the Content	I have covered this in class?	I have studied this at home?	I have revised this?	I can answer exam questions on this?

1 Physical chemistry (Yr 12)				
1.1 Atomic structure The chemical properties of elements depend on their atomic structure and in particular on the arrangement of electrons around the nucleus. The arrangement of electrons in orbitals is linked to the way in which elements are organised in the Periodic Table. Chemists can measure the mass of atoms and molecules to a high degree of accuracy in a mass spectrometer. The principles of operation of a modern mass spectrometer are studied				
1.1.1 Fundamental particles Appreciate that knowledge and understanding of atomic structure has evolved over time				
Protons, neutrons and electrons: relative charge and relative mass				
An atom consists of a nucleus containing protons and neutrons surrounded by electrons				
1.1.2 Mass number and isotopes Mass number (*A*) and atomic (proton) number (*Z*)				
Students should be able to:				
•• determine the number of fundamental particles in atoms and ions using mass number, atomic number and charge				
•• explain the existence of isotopes				
The principles of a simple time of flight (TOF) mass spectrometer, limited to electrospray ionisation, acceleration to give all ions constant kinetic energy, ion drift, ion detection, data analysis				
The mass spectrometer gives accurate information about relative isotopic mass and also about the relative abundance of isotopes				
Mass spectrometry can be used to identify elements				
Mass spectrometry can be used to determine relative molecular mass				
Students should be able to:				
•• interpret simple mass spectra of elements				
•• calculate relative atomic mass from isotopic abundance, limited to mononuclear ions				
1.1.3 Electron configuration Electron configurations of atoms and ions up to *Z* = 36 in terms of shells and sub-shells (orbitals) s, p and d				
Ionisation energies				
Students should be able to:				
•• define first ionisation energy				

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•• write equations for first and successive ionisation energies				
•• explain how first and successive ionisation energies in Period 3 (Na–Ar) and in Group 2 (Be–Ba) give evidence for electron configuration in sub-shells and in shells				
1.2 Amount of substance When chemists measure out an amount of a substance, they use an amount in moles. The mole is a useful quantity because one mole of a substance always contains the same number of entities of the substance. An amount in moles can be measured out by mass in grams, by volume in dm^3 of a solution of known concentration and by volume in dm^3 of a gas				
1.2.1 Relative atomic mass and relative molecular mass Relative atomic mass and relative molecular mass in terms of ^{12}C				
The term relative formula mass will be used for ionic compounds				
Students should be able to:				
•• define relative atomic mass (A_r)				
•• define relative molecular mass (M_r)				
1.2.2 The mole and the Avogadro constant The Avogadro constant as the number of particles in a mole				
The mole as applied to electrons, atoms, molecules, ions, formulas and equations				
The concentration of a substance in solution, measured in $mol\ dm^{-3}$				
Students should be able to carry out calculations:				
•• using the Avogadro constant				
•• using mass of substance, M_r, and amount in moles				
•• using concentration, volume and amount of substance in a solution				
Students will not be expected to recall the value of the Avogadro constant				
Students understand that calculated results can only be reported to the limits of the least accurate measurement				
1.2.3 The ideal gas equation The ideal gas equation $pV = nRT$ with the variables in SI units				
Students should be able to use the equation in calculations				
Students could be asked to find the M_r of a volatile liquid.				
Students will not be expected to recall the value of the gas constant, R				
1.2.4 Empirical and molecular formula Empirical formula is the simplest whole number ratio of atoms of each element in a compound				

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Molecular formula is the actual number of atoms of each element in a compound				
The relationship between empirical formula and molecular formula				
Students should be able to:				
•• calculate empirical formula from data giving composition by mass or percentage by mass				
•• calculate molecular formula from the empirical formula and relative molecular mass				
Students could be asked to find the empirical formula of a metal oxide.				
1.2.5 Balanced equations and associated calculations Equations (full and ionic)				
Percentage atom economy is: $\frac{\text{molecular mass of desired product}}{\text{sum of molecular masses of all reactants}} \times 100$				
Economic, ethical and environmental advantages for society and for industry of developing chemical processes with a high atom economy				
Students should be able to:				
•• write balanced equations for reactions studied				
•• balance equations for unfamiliar reactions when reactants and products are specified				
Students should be able to use balanced equations to calculate:				
•• masses				
•• volumes of gases				
•• percentage yields				
•• percentage atom economies				
•• concentrations and volumes for reactions in solutions				
Students could be asked to find:				
•• the concentration of ethanoic acid in vinegar				
•• the mass of calcium carbonate in an indigestion tablet				
•• the M_r of $MHCO_3$				
•• the M_r of succinic acid				
•• the mass of aspirin in an aspirin tablet				
•• the yield for the conversion of magnesium to magnesium oxide				
•• the M_r of a hydrated salt (eg magnesium sulfate) by heating to constant mass				
could be asked to find the percentage conversion of a Group 2 carbonate to its oxide by heat				
Students could be asked to determine the number of moles of water of crystallisation in a hydrated salt by titration				
Required practical 1				

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Make up a volumetric solution and carry out a simple acid–base titration				
1.3 Bonding The physical and chemical properties of compounds depend on the ways in which the compounds are held together by chemical bonds and by intermolecular forces. Theories of bonding explain how atoms or ions are held together in these structures. Materials scientists use knowledge of structure and bonding to engineer new materials with desirable properties. These new materials may offer new applications in a range of different modern technologies				
1.3.1 Ionic bonding Ionic bonding involves electrostatic attraction between oppositely charged ions in a lattice				
The formulas of compound ions eg sulfate, hydroxide, nitrate, carbonate and ammonium				
Students should be able to:				
•• predict the charge on a simple ion using the position of the element in the Periodic Table				
•• construct formulas for ionic compounds				
1.3.2 Nature of covalent and dative covalent bonds A single covalent bond contains a shared pair of electrons				
Multiple bonds contain multiple pairs of electrons				
A co-ordinate (dative covalent) bond contains a shared pair of electrons with both electrons supplied by one atom				
Students should be able to represent:				
•• a covalent bond using a line				
•• a co-ordinate bond using an arrow				
1.3.3 Metallic bonding Metallic bonding involves attraction between delocalised electrons and positive ions arranged in a lattice				
1.3.4 Bonding and physical properties The four types of crystal structure:				
•• ionic				
•• metallic				
•• macromolecular (giant covalent)				
•• molecular				
The structures of the following crystals as examples of these four types of crystal structure:				
•• diamond				
•• graphite				
•• ice				
•• iodine				
•• magnesium				

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•• sodium chloride				
Students should be able to:				
•• relate the melting point and conductivity of materials to the type of structure and the bonding present				
•• explain the energy changes associated with changes of state				
•• draw diagrams to represent these structures involving specified numbers of particles				
Students could be asked to find the type of structure of unknowns by experiment (eg to test solubility, conductivity and ease of melting)				
1.3.5 Shapes of simple molecules and ions Bonding pairs and lone (non-bonding) pairs of electrons as charge clouds that repel each other				
Pairs of electrons in the outer shell of atoms arrange themselves as far apart as possible to minimise repulsion				
Lone pair–lone pair repulsion is greater than lone pair–bond pair repulsion, which is greater than bond pair–bond pair repulsion				
The effect of electron pair repulsion on bond angles				
Students should be able to explain the shapes of, and bond angles in, simple molecules and ions with up to six electron pairs (including lone pairs of electrons) surrounding the central atom				
Students could be given familiar and unfamiliar examples of species and asked to deduce the shape according to valence shell electron pair repulsion (VSEPR) principles				
1.3.6 Bond polarity Electronegativity as the power of an atom to attract the pair of electrons in a covalent bond				
The electron distribution in a covalent bond between elements with different electronegativities will be unsymmetrical. This produces a polar covalent bond, and may cause a molecule to have a permanent dipole				
Students should be able to:				
•• use partial charges to show that a bond is polar				
•• explain why some molecules with polar bonds do not have a permanent dipole				
1.3.7 Forces between molecules Forces between molecules:				
•• permanent dipole–dipole forces				
•• induced dipole–dipole (van der Waals, dispersion, London) forces				
•• hydrogen bonding				
The melting and boiling points of molecular substances are influenced by the strength of these intermolecular forces				

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The importance of hydrogen bonding in the low density of ice and the anomalous boiling points of compounds				
Students should be able to:				
•• explain the existence of these forces between familiar and unfamiliar molecules				
•• explain how melting and boiling points are influenced by these intermolecular forces				
Students could try to deflect jets of various liquids from burettes to investigate the presence of different types and relative size of intermolecular forces				
1.4 Energetics The enthalpy change in a chemical reaction can be measured accurately. It is important to know this value for chemical reactions that are used as a source of heat energy in applications such as domestic boilers and internal combustion engines				
1.4.1 Enthalpy change Reactions can be endothermic or exothermic				
Enthalpy change (ΔH) is the heat energy change measured under conditions of constant pressure				
Standard enthalpy changes refer to standard conditions ie 100 kPa and a stated temperature (eg $\Delta H_{298}{}^{\ominus}$)				
Students should be able to:				
•• define standard enthalpy of combustion ($\Delta_c H^{\ominus}$)				
•• define standard enthalpy of formation ($\Delta_f H^{\ominus}$)				
1.4.2 Calorimetry The heat change, q, in a reaction is given by the equation $q = mc\Delta T$ where m is the mass of the substance that has a temperature change ΔT and a specific heat capacity c				
Students should be able to:				
•• use this equation to calculate the molar enthalpy change for a reaction				
•• use this equation in related calculations				
Students will not be expected to recall the value of the specific heat capacity, c, of a substance				
Required practical 2 Measurement of an enthalpy change				
Students could be asked to find ΔH for a reaction by calorimetry. Examples of reactions could include:				
•• dissolution of potassium chloride				
•• dissolution of sodium carbonate				
•• neutralising NaOH with HCl				
•• displacement reaction between $CuSO_4$ + Zn				
•• combustion of alcohols				
1.4.3 Applications of Hess's law Hess's law				

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Students should be able to use Hess’s law to perform calculations, including calculation of enthalpy changes for reactions from enthalpies of combustion or from enthalpies of formation				
Students could be asked to find ΔH for a reaction using Hess’s law and calorimetry, then present data in appropriate ways. Examples of reactions could include:				
•• thermal decomposition of $NaHCO_3$				
•• hydration of $MgSO_4$				
•• hydration of $CuSO_4$				
1.4.4 Bond enthalpies Mean bond enthalpy				
Students should be able to:				
•• define the term mean bond enthalpy				
•• use mean bond enthalpies to calculate an approximate value of ΔH for reactions in the gaseous phase				
•• explain why values from mean bond enthalpy calculations differ from those determined using Hess’s law				
Students understand that bond enthalpies are mean values across a range of compounds containing that bond				
3.1.5 Kinetics The study of kinetics enables chemists to determine how a change in conditions affects the speed of a chemical reaction. Whilst the reactivity of chemicals is a significant factor in how fast chemical reactions proceed, there are variables that can be manipulated in order to speed them up or slow them down				
1.5.1 Collision theory Reactions can only occur when collisions take place between particles having sufficient energy				
This energy is called the activation energy				
Students should be able to:				
•• define the term activation energy				
•• explain why most collisions do not lead to a reaction				
1.5.2 Maxwell–Boltzmann distribution Maxwell–Boltzmann distribution of molecular energies in gases				
Students should be able to draw and interpret distribution curves for different temperatures				
1.5.3 Effect of temperature on reaction rate Meaning of the term rate of reaction				
The qualitative effect of temperature changes on the rate of reaction				

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Students should be able to use the Maxwell–Boltzmann distribution to explain why a small temperature increase can lead to a large increase in rate				
Students could investigate the effect of temperature on the rate of reaction of sodium thiosulfate and hydrochloric acid by an initial rate method				
Students could investigate how knowledge and understanding of the factors that affect the rate of chemical reaction have changed methods of storage and cooking of food				
Required practical 3 Investigation of how the rate of a reaction changes with temperature				
1.5.4 Effect of concentration and pressure The qualitative effect of changes in concentration on collision frequency				
The qualitative effect of a change in the pressure of a gas on collision frequency				
Students should be able to explain how a change in concentration or a change in pressure influences the rate of a reaction				
Students could investigate the effect of changing the concentration of acid on the rate of a reaction of calcium carbonate and hydrochloric acid by a continuous monitoring method				
1.5.5 Catalysts A catalyst is a substance that increases the rate of a chemical reaction without being changed in chemical composition or amount				
Catalysts work by providing an alternative reaction route of lower activation energy				
Students should be able to use a Maxwell–Boltzmann distribution to help explain how a catalyst increases the rate of a reaction involving a gas				
1.6 Chemical equilibria, Le Chatelier's principle and K_c In contrast with kinetics, which is a study of how quickly reactions occur, a study of equilibria indicates how far reactions will go. Le Chatelier's principle can be used to predict the effects of changes in temperature, pressure and concentration on the yield of a reversible reaction. This has important consequences for many industrial processes. The further study of the equilibrium constant, K_c, considers how the mathematical expression for the equilibrium constant enables us to calculate how an equilibrium yield will be influenced by the concentration of reactants and products				

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1.6.1 Chemical equilibria and Le Chatelier's principle Many chemical reactions are reversible				
In a reversible reaction at equilibrium:				
•• forward and reverse reactions proceed at equal rates				
•• the concentrations of reactants and products remain constant				
Le Chatelier's principle				
Le Chatelier's principle can be used to predict the effects of changes in temperature, pressure and concentration on the position of equilibrium in homogeneous reactions				
A catalyst does not affect the position of equilibrium				
Students should be able to:				
•• use Le Chatelier's principle to predict qualitatively the effect of changes in temperature, pressure and concentration on the position of equilibrium				
•• explain why, for a reversible reaction used in an industrial process, a compromise temperature and pressure may be used				
Students could carry out test-tube equilibrium shifts to show the effect of concentration and temperature (eg $Cu(H_2O)_6^{2+}$ with concentrated HCl)				
1.6.2 Equilibrium constant K_c for homogeneous systems The equilibrium constant K_c is deduced from the equation for a reversible reaction				
The concentration, in mol dm^{-3}, of a species X involved in the expression for K_c is represented by [X] The value of the equilibrium constant is not affected either by changes in concentration or addition of a catalyst				
Students should be able to:				
•• construct an expression for K_c for a homogeneous system in equilibrium				
•• calculate a value for K_c from the equilibrium concentrations for a homogeneous system at constant temperature				
•• perform calculations involving K_c				
•• predict the qualitative effects of changes of temperature on the value of K_c MS 0.3 Students estimate the effect of changing experimental parameters on a measurable value eg how the value of K_c would change with temperature, given different specified conditions				
Students calculate the concentration of a reagent at equilibrium				
Students calculate the value of an equilibrium constant K_c				

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Students could determine the equilibrium constant, K_c, for the reaction of ethanol with ethanoic acid in the presence of a strong acid catalyst to ethyl ethanoate				
1.7 Oxidation, reduction and redox equations Redox reactions involve a transfer of electrons from the reducing agent to the oxidising agent. The change in the oxidation state of an element in a compound or ion is used to identify the element that has been oxidised or reduced in a given reaction. Separate half-equations are written for the oxidation or reduction processes. These half-equations can then be combined to give an overall equation for any redox reaction				
Oxidation is the process of electron loss and oxidising agents are electron acceptors				
Reduction is the process of electron gain and reducing agents are electron donors				
The rules for assigning oxidation states				
Students should be able to:				
•• work out the oxidation state of an element in a compound or ion from the formula				
•• write half-equations identifying the oxidation and reduction processes in redox reactions				
•• combine half-equations to give an overall redox equation				

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2 Inorganic chemistry (Yr 12)				
2.1 Periodicity The Periodic Table provides chemists with a structured organisation of the known chemical elements from which they can make sense of their physical and chemical properties. The historical development of the Periodic Table and models of atomic structure provide good examples of how scientific ideas and explanations develop over time				
2.1.1 Classification An element is classified as s, p, d or f block according to its position in the Periodic Table, which is determined by its proton number				
2.1.2 Physical properties of Period 3 elements The trends in atomic radius, first ionisation energy and melting point of the elements Na–Ar The reasons for these trends in terms of the structure of and bonding in the elements				
Students should be able to:				
•• explain the trends in atomic radius and first ionisation energy				
•• explain the melting point of the elements in terms of their structure and bonding				
2.2 Group 2, the alkaline earth metals The elements in Group 2 are called the alkaline earth metals. The trends in the solubilities of the hydroxides and the sulfates of these elements are linked to their use. Barium sulfate, magnesium hydroxide and magnesium sulfate have applications in medicines whilst calcium hydroxide is used in agriculture to change soil pH, which is essential for good crop production and maintaining the food supply				
The trends in atomic radius, first ionisation energy and melting point of the elements Mg–Ba Students should be able to:				
•• explain the trends in atomic radius and first ionisation energy				
•• explain the melting point of the elements in terms of their structure and bonding				
The reactions of the elements Mg–Ba with water				
The use of magnesium in the extraction of titanium from $TiCl_4$ The relative solubilities of the hydroxides of the elements Mg–Ba in water				
$Mg(OH)_2$ is sparingly soluble				
The use of $Mg(OH)_2$ in medicine and of $Ca(OH)_2$ in agriculture				
The use of CaO or $CaCO_3$ to remove SO_2 from flue gases				

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The relative solubilities of the sulfates of the elements Mg–Ba in water				
$BaSO_4$ is insoluble				
The use of acidified $BaCl_2$ solution to test for sulfate ions				
The use of $BaSO_4$ in medicine				
Students should be able to explain why $BaCl_2$ solution is used to test for sulfate ions and why it is acidified				
Students could test the reactions of Mg–Ba with water and Mg with steam and record their results				
Students could test the solubility of Group 2 hydroxides by mixing solutions of soluble Group 2 salts with sodium hydroxide and record their results				
Students could test the solubility of Group 2 sulfates by mixing solutions of soluble Group 2 salts with sulfuric acid and record their results				
Students could test for sulfate ions using acidified barium chloride and record their results				
Students could investigate the use of $BaSO_4$ in medicine				
2.3 Group 7(17), the halogens The halogens in Group 7 are very reactive non-metals. Trends in their physical properties are examined and explained. Fluorine is too dangerous to be used in a school laboratory but the reactions of chlorine are studied. Challenges in studying the properties of elements in this group include explaining the trends in ability of the halogens to behave as oxidising agents and the halide ions to behave as reducing agents				
2.3.1 Trends in properties The trends in electronegativity and boiling point of the halogens				
Students should be able to:				
•• explain the trend in electronegativity				
•• explain the trend in the boiling point of the elements in terms of their structure and bonding				
The trend in oxidising ability of the halogens down the group, including displacement reactions of halide ions in aqueous solution				
The trend in reducing ability of the halide ions, including the reactions of solid sodium halides with concentrated sulfuric acid				
The use of acidified silver nitrate solution to identify and distinguish between halide ions				
The trend in solubility of the silver halides in ammonia				
Students should be able to explain why:				
•• silver nitrate solution is used to identify halide ions				
•• the silver nitrate solution is acidified				
•• ammonia solution is added				

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Students could carry out test-tube reactions of solutions of the halogens (Cl_2, Br_2, I_2) with solutions containing their halide ions (eg KCl, KBr, KI)				
Students could record observations from reactions of NaCl, NaBr and NaI with concentrated sulfuric acid				
Students could carry out tests for halide ions using acidified silver nitrate, including the use of ammonia to distinguish the silver halides formed				
2.3.2 Uses of chlorine and chlorate(I) The reaction of chlorine with water to form chloride ions and chlorate(I) ions				
The reaction of chlorine with water to form chloride ions and oxygen				
Appreciate that society assesses the advantages and disadvantages when deciding if chemicals should be added to water supplies				
The use of chlorine in water treatment				
Appreciate that the benefits to health of water treatment by chlorine outweigh its toxic effects				
The reaction of chlorine with cold, dilute, aqueous NaOH and uses of the solution formed				
Students could investigate the treatment of drinking water with chlorine				
Students could investigate the addition of sodium fluoride to water supplies				
Required practical 4 Carry out simple test-tube reactions to identify:				
•• cations – Group 2, NH_4^+				
•• anions – Group 7 (halide ions), OH^-, CO_3^{2-}, SO_4^{2-}				

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3 Organic chemistry (Yr 12)				
3.1 Introduction to organic chemistry Organic chemistry is the study of the millions of covalent compounds of the element carbon These structurally diverse compounds vary from naturally occurring petroleum fuels to DNA and the molecules in living systems. Organic compounds also demonstrate human ingenuity in the vast range of synthetic materials created by chemists. Many of these compounds are used as drugs, medicines and plastics Organic compounds are named using the International Union of Pure and Applied Chemistry (IUPAC) system and the structure or formula of molecules can be represented in various different ways. Organic mechanisms are studied, which enable reactions to be explained In the search for sustainable chemistry, for safer agrochemicals and for new materials to match the desire for new technology, chemistry plays the dominant role				
3.1.1 Nomenclature Organic compounds can be represented by:				
•• empirical formula				
•• molecular formula				
•• general formula				
•• structural formula				
•• displayed formula				
•• skeletal formula				
The characteristics of a homologous series, a series of compounds containing the same functional group				
IUPAC rules for nomenclature				
Students should be able to:				
•• draw structural, displayed and skeletal formulas for given organic compounds				
•• apply IUPAC rules for nomenclature to name organic compounds limited to chains and rings with up to six carbon atoms each				
•• apply IUPAC rules for nomenclature to draw the structure of an organic compound from the IUPAC name limited to chains and rings with up to six carbon atoms each				
3.1.2 Reaction mechanisms Reactions of organic compounds can be explained using mechanisms				
Free-radical mechanisms:				
•• the unpaired electron in a radical is represented by a dot				
•• the use of curly arrows is not required for radical mechanisms				

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Students should be able to write balanced equations for the steps in a free-radical mechanism				
Other mechanisms:				
•• the formation of a covalent bond is shown by a curly arrow that starts from a lone electron pair or from another covalent bond				
•• the breaking of a covalent bond is shown by a curly arrow starting from the bond				
Students should be able to outline mechanisms by drawing the structures of the species involved and curly arrows to represent the movement of electron pairs				
3.1.3 Isomerism Structural isomerism				
Stereoisomerism				
E–*Z* isomerism is a form of stereoisomerism and occurs as a result of restricted rotation about the planar carbon– carbon double bond				
Cahn–Ingold–Prelog (CIP) priority rules				
Students should be able to:				
•• define the term structural isomer				
•• draw the structures of chain, position and functional group isomers				
•• define the term stereoisomer				
•• draw the structural formulas of *E* and *Z* isomers				
•• apply the CIP priority rules to *E* and *Z* isomers				
Students could be given the structure of one isomer and asked to draw further isomers. Various representations could be used to give the opportunity to identify those that are isomeric				
Students understand the origin of *E*–*Z* isomerism				
Students draw different forms of isomers				
3.2 Alkanes Alkanes are the main constituent of crude oil, which is an important raw material for the chemical industry. Alkanes are also used as fuels and the environmental consequences of this use are considered in this section				
3.2.1 Fractional distillation of crude oil Alkanes are saturated hydrocarbons				
Petroleum is a mixture consisting mainly of alkane hydrocarbons that can be separated by fractional distillation				
Fractional distillation of a crude oil substitute				
3.2.2 Modification of alkanes by cracking Cracking involves breaking C–C bonds in alkanes				

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Thermal cracking takes place at high pressure and high temperature and produces a high percentage of alkenes (mechanism not required)				
Catalytic cracking takes place at a slight pressure, high temperature and in the presence of a zeolite catalyst and is used mainly to produce motor fuels and aromatic hydrocarbons (mechanism not required)				
Students should be able to explain the economic reasons for cracking alkanes				
3.2.3 Combustion of alkanes Alkanes are used as fuels				
Combustion of alkanes and other organic compounds can be complete or incomplete				
The internal combustion engine produces a number of pollutants including NO_x, CO, carbon and unburned hydrocarbons				
These gaseous pollutants from internal combustion engines can be removed using catalytic converters				
Combustion of hydrocarbons containing sulfur leads to sulfur dioxide that causes air pollution				
Students should be able to explain why sulfur dioxide can be removed from flue gases using calcium oxide or calcium carbonate				
3.2.4 Chlorination of alkanes The reaction of methane with chlorine				
Students should be able to explain this reaction as a free-radical substitution mechanism involving initiation, propagation and termination steps				
3.3 Halogenoalkanes Halogenoalkanes are much more reactive than alkanes. They have many uses, including as refrigerants, as solvents and in pharmaceuticals. The use of some halogenoalkanes has been restricted due to the effect of chlorofluorocarbons (CFCs) on the atmosphere				
3.3.1 Nucleophilic substitution Halogenoalkanes contain polar bonds				
Halogenoalkanes undergo substitution reactions with the nucleophiles OH^-, CN^- and NH_3 Students should be able to:				
•• outline the nucleophilic substitution mechanisms of these reactions				
•• explain why the carbon–halogen bond enthalpy influences the rate of reaction				
Students could follow instructions when carrying out test-tube hydrolysis of halogenoalkanes to show their relative rates of reaction				

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Students could prepare a chloroalkane, purifying the product using a separating funnel and distillation				
3.3.2 Elimination The concurrent substitution and elimination reactions of a halogenoalkane (eg 2-bromopropane with potassium hydroxide)				
Students should be able to:				
•• explain the role of the reagent as both nucleophile and base				
•• outline the mechanisms of these reactions				
3.3.3 Ozone depletion Ozone, formed naturally in the upper atmosphere, is beneficial because it absorbs ultraviolet radiation				
Chlorine atoms are formed in the upper atmosphere when ultraviolet radiation causes C–Cl bonds in chlorofluorocarbons (CFCs) to break				
Chlorine atoms catalyse the decomposition of ozone and contribute to the hole in the ozone layer				
Appreciate that results of research by different groups in the scientific community provided evidence for legislation to ban the use of CFCs as solvents and refrigerants. Chemists have now developed alternative chlorine-free compounds				
Students should be able to use equations, such as the following, to explain how chlorine atoms catalyse decomposition of ozone: $Cl\bullet + O_3 \rightarrow ClO\bullet + O_2$ and $ClO\bullet + O_3 \rightarrow 2O_2 + Cl\bullet$				
Students could investigate the role of chemists in the introduction of legislation to ban the use of CFCs and in finding replacements				
3.4 Alkenes In alkenes, the high electron density of the carbon–carbon double bond leads to attack on these molecules by electrophiles. This section also covers the mechanism of addition to the double bond and introduces addition polymers, which are commercially important and have many uses in modern society				
3.4.1 Structure, bonding and reactivity Alkenes are unsaturated hydrocarbons				
Bonding in alkenes involves a double covalent bond, a centre of high electron density				
3.4.2 Addition reactions of alkenes Electrophilic addition reactions of alkenes with HBr, H_2SO_4 and Br_2 The use of bromine to test for unsaturation				
The formation of major and minor products in addition reactions of unsymmetrical alkenes				
Students should be able to:				

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•• outline the mechanisms for these reactions				
•• explain the formation of major and minor products by reference to the relative stabilities of primary, secondary and tertiary carbocation intermediates				
Students could test organic compounds for unsaturation using bromine water and record their observations				
3.4.3 Addition polymers Addition polymers are formed from alkenes and substituted alkenes				
The repeating unit of addition polymers				
IUPAC rules for naming addition polymers				
Addition polymers are unreactive				
Appreciate that knowledge and understanding of the production and properties of polymers has developed over time				
Typical uses of poly(chloroethene), commonly known as PVC, and how its properties can be modified using a plasticiser				
Students should be able to:				
•• draw the repeating unit from a monomer structure				
•• draw the repeating unit from a section of the polymer chain				
•• draw the structure of the monomer from a section of the polymer				
•• explain why addition polymers are unreactive				
•• explain the nature of intermolecular forces between molecules of polyalkenes				
Making poly(phenylethene) from phenylethene				
3.3.5 Alcohols Alcohols have many scientific, medicinal and industrial uses. Ethanol is one such alcohol and it is produced using different methods, which are considered in this section. Ethanol can be used as a biofuel				
3.5.1 Alcohol production Alcohols are produced industrially by hydration of alkenes in the presence of an acid catalyst				
Ethanol is produced industrially by fermentation of glucose				
The conditions for this process				
Ethanol produced industrially by fermentation is separated by fractional distillation and can then be used as a biofuel				
Students should be able to:				
•• explain the meaning of the term biofuel				
•• justify the conditions used in the production of ethanol by fermentation of glucose				

the Content	I have covered this in class?	I have studied this at home?	I have revised this?	I can answer exam questions on this?
•• write equations to support the statement that ethanol produced by fermentation is a carbon-neutral fuel and give reasons why this statement is not valid				
•• outline the mechanism for the formation of an alcohol by the reaction of an alkene with steam in the presence of an acid catalyst				
•• discuss the environmental (including ethical) issues linked to decision making about biofuel use				
Students could produce ethanol by fermentation, followed by purification by fractional distillation				
3.5.2 Oxidation of alcohols Alcohols are classified as primary, secondary and tertiary				
Primary alcohols can be oxidised to aldehydes which can be further oxidised to carboxylic acids				
Secondary alcohols can be oxidised to ketones				
Tertiary alcohols are not easily oxidised				
Acidified potassium dichromate(VI) is a suitable oxidising agent				
Students should be able to:				
•• write equations for these oxidation reactions (equations showing [O] as oxidant are acceptable)				
•• explain how the method used to oxidise a primary alcohol determines whether an aldehyde or carboxylic acid is obtained				
•• use chemical tests to distinguish between aldehydes and ketones including Fehling's solution and Tollens' reagent				
Students could carry out the preparation of an aldehyde by the oxidation of a primary alcohol				
Students could carry out the preparation of a carboxylic acid by the oxidation of a primary alcohol				
3.5.3 Elimination Alkenes can be formed from alcohols by acid-catalysed elimination reactions				
Alkenes produced by this method can be used to produce addition polymers without using monomers derived from crude oil				
Students should be able to outline the mechanism for the elimination of water from alcohols				
Students could carry out the preparation of cyclohexene from cyclohexanol, including purification using a separating funnel and by distillation				
Required practical 5 Distillation of a product from a reaction				

the Content	I have covered this in class?	I have studied this at home?	I have revised this?	I can answer exam questions on this?
3.6 Organic analysis Our understanding of organic molecules, their structure and the way they react, has been enhanced by organic analysis. This section considers some of the analytical techniques used by chemists, including test-tube reactions and spectroscopic techniques				
3.6.1 Identification of functional groups by test-tube reactions The reactions of functional groups listed in the specification				
Students should be able to identify the functional groups using reactions in the specification				
Students could carry out test-tube reactions in the specification to distinguish alcohols, aldehydes, alkenes and carboxylic acids				
Required practical 6 Tests for alcohol, aldehyde, alkene and carboxylic acid				
3.6.2 Mass spectrometry Mass spectrometry can be used to determine the molecular formula of a compound				
Students should be able to use precise atomic masses and the precise molecular mass to determine the molecular formula of a compound				
3.6.3 Infrared spectroscopy Bonds in a molecule absorb infrared radiation at characteristic wavenumbers				
'Fingerprinting' allows identification of a molecule by comparison of spectra				
Students should be able to:				
•• use infrared spectra and the Chemistry Data Sheet or Booklet to identify particular bonds, and therefore functional groups, and also to identify impurities				
The link between absorption of infrared radiation by bonds in CO_2, methane and water vapour and global warming				
Students should be able to use data in the Chemistry Data Sheet or Booklet to suggest possible structures for molecules				

the Content	I have covered this in class?	I have studied this at home?	I have revised this?	I can answer exam questions on this?

4 Physical chemistry (Yr 13)				
1.8 Thermodynamics The further study of thermodynamics builds on the Energetics section and is important in understanding the stability of compounds and why chemical reactions occur. Enthalpy change is linked with entropy change enabling the free-energy change to be calculated				
1.8.1 Born–Haber cycles Lattice enthalpy can be defined as either enthalpy of lattice dissociation or enthalpy of lattice formation				
Born–Haber cycles are used to calculate lattice enthalpies using the following data:				
•• enthalpy of formation				
•• ionisation energy				
•• enthalpy of atomisation				
•• bond enthalpy				
•• electron affinity				
Students should be able to:				
•• define each of the above terms and lattice enthalpy				
•• construct Born–Haber cycles to calculate lattice enthalpies using these enthalpy changes				
•• construct Born–Haber cycles to calculate one of the other enthalpy changes				
•• compare lattice enthalpies from Born–Haber cycles with those from calculations based on a perfect ionic model to provide evidence for covalent character in ionic compounds				
Cycles are used to calculate enthalpies of solution for ionic compounds from lattice enthalpies and enthalpies of hydration				
Students should be able to:				
•• define the term enthalpy of hydration				
•• perform calculations of an enthalpy change using these cycles				
1.8.2 Gibbs free-energy change, ΔG, and entropy change, ΔS ΔH, whilst important, is not sufficient to explain feasible change				
The concept of increasing disorder (entropy change, ΔS)				
ΔS accounts for the above deficiency, illustrated by physical changes and chemical changes				
The balance between entropy and enthalpy determines the feasibility of a reaction given by the relationship: $\Delta G = \Delta H - T\Delta S$ (derivation not required)				

the Content	I have covered this in class?	I have studied this at home?	I have revised this?	I can answer exam questions on this?
For a reaction to be feasible, the value of ΔG must be zero or negative				
Students should be able to:				
•• calculate entropy changes from absolute entropy values				
•• use the relationship $\Delta G = \Delta H - T\Delta S$ to determine how ΔG varies with temperature				
•• use the relationship $\Delta G = \Delta H - T\Delta S$ to determine the temperature at which a reaction becomes feasible				
Students could be asked to find ΔS for vaporization of water using a kettle				
Students rearrange the equation $\Delta G = \Delta H - T\Delta S$ to find unknown values				
Students determine ΔS and ΔH from a graph of ΔG versus T				
1.9 Rate equations In rate equations, the mathematical relationship between rate of reaction and concentration gives information about the mechanism of a reaction that may occur in several steps				
1.9.1 Rate equations The rate of a chemical reaction is related to the concentration of reactants by a rate equation of the form: $Rate = k[\mathrm{A}]^m[\mathrm{B}]^n$ where m and n are the orders of reaction with respect to reactants A and B and k is the rate constant				
The orders m and n are restricted to the values 0, 1, and 2				
The rate constant k varies with temperature as shown by the equation: $k = \mathrm{A}e^{-Ea/RT}$ where A is a constant, known as the Arrhenius constant, E_a is the activation energy and T is the temperature in K				
Students should be able to:				
•• define the terms order of reaction and rate constant				
•• perform calculations using the rate equation				
•• explain the qualitative effect of changes in temperature on the rate constant k				
•• perform calculations using the equation $k = \mathrm{A}e^{-Ea/RT}$				
•• understand that the equation $k = \mathrm{A}e^{-Ea/RT}$ can be rearranged into the form $\ln k = -E_a/RT + \ln \mathrm{A}$ and know how to use this rearranged equation with experimental data to plot a straight line graph with slope $-E_a/R$ These equations and the gas constant, R, will be given when required				
Students use given rate data and deduce a rate equation, then use some of the data to calculate the rate constant including units. Rate equations could be given and students asked to calculate rate constant or rate				
Students use a graph of concentration–time and calculate the rate constant of a zero-order reaction by determination of the gradient				

the Content	I have covered this in class?	I have studied this at home?	I have revised this?	I can answer exam questions on this?
1.9.2 Determination of rate equation The rate equation is an experimentally determined relationship				
The orders with respect to reactants can provide information about the mechanism of a reaction				
Students should be able to:				
•• use concentration–time graphs to deduce the rate of a reaction				
•• use initial concentration–time data to deduce the initial rate of a reaction				
•• use rate–concentration data or graphs to deduce the order (0, 1 or 2) with respect to a reactant				
•• derive the rate equation for a reaction from the orders with respect to each of the reactants				
•• use the orders with respect to reactants to provide information about the rate determining/limiting step of a reaction				
Students could determine the order of reaction for a reactant in the iodine clock reaction				
Students could be given data to plot and interpret in terms of order with respect to a reactant. Alternatively, students could just be given appropriate graphs and asked to derive order(s)				
Students calculate the rate constant of a zero-order reaction by determining the gradient of a concentration–time graph				
Students plot concentration–time graphs from collected or supplied data and draw an appropriate best-fit curve				
Students draw tangents to such curves to deduce rates at different times				
Required practical 7 Measuring the rate of reaction:				
•• by an initial rate method				
•• by a continuous monitoring method				
1.10 Equilibrium constant K_p for homogeneous systems The further study of equilibria considers how the mathematical expression for the equilibrium constant K_p enables us to calculate how an equilibrium yield will be influenced by the partial pressures of reactants and products. This has important consequences for many industrial processes				
The equilibrium constant K_p is deduced from the equation for a reversible reaction occurring in the gas phase				

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K_p is the equilibrium constant calculated from partial pressures for a system at constant temperature				
Students should be able to:				
•• derive partial pressure from mole fraction and total pressure				
•• construct an expression for K_p for a homogeneous system in equilibrium				
•• perform calculations involving K_p				
•• predict the qualitative effects of changes in temperature and pressure on the position of equilibrium				
•• predict the qualitative effects of changes in temperature on the value of K_p				
•• understand that, whilst a catalyst can affect the rate of attainment of an equilibrium, it does not affect the value of the equilibrium constant				
Students calculate the partial pressures of reactants and products at equilibrium				
Students calculate the value of an equilibrium constant K_p				
1.11 Electrode potentials and electrochemical cells Redox reactions take place in electrochemical cells where electrons are transferred from the reducing agent to the oxidising agent indirectly via an external circuit. A potential difference is created that can drive an electric current to do work. Electrochemical cells have very important commercial applications as a portable supply of electricity to power electronic devices such as mobile phones, tablets and laptops. On a larger scale, they can provide energy to power a vehicle				
1.11.1 Electrode potentials and cells IUPAC convention for writing half-equations for electrode reactions				
The conventional representation of cells				
Cells are used to measure electrode potentials by reference to the standard hydrogen electrode				
The importance of the conditions when measuring the electrode potential, E (Nernst equation not required)				
Standard electrode potential, $E^\ominus$, refers to conditions of 298 K, 100 kPa and 1.00 mol dm^{-3} solution of ions				
Standard electrode potentials can be listed as an electrochemical series				
Students should be able to:				
•• use $E^\ominus$ values to predict the direction of simple redox reactions				
•• calculate the EMF of a cell				
•• write and apply the conventional representation of a cell				

the Content	I have covered this in class?	I have studied this at home?	I have revised this?	I can answer exam questions on this?

Students could make simple cells and use them to measure unknown electrode potentials				
Students could be asked to plan and carry out an experiment to investigate the effect of changing conditions, such as concentration or temperature, in a voltaic cell such as $Zn|Zn^{2+}||Cu^{2+}|Cu$ AT				
Students could use $E^{\ominus}$ values to predict the direction of simple redox reactions, then test these predictions by simple test-tube reactions				
Required practical 8 Measuring the EMF of an electrochemical cell				
1.11.2 Commercial applications of electrochemical cells Electrochemical cells can be used as a commercial source of electrical energy				
The simplified electrode reactions in a lithium cell: Positive electrode: $Li^+ + CoO^2 + e^- \rightarrow Li^+[CoO^2]^-$ Negative electrode: $Li \rightarrow Li^+ + e^-$				
Cells can be non-rechargeable (irreversible), rechargeable or fuel cells				
Fuel cells are used to generate an electric current and do not need to be electrically recharged				
The electrode reactions in an alkaline hydrogen–oxygen fuel cell				
The benefits and risks to society associated with using these cells				
Students should be able to:				
•• use given electrode data to deduce the reactions occurring in non-rechargeable and rechargeable cells				
•• deduce the EMF of a cell				
•• explain how the electrode reactions can be used to generate an electric current				
Students could investigate how knowledge and understanding of electrochemical cells has evolved from the first voltaic battery				
1.12 Acids and bases Acids and bases are important in domestic, environmental and industrial contexts. Acidity in aqueous solutions is caused by hydrogen ions and a logarithmic scale, pH, has been devised to measure acidity				
Buffer solutions, which can be made from partially neutralised weak acids, resist changes in pH and find many important industrial and biological applications				
1.12.1 Brønsted–Lowry acid–base equilibria in aqueous solution An acid is a proton donor				

the Content	I have covered this in class?	I have studied this at home?	I have revised this?	I can answer exam questions on this?
A base is a proton acceptor				
Acid–base equilibria involve the transfer of protons				
1.12.2 Definition and determination of pH The concentration of hydrogen ions in aqueous solution covers a very wide range. Therefore, a logarithmic scale, the pH scale, is used as a measure of hydrogen ion concentration				
$\text{pH} = -\log_{10}[H^+]$ Students should be able to:				
•• convert concentration of hydrogen ions into pH and vice versa				
•• calculate the pH of a solution of a strong acid from its concentration				
Students carry out pH calculations				
Students could be given concentration values and asked to calculate pH or vice versa				
3.1.12.3 The ionic product of water, K_W Water is slightly dissociated				
K_W is derived from the equilibrium constant for this dissociation				
$K_W = [H^+][OH^-]$ The value of K_W varies with temperature				
Students should be able to use K_W to calculate the pH of a strong base from its concentration				
Students use an appropriate number of decimal places in pH calculations				
Students understand standard form when applied to areas such as (but not limited to) K_W				
Students use $K_W = [H_+][OH_-]$ to find the pH of strong bases				
1.12.4 Weak acids and bases K_a for weak acids Weak acids and weak bases dissociate only slightly in aqueous solution				
K_a is the dissociation constant for a weak acid				
$pK_a = -\log_{10} K_a$ Students should be able to:				
•• construct an expression for K_a				
•• perform calculations relating the pH of a weak acid to the concentration of the acid and the dissociation constant, K_a				
•• convert K_a into pK_a and vice versa				
Students carry out pK_a calculations and give appropriate units				
Students understand standard form when applied to areas such as (but not limited to) K_a				
Students could calculate K_a of a weak acid by measuring the pH at half neutralisation				
1.12.5 pH curves, titrations and indicators Titrations of acids with bases				
Students should be able to perform calculations for these titrations based on experimental results				

the Content	I have covered this in class?	I have studied this at home?	I have revised this?	I can answer exam questions on this?
Typical pH curves for acid–base titrations in all combinations of weak and strong monoprotic acids and bases				
Students should be able to:				
•• sketch and explain the shapes of typical pH curves				
•• use pH curves to select an appropriate indicator				
Students could plot pH curves to show how pH changes during reactions				
Required practical 9 Investigate how pH changes when a weak acid reacts with a strong base and when a strong acid reacts with a weak base				
1.12.6 Buffer action A buffer solution maintains an approximately constant pH, despite dilution or addition of small amounts of acid or base				
Acidic buffer solutions contain a weak acid and the salt of that weak acid				
Basic buffer solutions contain a weak base and the salt of that weak base				
Applications of buffer solutions				
Students should be able to:				
•• explain qualitatively the action of acidic and basic buffers				
•• calculate the pH of acidic buffer solutions				
Students could be asked to prepare and test a buffer solution with a specific pH value				
Students make appropriate mathematical approximations in buffer calculations				

the Content	I have covered this in class?	I have studied this at home?	I have revised this?	I can answer exam questions on this?

the Content	I have covered this in class?	I have studied this at home?	I have revised this?	I can answer exam questions on this?
5 Inorganic chemistry (Yr 13)				
2.4 Properties of Period 3 elements and their oxides The reactions of the Period 3 elements with oxygen are considered. The pH of the solutions formed when the oxides react with water illustrates further trends in properties across this period. Explanations of these reactions offer opportunities to develop an in-depth understanding of how and why these reactions occur				
The reactions of Na and Mg with water				
The trends in the reactions of the elements Na, Mg, Al, Si, P and S with oxygen, limited to the formation of Na_2O, MgO, Al_2O_3, SiO_2, P_4O_{10}, SO_2 and SO_3				
The trend in the melting point of the highest oxides of the elements Na–S				
The reactions of the oxides of the elements Na–S with water, limited to Na_2O, MgO, Al_2O_3, SiO_2, P_4O_{10}, SO_2 and SO_3, and the pH of the solutions formed				
The structures of the acids and the anions formed when P_4O_{10}, SO_2 and SO_3 react with water				
Students should be able to:				
•• explain the trend in the melting point of the oxides of the elements Na–S in terms of their structure and bonding				
•• explain the trends in the reactions of the oxides with water in terms of the type of bonding present in each oxide				
•• write equations for the reactions that occur between the oxides of the elements Na–S and given acids and bases				
Students could carry out reactions of elements with oxygen and test the pH of the resulting oxides				
2.5 Transition metals The 3d block contains 10 elements, all of which are metals. Unlike the metals in Groups 1 and 2, the transition metals Ti to Cu form coloured compounds and compounds where the transition metal exists in different oxidation states. Some of these metals are familiar as catalysts. The properties of these elements are studied in this section with opportunities for a wide range of practical investigations				
2.5.1 General properties of transition metals Transition metal characteristics of elements Ti–Cu arise from an incomplete d sub-level in atoms or ions				
The characteristic properties include:				
•• complex formation				

the Content	I have covered this in class?	I have studied this at home?	I have revised this?	I can answer exam questions on this?
•• formation of coloured ions				
•• variable oxidation state				
•• catalytic activity				
A ligand is a molecule or ion that forms a co-ordinate bond with a transition metal by donating a pair of electrons				
A complex is a central metal atom or ion surrounded by ligands				
Co-ordination number is number of co-ordinate bonds to the central metal atom or ion				
2.5.2 Substitution reactions H_2O, NH_3 and Cl^- can act as monodentate ligands				
The ligands NH_3 and H_2O are similar in size and are uncharged				
Exchange of the ligands NH_3 and H_2O occurs without change of co-ordination number (eg Co^{2+} and Cu^{2+})				
Substitution may be incomplete (eg the formation of $[Cu(NH_3)_4(H_2O)_2]^{2+}$)				
The Cl^- ligand is larger than the uncharged ligands NH_3 and H_2O Exchange of the ligand H_2O by Cl^- can involve a change of co-ordination number (eg Co^{2+}, Cu^{2+} and Fe^{3+})				
Ligands can be bidentate (eg $H_2NCH_2CH_2NH_2$ and $C_2O_4{}^{2-}$)				
Ligands can be multidentate (eg $EDTA^{4-}$)				
Haem is an iron(II) complex with a multidentate ligand				
Oxygen forms a co-ordinate bond to Fe(II) in haemoglobin, enabling oxygen to be transported in the blood				
Carbon monoxide is toxic because it replaces oxygen co-ordinately bonded to Fe(II) in haemoglobin				
Bidentate and multidentate ligands replace monodentate ligands from complexes. This is called the chelate effect				
Students should be able to explain the chelate effect, in terms of the balance between the entropy and enthalpy change in these reactions				
Students could carry out test-tube reactions of complexes with monodentate, bidentate and multidentate ligands to compare ease of substitution				
Students could carry out test-tube reactions of solutions of metal aqua ions with ammonia or concentrated hydrochloric acid				
2.5.3 Shapes of complex ions Transition metal ions commonly form octahedral complexes with small ligands (eg H_2O and NH_3)				

the Content	I have covered this in class?	I have studied this at home?	I have revised this?	I can answer exam questions on this?
Octahedral complexes can display *cis–trans* isomerism (a special case of *E–Z* isomerism) with monodentate ligands and optical isomerism with bidentate ligands				
Transition metal ions commonly form tetrahedral complexes with larger ligands (eg Cl^-)				
Square planar complexes are also formed and can display *cis–trans* isomerism				
Cisplatin is the *cis* isomer				
Ag_+ forms the linear complex $[Ag(NH_3)_2]^+$ as used in Tollens' reagent				
Students understand and draw the shape of complex ions				
Students understand the origin of *cis–trans* and optical isomerism				
Students draw *cis–trans* and optical isomers				
Students describe the types of stereoisomerism shown by molecules/ complexes				
2.5.4 Formation of coloured ions Transition metal ions can be identified by their colour				
Colour arises when some of the wavelengths of visible light are absorbed and the remaining wavelengths of light are transmitted or reflected				
d electrons move from the ground state to an excited state when light is absorbed				
The energy difference between the ground state and the excited state of the d electrons is given by: $\Delta E = h\nu = hc/\lambda$ Changes in oxidation state, coordination number and ligand alter ΔE and this leads to a change in colour				
The absorption of visible light is used in spectroscopy				
A simple colorimeter can be used to determine the concentration of coloured ions in solution				
Students could determine the concentration of a solution of copper(II) ions by colorimetry				
Students determine the concentration of a solution from a graph of absorption versus concentration				
Students could determine the concentration of a coloured complex ion by colorimetry				
2.5.5 Variable oxidation states Transition elements show variable oxidation states				
Vanadium species in oxidation states IV, III and II are formed by the reduction of vanadate(V) ions by zinc in acidic solution				
The redox potential for a transition metal ion changing from a higher to a lower oxidation state is influenced by pH and by the ligand				
The reduction of $[Ag(NH_3)_2]^+$ (Tollens' reagent) to metallic silver is used to distinguish between aldehydes and ketones				

the Content	I have covered this in class?	I have studied this at home?	I have revised this?	I can answer exam questions on this?
The redox titrations of Fe^{2+} and $C_2O_4{}^{2-}$ with $MnO_4{}^-$ Students should be able to perform calculations for these titrations and similar redox reactions				
Students could reduce vanadate(V) with zinc in acidic solution				
Students could carry out test-tube reactions of Tollens' reagent to distinguish aldehydes and ketones				
Students could carry out redox titrations				
Examples include, finding:				
•• the mass of iron in an iron tablet				
•• the percentage of iron in steel				
•• the M_r of hydrated ammonium iron(II) sulfate				
•• the M_r of ethanedioic acid				
•• the concentration of H_2O_2 in hair bleach				
2.5.6 Catalysts Transition metals and their compounds can act as heterogeneous and homogeneous catalysts				
A heterogeneous catalyst is in a different phase from the reactants and the reaction occurs at active sites on the surface				
The use of a support medium to maximise the surface area of a heterogeneous catalyst and minimise the cost				
V_2O_5 acts as a heterogeneous catalyst in the Contact process				
Fe is used as a heterogeneous catalyst in the Haber process				
Heterogeneous catalysts can become poisoned by impurities that block the active sites and consequently have reduced efficiency; this has a cost implication				
A homogeneous catalyst is in the same phase as the reactants				
When catalysts and reactants are in the same phase, the reaction proceeds through an intermediate species				
Students should be able to:				
•• explain the importance of variable oxidation states in catalysis				
•• explain, with the aid of equations, how V_2O_5 acts as a catalyst in the Contact process				
•• explain, with the aid of equations, how Fe^{2+} ions catalyse the reaction between I^- and $S_2O_8{}^{2-}$				
•• explain, with the aid of equations, how Mn^{2+} ions autocatalyse the reaction between $C_2O_4{}^{2-}$ and $MnO_4{}^-$				
Students could investigate Mn^{2+} as the autocatalyst in the reaction between ethanedioic acid and acidified potassium manganate(VII)				
2.6 Reactions of ions in aqueous solution The reactions of transition metal ions in aqueous solution provide a practical opportunity for students to show and to				

the Content	I have covered this in class?	I have studied this at home?	I have revised this?	I can answer exam questions on this?
understand how transition metal ions can be identified by test-tube reactions in the laboratory				
In aqueous solution, the following metal-aqua ions are formed: $[M(H_2O)_6]^{2+}$, limited to M = Fe and Cu $[M(H_2O)_6]^{3+}$, limited to M = Al and Fe The acidity of $[M(H_2O)_6]^{3+}$ is greater than that of $[M(H_2O)_6]^{2+}$ Some metal hydroxides show amphoteric character by dissolving in both acids and bases (eg hydroxides of Al^{3+})				
Students should be able to:				
•• explain, in terms of the charge/size ratio of the metal ion, why the acidity of $[M(H_2O)_6]^{3+}$ is greater than that of $[M(H_2O)_6]^{2+}$				
•• describe and explain the simple test-tube reactions of: M^{2+}(aq) ions, limited to M = Fe and Cu, and of $M^{3+(}$aq) ions, limited to M = Al and Fe, with the bases OH^-, NH_3 and $CO_3{}^{2}$				
Students could carry out test-tube reactions of metal-aqua ions with NaOH, NH_3 and Na_2CO_3				
Students could carry out test-tube reactions to identify the positive and negative ions in this specification				
Students could identify unknown substances using reagents				
Required practical 11 Carry out simple test-tube reactions to identify transition metal ions in aqueous solution				

the Content	I have covered this in class?	I have studied this at home?	I have revised this?	I can answer exam questions on this?

the Content	I have covered this in class?	I have studied this at home?	I have revised this?	I can answer exam questions on this?
6 Organic chemistry (Yr 13)				
3.7 Optical isomerism Compounds that contain an asymmetric carbon atom form stereoisomers that differ in their effect on plane polarised light. This type of isomerism is called optical isomerism				
Optical isomerism is a form of stereoisomerism and occurs as a result of chirality in molecules, limited to molecules with a single chiral centre				
An asymmetric carbon atom is chiral and gives rise to optical isomers (enantiomers), which exist as non superimposable mirror images and differ in their effect on plane polarised light				
A mixture of equal amounts of enantiomers is called a racemic mixture (racemate)				
Students should be able to:				
•• draw the structural formulas and displayed formulas of enantiomers				
•• understand how racemic mixtures (racemates) are formed and why they are optically inactive				
Students could be asked to recognise the presence of a chiral centre in a given structure in 2D or 3D forms				
They could also be asked to draw the 3D representation of chiral centres in various species				
Students understand the origin of optical isomerism				
Passing polarised light through a solution of sucrose				
3.8 Aldehydes and ketones Aldehydes, ketones, carboxylic acids and their derivatives all contain the carbonyl group which is attacked by nucleophiles. This section includes the addition reactions of aldehydes and ketones				
Aldehydes are readily oxidised to carboxylic acids				
Chemical tests to distinguish between aldehydes and ketones including Fehling's solution and Tollens' reagent				
Aldehydes can be reduced to primary alcohols, and ketones to secondary alcohols, using $NaBH_4$ in aqueous solution				
These reduction reactions are examples of nucleophilic addition				
The nucleophilic addition reactions of carbonyl compounds with KCN, followed by dilute acid, to produce hydroxynitriles				
Aldehydes and unsymmetrical ketones form mixtures of enantiomers when they react with KCN followed by dilute acid				
The hazards of using KCN				
Students should be able to:				

the Content	I have covered this in class?	I have studied this at home?	I have revised this?	I can answer exam questions on this?
•• write overall equations for reduction reactions using [H] as the reductant				
•• outline the nucleophilic addition mechanism for reduction reactions with $NaBH_4$ (the nucleophile should be shown as H^-)				
•• write overall equations for the formation of hydroxynitriles using HCN				
•• outline the nucleophilic addition mechanism for the reaction with KCN followed by dilute acid				
•• explain why nucleophilic addition reactions of KCN, followed by dilute acid, can produce a mixture of enantiomers				
Students could carry out test-tube reactions of Tollens' reagent and Fehling's solution to distinguish aldehydes and ketones				
3.9 Carboxylic acids and derivatives Carboxylic acids are weak acids but strong enough to liberate carbon dioxide from carbonates. Esters occur naturally in vegetable oils and animal fats. Important products obtained from esters include biodiesel, soap and glycerol				
3.9.1 Carboxylic acids and esters The structures of:				
•• carboxylic acids				
•• esters				
Carboxylic acids are weak acids but will liberate CO_2 from carbonates				
Carboxylic acids and alcohols react, in the presence of an acid catalyst, to give esters				
Common uses of esters (eg in solvents, plasticisers, perfumes and food flavourings)				
Vegetable oils and animal fats are esters of propane-1,2,3-triol (glycerol)				
Esters can be hydrolysed in acid or alkaline conditions to form alcohols and carboxylic acids or salts of carboxylic acids				
Vegetable oils and animal fats can be hydrolysed in alkaline conditions to give soap (salts of long-chain carboxylic acids) and glycerol				
Biodiesel is a mixture of methyl esters of long-chain carboxylic acids				
Biodiesel is produced by reacting vegetable oils with methanol in the presence of a catalyst				
Students could make esters by reacting alcohols with carboxylic acids, purifying the product using a separating funnel and by distillation				

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Students could identify an ester by measuring its boiling point, followed by hydrolysis to form the carboxylic acid, which is purified by recrystallisation, and determine its melting point				
Students could make soap				
Students could make biodiesel				
3.9.2 Acylation The structures of:				
•• acid anhydrides				
•• acyl chlorides				
•• amides				
The nucleophilic addition–elimination reactions of water, alcohols, ammonia and primary amines with acyl chlorides and acid anhydrides				
The industrial advantages of ethanoic anhydride over ethanoyl chloride in the manufacture of the drug aspirin				
Students should be able to outline the mechanism of nucleophilic addition–elimination reactions of acyl chlorides with water, alcohols, ammonia and primary amines				
Students could record observations from reaction of ethanoyl chloride and ethanoic anhydride with water, ethanol, ammonia and phenylamine				
Students could carry out the preparation of aspirin, purification by recrystallisation and determination of its melting point				
Students could carry out the purification of impure benzoic acid and determination of its melting point				
Required practical 10 Preparation of:				
•• a pure organic solid and test of its purity				
•• a pure organic liquid				
3.10 Aromatic chemistry Aromatic chemistry takes benzene as an example of this type of molecule and looks at the structure of the benzene ring and its substitution reactions				
3.10.1 Bonding The nature of the bonding in a benzene ring, limited to planar structure and bond length intermediate between single and double				
Delocalisation of p electrons makes benzene more stable than the theoretical molecule cyclohexa-1,3,5-triene				
Students should be able to:				
•• use thermochemical evidence from enthalpies of hydrogenation to account for this extra stability				
•• explain why substitution reactions occur in preference to addition reactions				

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3.10.2 Electrophilic substitution Electrophilic attack on benzene rings results in substitution, limited to monosubstitutions				
Nitration is an important step in synthesis, including the manufacture of explosives and formation of amines				
Friedel–Crafts acylation reactions are also important steps in synthesis				
Students should be able to outline the electrophilic substitution mechanisms of:				
•• nitration, including the generation of the nitronium ion				
•• acylation using $AlCl_3$ as a catalyst				
Students could carry out the preparation of methyl 3-nitrobenzoate by nitration of methyl benzoate, purification by recrystallisation and determination of melting point				
3.11 Amines Amines are compounds based on ammonia where hydrogen atoms have been replaced by alkyl or aryl groups. This section includes their reactions as nucleophiles				
3.11.1 Preparation Primary aliphatic amines can be prepared by the reaction of ammonia with halogenoalkanes and by the reduction of nitriles				
Aromatic amines, prepared by the reduction of nitro compounds, are used in the manufacture of dyes				
3.11.2 Base properties Amines are weak bases				
The difference in base strength between ammonia, primary aliphatic and primary aromatic amines				
Students should be able to explain the difference in base strength in terms of the availability of the lone pair of electrons on the N atom				
3.11.3 Nucleophilic properties Amines are nucleophiles				
The nucleophilic substitution reactions of ammonia and amines with halogenoalkanes to form primary, secondary, tertiary amines and quaternary ammonium salts				
The use of quaternary ammonium salts as cationic surfactants				
The nucleophilic addition–elimination reactions of ammonia and primary amines with acyl chlorides and acid anhydrides				
Students should be able to outline the mechanisms of:				
•• these nucleophilic substitution reactions				
•• the nucleophilic addition–elimination reactions of ammonia and primary amines with acyl chlorides				
3.12 Polymers				

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The study of polymers is extended to include condensation polymers. The ways in which condensation polymers are formed are studied, together with their properties and typical uses. Problems associated with the reuse or disposal of both addition and condensation polymers are considered				
3.12.1 Condensation polymers Condensation polymers are formed by reactions between:				
•• dicarboxylic acids and diols				
•• dicarboxylic acids and diamines				
•• amino acids				
The repeating units in polyesters (eg Terylene) and polyamides (eg nylon 6,6 and Kevlar) and the linkages between these repeating units				
Typical uses of these polymers				
Students should be able to:				
•• draw the repeating unit from monomer structure(s)				
•• draw the repeating unit from a section of the polymer chain				
•• draw the structure(s) of the monomer(s) from a section of the polymer				
•• explain the nature of the intermolecular forces between molecules of condensation polymers				
Making nylon 6,6				
3.12.2 Biodegradability and disposal of polymers Polyalkenes are chemically inert and non-biodegradable				
Polyesters and polyamides can be broken down by hydrolysis and are biodegradable				
The advantages and disadvantages of different methods of disposal of polymers, including recycling				
Students should be able to explain why polyesters and polyamides can be hydrolysed but polyalkenes cannot				
Students could research problems associated with the disposal of different polymers				
3.13 Amino acids, proteins and DNA Amino acids, proteins and DNA are the molecules of life. In this section, the structure and bonding in these molecules and the way they interact is studied. Drug action is also considered				
3.13.1 Amino acids Amino acids have both acidic and basic properties, including the formation of zwitterions				
Students should be able to draw the structures of amino acids as zwitterions and the ions formed from amino acids:				
•• in acid solution				
•• in alkaline solution				

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3.13.2 Proteins Proteins are sequences of amino acids joined by peptide links				
The importance of hydrogen bonding and sulfur–sulfur bonds in proteins				
The primary, secondary (α-helix and β–pleated sheets) and tertiary structure of proteins				
Hydrolysis of the peptide link produces the constituent amino acids				
Amino acids can be separated and identified by thin-layer chromatography				
Amino acids can be located on a chromatogram using developing agents such as ninhydrin or ultraviolet light and identified by their R_f values				
Students should be able to:				
•• draw the structure of a peptide formed from up to three amino acids				
•• draw the structure of the amino acids formed by hydrolysis of a peptide				
•• identify primary, secondary and tertiary structures in diagrams				
•• explain how these structures are maintained by hydrogen bonding and S–S bonds				
•• calculate R_f values from a chromatogram				
3.13.3 Enzymes Enzymes are proteins				
The action of enzymes as catalysts, including the concept of a stereospecific active site that binds to a substrate molecule				
The principle of a drug acting as an enzyme inhibitor by blocking the active site				
Computers can be used to help design such drugs				
Students should be able to explain why a stereospecific active site can only bond to one enantiomeric form of a substrate or drug				
3.13.4 DNA The structures of the phosphate ion, 2-deoxyribose (a pentose sugar) and the four bases adenine, cytosine, guanine and thymine are given in the Chemistry Data Booklet				
A nucleotide is made up from a phosphate ion bonded to 2-deoxyribose which is in turn bonded to one of the four bases adenine, cytosine, guanine and thymine				
A single strand of DNA (deoxyribonucleic acid) is a polymer of nucleotides linked by covalent bonds between the phosphate group of one nucleotide and the 2-deoxyribose of another nucleotide. This results in a sugar-phosphatesugar-phosphate polymer chain with bases attached to the sugars in the chain				

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DNA exists as two complementary strands arranged in the form of a double helix				
Students should be able to explain how hydrogen bonding between base pairs leads to the two complementary strands of DNA				
3.13.5 Action of anticancer drugs The Pt(II) complex cisplatin is used as an anticancer drug				
Cisplatin prevents DNA replication in cancer cells by a ligand replacement reaction with DNA in which a bond is formed between platinum and a nitrogen atom on guanine				
Appreciate that society needs to assess the balance between the benefits and the adverse effects of drugs, such as the anticancer drug cisplatin				
Students should be able to:				
•• explain why cisplatin prevents DNA replication				
•• explain why such drugs can have adverse effects				
3.14 Organic synthesis The formation of new organic compounds by multi-step syntheses using reactions included in the specification is covered in this section				
The synthesis of an organic compound can involve several steps				
Students should be able to:				
•• explain why chemists aim to design processes that do not require a solvent and that use non-hazardous starting materials				
•• explain why chemists aim to design production methods with fewer steps that have a high percentage atom economy				
•• use reactions in this specification to devise a synthesis, with up to four steps, for an organic compound				
3.15 Nuclear magnetic resonance spectroscopy Chemists use a variety of techniques to deduce the structure of compounds. In this section, nuclear magnetic resonance spectroscopy is added to mass spectrometry and infrared spectroscopy as an analytical technique. The emphasis is on the use of analytical data to solve problems rather than on spectroscopic theory				

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Appreciation that scientists have developed a range of analytical techniques which together enable the structures of new compounds to be confirmed				
Nuclear magnetic resonance (NMR) gives information about the position of ^{13}C or ^{1}H atoms in a molecule				
^{13}C NMR gives simpler spectra than ^{1}H NMR				
The use of the δ scale for recording chemical shift				
Chemical shift depends on the molecular environment				
Integrated spectra indicate the relative numbers of ^{1}H atoms in different environments				
^{1}H NMR spectra are obtained using samples dissolved in deuterated solvents or CCl_4 The use of tetramethylsilane (TMS) as a standard				
Students should be able to:				
•• explain why TMS is a suitable substance to use as a standard				
•• use ^{1}H NMR and ^{13}C NMR spectra and chemical shift data from the Chemistry Data Booklet to suggest possible structures or part structures for molecules				
•• use integration data from ^{1}H NMR spectra to determine the relative numbers of equivalent protons in the molecule				
•• use the n+1 rule to deduce the spin–spin splitting patterns of adjacent, non-equivalent protons, limited to doublet, triplet and quartet formation in aliphatic compounds				
Students should be able to use data in the Chemistry Data Booklet to suggest possible structures for molecules				
3.16 Chromatography Chromatography provides an important method of separating and identifying components in a mixture				
Different types of chromatography are used depending on the composition of mixture to be separated				
Chromatography can be used to separate and identify the components in a mixture				
Types of chromatography include:				
•• thin-layer chromatography (TLC) – a plate is coated with a solid and a solvent moves up the plate				
•• column chromatography (CC) – a column is packed with a solid and a solvent moves down the column				
•• gas chromatography (GC) – a column is packed with a solid or with a solid coated by a liquid, and a gas is passed through the column under pressure at high temperature				
Separation depends on the balance between solubility in the moving phase and retention by the stationary phase				
Retention times and R_f values are used to identify different substances				

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The use of mass spectrometry to analyse the components separated by GC				
Students should be able to:				
•• calculate R_f values from a chromatogram				
•• compare retention times and R_f values with standards to identify different substances				
Students could use thin-layer chromatography to identify analgesics				
Students could use thin-layer chromatography to identify transition metal ions in a solution				
Required practical 12 Separation of species by thin-layer chromatography				

the Content	I have covered this in class?	I have studied this at home?	I have revised this?	I can answer exam questions on this?
7 Mathematics for Chemistry				
Arithmetic and numerical computation				
MS 0.0 Recognise and make use of appropriate units in calculation				
Students may be tested on their ability to:				
•• convert between units eg cm$_3$ to dm$_3$ as part of volumetric calculations				
•• give units for an equilibrium constant or a rate constant				
•• understand that different units are used in similar topic areas, so that conversions may be necessary, eg entropy in J mol$_{-1}$ K$_{-1}$ and enthalpy changes in kJ mol^{-1}.				
MS 0.1 Recognise and use expressions in decimal and ordinary form				
Students may be tested on their ability to:				
•• use an appropriate number of decimal places in calculations eg for pH				
•• carry out calculations using numbers in standard and ordinary form eg use of Avogadro's number				
•• understand standard form when applied to are such as (but not limited to) K_w				
•• convert between numbers in standard and ordinary form				
•• understand that significant figures need retaining when making conversions between standard and ordinary form eg 0.0050 mol dm^{-3} is equivalent to 5.0×10^{-3} mol dm^{-3}.				
MS 0.2 Use ratios, fractions and percentages				
Students may be tested on their ability to:				
•• calculate percentage yields				
•• calculate the atom economy of a reaction				
•• construct and/or balance equations using ratios				
MS0.3 Estimate results				
Students may be tested on their ability to:				
•• evaluate the effect of changing experimental parameters on measurable values eg how the value of K$_c$ would change with temperature given different specified conditions.				
MS0.4 Use calculators to find and use power, exponential and logarithmic functions				
Students may be tested on their ability to:				

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•• carry out calculations using the Avogadro constant				
•• carry out pH and pK_a calculations				
•• make appropriate mathematical approximations in buffer calculations.				
Handling data				
MS1.1Use an appropriate number of significant figures				
Students may be tested on their ability to:				
•• report calculations to an appropriate number of significant figures, given raw data quoted to varying numbers of significant figures				
•• understand that calculated results can only be reported to the limits of the least accurate measurement				
MS1.2Find arithmetic means				
Students may be tested on their ability to:				
•• calculate weighted means eg calculation of an atomic mass based on supplied isotopic abundances				
•• select appropriate titration data (ie identification of outliers) in order to calculate mean titres.MS1.3Identify uncertainties in measurements and use simple techniques to determine uncertainty when data are combined Students may be tested on their ability to:				
•• determine uncertainty when two burette readings are used to calculate a titre value.				
Algebra				
MS2.1Understand and use the symbols: =,<, <<, >>, >, ∝, ~, equilibrium sign				
MS2.2Change the subject of an equation				
Students may be tested on their ability to:				
•• carry out structured and unstructured mole calculations eg calculate a rate constant k from a rate equation.				
MS2.3Substitute numerical values into algebraic equations using appropriate units for physical quantities				
Students may be tested on their ability to:				
•• carry out structured and unstructured mole calculations				
•• carry out rate calculations				
•• calculate the value of an equilibrium constant K_c.				
MS2.4Solve algebraic equations				

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Students may be tested on their ability to:				
•• carry out Hess's law calculations				
•• calculate a rate constant k from a rate equation.				
MS2.5Use logarithms in relation to quantities that range over several orders of magnitude				
Students may be tested on their ability to:				
•• carry out pH and pK_a calculations.				

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Practical Work in Chemistry				
Apparatus and Techniques				
Use appropriate apparatus to record a range of measurements (to include mass, time, volume of liquids and gases, temperature)				
Use water bath or electric heater or sand bath for heating				
Measure pH using pH charts, or pH meter, or pH probe on a data logger				
Use laboratory apparatus for a variety of experimental techniques including:				
•• titration, using burette and pipette				
•• distillation and heating under reflux, including setting up glassware using retort stand and clamps				
•• qualitative tests for ions and organic functional groups				
•• filtration, including use of fluted filter paper, or filtration under reduced pressure				
Use volumetric flask, including accurate technique for making up a standard solution				
Use acid–base indicators in titrations of weak/strong acids with weak/strong alkalis				
Purify:				
•• a solid product by recrystallisation				
•• a liquid product, including use of separating funnel				
Use melting point apparatus				
Use thin-layer or paper chromatography				
Set up electrochemical cells and measuring voltages				
Safely and carefully handle solids and liquids, including corrosive, irritant, flammable and toxic substances				
Measure rates of reaction by at least two different methods, for example:				
•• an initial rate method such as a clock reaction				
•• a continuous monitoring method				
Core Practicals				
1 Make up a volumetric solution and carry out a simple acid–base titration				
2 Measurement of an enthalpy change				
3 Investigation of how the rate of a reaction changes with temperature				
4 Carry out simple test-tube reactions to identify:				
•• cations – Group 2, NH_4^+				
•• anions – Group 7 (halide ions), OH^-, CO_3^{2-}, SO_4^{2-}				
5 Distillation of a product from a reaction				
6 Tests for alcohol, aldehyde, alkene and carboxylic acid				
7 Measuring the rate of reaction:				

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•• by an initial rate method				
•• by a continuous monitoring method				
8 Measuring the EMF of an electrochemical cell				
9 Investigate how pH changes when a weak acid reacts with a strong base and when a strong acid reacts with a weak base				
10 Preparation of:				
•• a pure organic solid and test of its purity				
•• a pure organic liquid				
11 Carry out simple test-tube reactions to identify transition metal ions in aqueous solution				
12 Separation of species by thin-layer chromatography				

Practical Skills				
3.1 Independent thinking				
1.1 Solve problems set in practical contexts				
1.2 Apply scientific knowledge to practical contexts				
3.2 Use and application of scientific methods and practices				
2.1 Comment on experimental design and evaluate scientific methods				
2.2 Present data in appropriate ways				
2.3 Evaluate results and draw conclusions with reference to measurement uncertainties and errors				
2.4 Identify variables including those that must be controlled				
3.3 Numeracy and the application of mathematical concepts in a practical context				
3.1 Plot and interpret graphs				
3.2 Process and analyse data using appropriate mathematical skills as exemplified in the mathematical appendix for each science				
3.3 Consider margins of error, accuracy and precision of data				
3.4 Instruments and equipment				
4.1 Know and understand how to use a wide range of experimental and practical instruments, equipment and techniques appropriate to the knowledge and understanding included in the specification				