based on the different types of proton present from chemical shift values <i>ii.</i> by using the spin-spin coupling pattern to identify the number of protons adjacent to a given proton <i>iii.</i> the effect of radio waves on proton spin in nmr, limited to ^1H nuclei <i>iv.</i> the use of magnetic resonance imaging as a non-invasive technique, eg scanning for brain disorders, or the use of nmr to check the purity of a compound in the pharmaceutical industry 	<ul style="list-style-type: none"> • Structure Determination
<p>c. demonstrate an understanding of the use of IR spectra to follow the progress of a reaction involving change of functional groups, eg in the chemical industry to determine the extent of the reaction</p>	<ul style="list-style-type: none"> • Structure Determination
<p>d. interpret simple mass spectra to suggest possible structures of a simple compound from the m/e of the molecular ion and fragmentation patterns</p>	<ul style="list-style-type: none"> • Structure Determination
<p>e. describe the principles of gas chromatography and HPLC as used as methods of separation of mixtures, prior to further analysis (theory of R_f values not required), and also to determine if substances are present in industrial chemical processes.</p>	<ul style="list-style-type: none"> • Structure Determination

Unit 5. General Principles of Chemistry II – Transition Metals and Organic Nitrogen Chemistry

5.3 Redox and the chemistry of the transition metals 1. Application of redox equilibria 2. Transition metals and their chemistry	Boardworks A2 Chemistry presentation title
1a. demonstrate an understanding of the terms ‘oxidation number’, ‘redox’, ‘half-reactions’ and use these to interpret reactions involving electron transfer	<ul style="list-style-type: none"> • Redox Reactions and Electrode Potentials • Applications of Redox Chemistry
1b. relate changes in oxidation number to reaction stoichiometry	<ul style="list-style-type: none"> • Redox Reactions and Electrode Potentials •
1c. recall the definition of standard electrode potential and standard hydrogen electrode and understand the need for a reference electrode	<ul style="list-style-type: none"> • Redox Reactions and Electrode Potentials •
1d. set up some simple cells and calculate values of $E_{\text{cell}}^{\ominus}$ from standard electrode potential values and use them to predict the thermodynamic feasibility and extent of reactions	<ul style="list-style-type: none"> • Redox Reactions and Electrode Potentials • Applications of Redox Chemistry
1e. demonstrate an understanding that $E_{\text{cell}}^{\ominus}$ is directly proportional to the total entropy change and to $\ln K$ for a reaction	
1f. demonstrate an understanding of why the predictions in 5.3.1d may not be borne out in practice due to kinetic effects and non-standard conditions	
1g. carry out and evaluate the results of an experiment involving the use of standard electrode potentials to predict the feasibility of a reaction, eg interchange of the oxidation states of vanadium or manganese	<ul style="list-style-type: none"> • Redox Reactions and Electrode Potentials • Applications of Redox Chemistry

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<p>1h. demonstrate an understanding of the procedures of the redox titrations below (i and ii) and carry out a redox titration with one:</p> <p><i>i.</i> potassium manganate(VII), eg the estimation of iron in iron tablets</p> <p><i>ii.</i> sodium thiosulfate and iodine, eg estimation of percentage of copper in an alloy</p>	<ul style="list-style-type: none"> • Uses of Transition Metals
<p>1i. discuss the uncertainty of measurements and their implications for the validity of the final results</p>	
<p>1j. discuss the use of hydrogen and alcohol fuel cells as energy sources, including the source of the hydrogen and alcohol, eg used in space exploration, in electric cars</p>	<ul style="list-style-type: none"> • Applications of Redox Chemistry
<p>1k. demonstrate an understanding of the principles of modern breathalysers based on an ethanol fuel cell and compare this to methods based on the use of IR and to the reduction of chromium compounds.</p>	<ul style="list-style-type: none"> • Applications of Redox Chemistry
<p>2a. describe transition metals as those elements which form one or more stable ions which have incompletely filled d orbitals their chemistry</p>	<ul style="list-style-type: none"> • Introducing Transition Metals
<p>2b. derive the electronic configuration of the atoms of the d- block elements (Sc to Zn) and their simple ions from their atomic number</p>	<ul style="list-style-type: none"> • Introducing Transition Metals
<p>2c. discuss the evidence for the electronic configurations of the elements Sc to Zn based on successive ionization energies</p>	<ul style="list-style-type: none"> • Introducing Transition Metals
<p>2d. recall that transition elements in general:</p> <p><i>i.</i> show variable oxidation number in their compounds, eg redox reactions of vanadium</p> <p><i>ii.</i> form coloured ions in solution</p> <p><i>iii.</i> form complex ions involving monodentate and bidentate ligands</p> <p><i>iv.</i> can act as catalysts both as the elements and as their compounds</p>	<ul style="list-style-type: none"> • Introducing Transition Metals • Transition Metals: Colours and Reactions • Uses of Transition Metals
<p>2e. recall the shapes of complex ions limited to linear $[\text{CuCl}_2]^-$, planar $[\text{Pt}(\text{NH}_3)_2\text{Cl}_2]$, tetrahedral $[\text{CrCl}_4]^-$ and octahedral $[\text{Cr}(\text{NH}_3)_6]^{3+}$, $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$ and other aqua complexes</p>	<ul style="list-style-type: none"> • Introducing Transition Metals

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<p>2f. use the chemistries of chromium and copper to illustrate and explain some properties of transition metals as follows:</p> <ol style="list-style-type: none"> <i>i.</i> the formation of a range of compounds in which they are present in different oxidation states <i>ii.</i> the presence of dative covalent bonding in complex ions, including the aqua-ions <i>iii.</i> the colour or lack of colour of aqueous ions and other complex ions, resulting from the splitting of the energy levels of the d orbitals by ligands <i>iv.</i> simple ligand exchange reactions <i>v.</i> relate relative stability of complex ions to the entropy changes of ligand exchange reactions involving polydentate ligands (qualitatively only), eg EDTA <i>vi.</i> relate disproportionation reactions to standard electrode potentials and hence to $E_{\text{cell}}^{\ominus}$ 	<ul style="list-style-type: none"> • Transition Metals: Colours and Reactions
<p>2g. carry out experiments to:</p> <ol style="list-style-type: none"> <i>i.</i> investigate ligand exchange in copper complexes <i>ii.</i> study the redox chemistry of chromium in oxidation states Cr(VI), Cr(III) and Cr(II) <i>iii.</i> prepare a sample of a complex, eg chromium(II) ethanoate 	<ul style="list-style-type: none"> • Transition Metals: Colours and Reactions • Uses of Transition Metals
<p>2h. recall that transition metals and their compounds are important as catalysts and that their activity may be associated with variable oxidation states of the elements or surface activity, eg catalytic converters in car exhausts</p>	<ul style="list-style-type: none"> • Uses of Transition Metals
<p>2i. explain why the development of new catalysts is a priority area for chemical research today and, in this context, explain how the scientific community reports and validates new discoveries and explanations, eg the development of new catalysts for making ethanoic acid from methanol and carbon monoxide with a high atom economy (green chemistry)</p>	<ul style="list-style-type: none"> • Uses of Transition Metals
<p>2j. carry out and interpret the reactions of transition metal ions with aqueous sodium hydroxide and aqueous ammonia, both in excess, limited to reactions with aqueous solutions of Cr(III), Mn(II), Fe(II), Fe(III), Ni(II), Cu(II), Zn(II)</p>	<ul style="list-style-type: none"> • Transition Metals: Colours and Reactions

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2k. write ionic equations to show the difference between amphoteric behaviour and ligand exchange in the reactions in 5.3.2g	<ul style="list-style-type: none"> • Transition Metals: Colours and Reactions
2l. discuss the uses of transition metals and/or their compounds, eg in polychromic sun glasses, chemotherapy drugs.	<ul style="list-style-type: none"> • Uses of Transition Metals

5.4 Organic chemistry – arenes, nitrogen compounds and synthesis	Boardworks A2 Chemistry presentation title
1. Arenes: benzene 2. Organic nitrogen compounds: amines, amides, amino acids and proteins 3. Organic synthesis	
1a. use thermochemical, x-ray diffraction and infrared data as evidence for the structure and stability of the benzene ring	<ul style="list-style-type: none"> • Aromatic Compounds
1b. describe the following reactions of benzene, limited to: <i>i.</i> combustion to form a smoky flame treatment with: <i>ii.</i> bromine <i>iii.</i> concentrated nitric and sulfuric acids <i>iv.</i> fuming sulfuric acid <i>v.</i> halogenoalkanes and acyl chlorides with aluminium chloride as catalyst (Friedel-Crafts reaction) <i>vi.</i> addition reactions with hydrogen	<ul style="list-style-type: none"> • Aromatic Compounds
1c. describe the mechanism of the electrophilic substitution reactions of benzene in halogenation, nitration and Friedel-Crafts reactions including the formation of the electrophile	<ul style="list-style-type: none"> • Aromatic Compounds
1d. carry out the reactions in 5.4.1b where appropriate (using methylbenzene or methoxybenzene)	
1e. carry out the reaction of phenol with bromine water and dilute nitric acid and use these results to illustrate the activation of the benzene ring.	<ul style="list-style-type: none"> • Aromatic Compounds
2a. give examples of: <i>i.</i> molecules that contain amine and amide functional groups <i>ii.</i> amino acids	<ul style="list-style-type: none"> • Amines • Polymers and Amino Acids

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<p>2b. describe and carry out, where appropriate (using butylamine and phenylamine), reactions to investigate the typical behaviour of primary amines. This will be limited to:</p> <ul style="list-style-type: none"> <i>i.</i> characteristic smell <i>ii.</i> miscibility with water as a result of hydrogen bonding and the alkaline nature of the resulting solution <i>iii.</i> formation of salts <i>iv.</i> complex ion formation with copper(II) ions <i>v.</i> treatment with ethanoyl chloride and halogenoalkanes, eg making paracetamol 	<ul style="list-style-type: none"> • Amines • Acyl Compounds
<p>2c. describe the reduction of aromatic nitro-compounds using tin and concentrated hydrochloric acid to form amines</p>	<ul style="list-style-type: none"> • Amines
<p>2d. describe and carry out, where appropriate, the reaction of aromatic amines with nitrous acid to form benzenediazonium ions followed by a coupling reaction with phenol to form a dye</p>	<ul style="list-style-type: none"> • Amines
<p>2e. recall the synthesis of amides using acyl chlorides</p>	<ul style="list-style-type: none"> • Amines • Acyl Compounds
<p>2f. describe:</p> <ul style="list-style-type: none"> <i>i.</i> condensation polymerization for the formation of polyesters such as terylene and polyamides such as nylon and Kevlar <i>ii.</i> addition polymerization including poly(propenamide) and poly(ethenol) 	<ul style="list-style-type: none"> • Polymers and Amino Acids
<p>2g. draw the structural formulae of the repeat units of the polymers in 5.4.2f</p>	<ul style="list-style-type: none"> • Polymers and Amino Acids
<p>2h. comment on the physical properties of polyamides and the solubility in water of the addition polymer poly(ethenol) in terms of hydrogen bonding, eg soluble laundry bags or liquid detergent capsules (liquitabs)</p>	<ul style="list-style-type: none"> • Polymers and Amino Acids
<p>2i. describe and carry out, where appropriate, experiments to investigate the characteristic behaviour of amino acids. This is limited to:</p> <ul style="list-style-type: none"> <i>i.</i> acidity and basicity and the formation of zwitterions <i>ii.</i> separation and identification by chromatography <i>iii.</i> effect of aqueous solutions on plane-polarised monochromatic light <i>iv.</i> formation of peptide groups in proteins by condensation polymerization <i>v.</i> reaction with ninhydrin. 	<ul style="list-style-type: none"> • Polymers and Amino Acids

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<p>3a. give examples to illustrate the importance of organic synthesis in research for the production of useful products</p>	<ul style="list-style-type: none"> • Organic Synthesis
<p>3b. explain why sensitive methods of chemical analysis are important when planning and monitoring organic syntheses</p>	
<p>3c. deduce the empirical formulae, molecular formulae and structural formulae from data drawn from combustion analysis, elemental percentage composition, characteristic reactions of functional groups, infrared spectra, mass spectra and nuclear magnetic resonance</p>	
<p>3d. use knowledge of organic chemistry contained in this specifications to solve problems such as:</p> <ul style="list-style-type: none"> <i>i.</i> predicting the properties of unfamiliar compounds containing one or more of the functional groups included in the specification, and explain these predictions <i>ii.</i> planning reaction schemes of up to four steps, recalling familiar reactions and using unfamiliar reactions given sufficient information <i>iii.</i> selecting suitable practical procedures for carrying out reactions involving compounds with functional groups included in the specification <i>iv.</i> identifying appropriate control measures to reduce risk during a synthesis based upon data of hazards <i>v.</i> understanding why, in the synthesis of stereo-specific drugs, it is important to understand the mechanism of the reaction and how this can help to plan the synthesis 	<ul style="list-style-type: none"> • Organic Synthesis
<p>3e. explain why the pharmaceutical industry has adopted combinatorial chemistry in drug research, including passing reactants over reagents on polymer supports</p>	

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<p>3f. describe and carry out, where appropriate, the preparation of a compound, eg cholesteryl benzoate (a liquid crystal) and of methyl 3-nitrobenzoate, requiring some of the following techniques:</p> <ul style="list-style-type: none"><i>i.</i> refluxing<i>ii.</i> purification by washing, eg with water and sodium carbonate solution<i>iii.</i> solvent extraction<i>iv.</i> recrystallization<i>v.</i> drying<i>vi.</i> distillation<i>vii.</i> steam distillation<i>viii.</i> melting temperature determination<i>ix.</i> boiling temperature determination.	
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Unit 4. Rings, Polymers and Analysis	
Module 4.1 Rings, Acids and Amines	Boardworks A2 Chemistry presentation title
4.1.1 Arenes: Structure of benzene; Electrophilic substitution of arenes; Phenols	<ul style="list-style-type: none"> • Aromatic Compounds
4.1.2 Carbonyl Compounds: Reactions of carbonyl compounds; Characteristic tests for carbonyl compounds	<ul style="list-style-type: none"> • Carbonyl Compounds
4.1.3 Carboxylic Acids and Esters: Properties of carboxylic acids; Esters, triglycerides, unsaturated and saturated fats	<ul style="list-style-type: none"> • Carbonyl Compounds • Acyl Compounds
4.1.4 Amines: Basicity of amines; Preparation of amines; Synthesis of azo dyes	<ul style="list-style-type: none"> • Amines
Module 4.2 Polymers and Synthesis	Boardworks A2 Chemistry presentation title
4.2.1 Amino Acids and Chirality: Amino acids; Peptide formation and hydrolysis of proteins; Optical isomerism	<ul style="list-style-type: none"> • Polymers and Amino Acids • Organic Synthesis
4.2.2 Polyesters and Polyamides: Condensation polymers; Hydrolysis and degradable polymers	<ul style="list-style-type: none"> • Polymers and Amino Acids
4.2.3 Synthesis: Synthetic routes; Chirality in pharmaceutical synthesis	<ul style="list-style-type: none"> • Polymers and Amino Acids • Organic Synthesis
Module 4.3 Analysis	Boardworks A2 Chemistry presentation title
4.3.1 Chromatography: Types of chromatography; Combining mass spectrometry with chromatography	<ul style="list-style-type: none"> • Structure Determination
4.3.2 Spectroscopy: NMR spectroscopy; Combined techniques	<ul style="list-style-type: none"> • Structure Determination

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Unit 5. Equilibria, Energetics and Elements

Module 5.1 Rates, Equilibrium and pH	Boardworks A2 Chemistry presentation title
5.1.1 How Fast? Rate graphs and orders; Rate equations; rate constants; Rate-determining step	<ul style="list-style-type: none"> • Kinetics
5.1.2 How Far? Equilibrium	<ul style="list-style-type: none"> • Equilibria
5.1.3 Acids, Bases and Buffers: Brønsted–Lowry acids and bases; Strong and weak acids; pH and $[H^+(aq)]$; Buffers: actions, uses and calculations; Neutralisation	<ul style="list-style-type: none"> • Acids and Bases
Module 5.2 Energy	Boardworks A2 Chemistry presentation title
5.2.1 Lattice Enthalpy: Lattice enthalpy; Born–Haber and related enthalpy cycles	<ul style="list-style-type: none"> • Thermodynamics
5.2.2 Enthalpy and Entropy: Entropy; Balance between entropy and enthalpy changes	<ul style="list-style-type: none"> • Thermodynamics
5.2.3 Electrode Potentials and Fuel Cells: Redox; Electrode potentials; Feasibility of reactions; Storage and fuel cells	<ul style="list-style-type: none"> • Redox Reactions and Electrode Potentials • Applications of Redox Chemistry
Module 5.3 Transition Elements	Boardworks A2 Chemistry presentation title
5.3.1 Transition Elements: Properties; Precipitated reactions; Ligands and complex ions; Ligand substitution; Redox reactions and titrations	<ul style="list-style-type: none"> • Introducing Transition Metals • Transition Metals: Colours and Reactions • Uses of Transition Metals