

1.1 Particles in the atom and atomic radius

Particles in the atom and atomic radius

Can you describe the atom as mostly empty space with a small, dense nucleus of protons and neutrons, surrounded by electrons in shells?



Can you identify protons, neutrons and electrons from their relative charges and relative masses?



Can you define the terms atomic (proton) number and mass (nucleon) number?



Can you describe how mass and charge are distributed within an atom?



Can you describe the behaviour of beams of protons, neutrons and electrons moving at the same velocity in an electric field?



Can you work out the numbers of protons, neutrons and electrons in an atom or ion from its proton number, mass number and charge?



Can you explain qualitatively how atomic radius varies across a period and down a group?



Can you explain qualitatively how ionic radius varies across a period and down a group?



1.2 Isotopes

Isotopes

Can you define the term isotope in terms of numbers of protons and neutrons?



Can you use isotope notation showing mass number and proton number, e.g. $^{12}_6\text{C}$?



Can you state and explain why isotopes of the same element have the same chemical properties?



Can you state and explain why isotopes of the same element have different physical properties, limited to mass and density?



1.3 Electrons, energy levels and atomic orbitals

Shells, sub-shells and orbitals

Can you use the terms shell, sub-shell, orbital, principal quantum number (n) and ground state?



Can you state the number of orbitals in s, p and d sub-shells and the number of electrons each can hold?



Can you describe the relative energies of the s, p and d sub-shells in the first three shells, and of the 4s and 4p sub-shells?



Can you describe and sketch the shapes of s and p orbitals?



Electronic configurations

Can you describe the number and relative energies of electrons in each shell, sub-shell and orbital of an atom?



Can you explain electronic configurations in terms of the energy of the electrons and repulsion between electrons?



Can you work out the electronic configuration of atoms and ions using full (1s² 2s² 2p⁶) and shorthand ([Ar] 3d⁶ 4s²) notation, e.g. for Fe?



Can you use electrons-in-boxes notation to show the electronic configuration of an atom or ion, e.g. Fe?



Can you describe a free radical as a species with one or more unpaired electrons?



1.4 Ionisation energy

Ionisation energy

Can you define and use the term first ionisation energy, IE?



Can you write equations, with state symbols, for first, second and subsequent ionisation energies?



Can you identify and explain the trends in ionisation energies across a period and down a group?



Can you identify and explain the variation in successive ionisation energies of an element?



Can you explain that ionisation energy depends on the attraction between the nucleus and the outer electron?



Can you explain how nuclear charge, atomic or ionic radius, shielding by inner shells and sub-shells, and spin-pair repulsion affect ionisation energy?



Can you deduce the electronic configuration of an element from successive ionisation energy data?



Can you deduce the position of an element in the Periodic Table from successive ionisation energy data?



2.1-2.2

Relative masses and the mole

Relative masses of atoms and molecules

Can you define the unified atomic mass unit as one twelfth of the mass of a carbon-12 atom?



Can you define relative atomic mass, A_r , in terms of the unified atomic mass unit?



Can you define relative isotopic mass in terms of the unified atomic mass unit?



Can you define relative molecular mass, M_r , and relative formula mass in terms of the unified atomic mass unit?



The mole and the Avogadro constant

Can you define and use the term mole in terms of the Avogadro constant?



2.3

Formulae

Ionic formulae and equations

Can you write formulae of ionic compounds from ionic charges and oxidation numbers shown as Roman numerals?



Can you predict the charge on an ion from the position of the element in the Periodic Table?



Can you recall the names and formulae of the ions NO_3^- , CO_3^{2-} , SO_4^{2-} , OH^- , NH_4^+ , Zn^{2+} , Ag^+ , HCO_3^- and PO_4^{3-} ?



Can you write and construct balanced equations, including ionic equations that leave out spectator ions?



Can you use appropriate state symbols, (s), (l), (g) and (aq), in equations?



Empirical and molecular formulae

Can you define and use the terms empirical formula and molecular formula?



Can you understand and use the terms anhydrous, hydrated and water of crystallisation?



Can you calculate empirical and molecular formulae using given data?



Mole calculations

Can you carry out mole calculations involving reacting masses, including percentage yield?



Can you carry out mole calculations involving volumes of gases, e.g. in the combustion of hydrocarbons?



Can you carry out mole calculations involving volumes and concentrations of solutions?



Can you carry out mole calculations involving limiting reagents and excess reagents?



Can you deduce stoichiometric relationships from calculations involving reacting masses, gas volumes and solutions?



3.1-3.3

Electronegativity, ionic and metallic bonding

Electronegativity and bonding

Can you define electronegativity as the power of an atom to attract electrons to itself?



Can you explain how nuclear charge, atomic radius and shielding by inner shells and sub-shells affect electronegativity?



Can you state and explain the trends in electronegativity across a period and down a group?



Can you use differences in Pauling electronegativity values to predict whether a compound has ionic or covalent bonding?



Ionic bonding

Can you define ionic bonding as the electrostatic attraction between oppositely charged ions (cations and anions)?



Can you describe ionic bonding in sodium chloride, NaCl, magnesium oxide, MgO, and calcium fluoride, CaF₂?



Metallic bonding

Can you define metallic bonding as the electrostatic attraction between positive metal ions and delocalised electrons?



3.4

Covalent and coordinate bonding

Covalent and coordinate bonds

Can you describe covalent bonding in H₂, O₂, N₂, Cl₂, HCl, CO₂, NH₃, CH₄, C₂H₆ and C₂H₄?



Can you describe how some atoms in Period 3 can expand their octet, as in SO₂, PCl₅ and SF₆?



Can you describe coordinate (dative covalent) bonding, including the formation of the ammonium ion, NH₄⁺, and in the Al₂Cl₆ molecule?

 σ and π bonds and hybridisation

Can you describe covalent bonds in terms of orbital overlap, giving σ bonds and π bonds?



Can you describe the bonding in H₂, C₂H₆, C₂H₄, HCN and N₂ in terms of σ and π bonds?



Can you describe hybridisation to form sp, sp² and sp³ orbitals?



Bond energy and bond length

Can you define bond energy as the energy required to break one mole of a particular covalent bond in the gaseous state?



Can you define bond length as the internuclear distance of two covalently bonded atoms?



Can you use bond energy and bond length to compare the reactivity of covalent molecules?



3.5-3.7

Shapes of molecules and intermolecular forces

Shapes of molecules

Can you use VSEPR theory to state the shapes and bond angles of BF₃ (trigonal planar, 120°), CO₂ (linear, 180°), CH₄ (tetrahedral, 109.5°), NH₃ (pyramidal, 107°), H₂O (non-linear, 104.5°), SF₆ (octahedral, 90°) and PF₅ (trigonal bipyramidal, 120° and 90°)?



Can you predict the shapes and bond angles of molecules and ions analogous to those above?



Intermolecular forces and bond properties

Can you describe hydrogen bonding, limited to molecules containing N-H and O-H groups, including ammonia and water?



Can you use hydrogen bonding to explain the anomalous properties of water: high melting and boiling points, high surface tension and the lower density of ice?



Can you use electronegativity to explain bond polarity and dipole moments of molecules?



Can you describe van der Waals' forces as including instantaneous dipole-induced dipole (id-id or London dispersion) forces and permanent dipole-permanent dipole (pd-pd) forces?



Can you describe hydrogen bonding as a special case of permanent dipole-permanent dipole forces?



Can you state that ionic, covalent and metallic bonds are generally much stronger than intermolecular forces?



Dot-and-cross diagrams

Can you draw dot-and-cross diagrams to show ionic, covalent and coordinate bonding, including molecules with expanded octets and species with an odd number of electrons?



4.1 The gaseous state**Ideal and real gases and $pV = nRT$**

Can you explain gas pressure in terms of collisions of gas molecules with the walls of the container?



Can you state that an ideal gas has particles of zero volume and no intermolecular forces of attraction?



Can you use the ideal gas equation, $pV = nRT$, in calculations, including finding M_r ?

**4.2 Bonding and structure****Lattice structures**

Can you describe giant ionic lattice structures, e.g. sodium chloride and magnesium oxide?



Can you describe simple molecular lattice structures, e.g. iodine, buckminsterfullerene C₆₀ and ice?



Can you describe giant molecular lattice structures, e.g. silicon(IV) oxide, graphite and diamond?



Can you describe giant metallic lattice structures, e.g. copper?

**Structure and properties**

Can you describe, interpret and predict the effect of structure and bonding on melting point, boiling point, electrical conductivity and solubility?



Can you deduce the type of structure and bonding in a substance from given information?



5.1 Enthalpy change, ΔH **Enthalpy changes**

Can you explain that chemical reactions involve enthalpy changes that are exothermic (ΔH negative) or endothermic (ΔH positive)?



Can you construct and interpret a reaction pathway diagram in terms of the enthalpy change of reaction and the activation energy?



Can you define standard conditions as 298 K and 101 kPa, shown by the symbol $\ominus$?



Can you define and use the enthalpy change of reaction, ΔH_r ?



Can you define and use the enthalpy change of formation, ΔH_f ?



Can you define and use the enthalpy change of combustion, ΔH_c ?



Can you define and use the enthalpy change of neutralisation, ΔH_{neut} ?

**Bond energies and calorimetry**

Can you explain that energy transfers in reactions happen because bonds are broken and made?



Can you calculate an enthalpy change of reaction using bond energy data (bond energies are positive because bond breaking is endothermic)?



Can you explain why some bond energies are exact and some are average values?



Can you calculate enthalpy changes from experimental results using $q = mc\Delta T$ and $\Delta H = -mc\Delta T/n$?

**5.2 Hess's law****Hess's law**

Can you apply Hess's law to construct simple energy cycles?



Can you carry out energy cycle calculations to find enthalpy changes that cannot be measured directly, e.g. ΔH_f from ΔH_c data?



Can you carry out energy cycle calculations using average bond energy data?



6.1 Redox processes

Electron transfer and changes in oxidation number

Can you calculate the oxidation numbers of elements in compounds and ions?



Can you use changes in oxidation numbers to help balance chemical equations?



Can you explain redox, oxidation and reduction in terms of electron transfer and changes in oxidation number?



Can you explain disproportionation in terms of electron transfer and changes in oxidation number?



Can you explain and use the terms oxidising agent and reducing agent?



Can you use a Roman numeral to show the magnitude of the oxidation number of an element, e.g. iron(II) and iron(III)?



Reversible reactions and Le Chatelier's principle

Can you explain what is meant by a reversible reaction?



Can you explain dynamic equilibrium in terms of equal rates of forward and reverse reactions and constant concentrations?



Can you explain why a closed system is needed for equilibrium to be set up?



Can you define Le Chatelier's principle: if a change is made to a system at equilibrium, the position of equilibrium moves to minimise the change?



Can you use Le Chatelier's principle to deduce qualitatively the effects of changes in temperature, concentration, pressure or presence of a catalyst on the position of equilibrium?



Can you state whether changes in temperature, concentration, pressure or the presence of a catalyst affect the value of the equilibrium constant?

 **K_c and K_p**

Can you deduce expressions for the equilibrium constant K_c in terms of concentrations?



Can you use the terms mole fraction and partial pressure?



Can you deduce expressions for the equilibrium constant K_p in terms of partial pressures?



Can you use K_c and K_p expressions in calculations (without solving quadratic equations)?



Can you calculate the quantities present at equilibrium from given data?

**Industrial processes**

Can you describe and explain the conditions used in the Haber process using equilibrium principles?



Can you describe and explain the conditions used in the Contact process using equilibrium principles?

**Acids, bases and pH**

Can you state the names and formulae of the common acids hydrochloric acid, HCl, sulfuric acid, H_2SO_4 , nitric acid, HNO_3 , and ethanoic acid, CH_3COOH ?



Can you state the names and formulae of the common alkalis sodium hydroxide, NaOH, potassium hydroxide, KOH, and ammonia, NH_3 ?



Can you describe the Brønsted-Lowry theory of acids and bases as proton donors and proton acceptors?



Can you describe strong acids and strong bases as fully dissociated and weak acids and weak bases as partially dissociated in aqueous solution?



Can you recall that under standard conditions water has pH 7, acidic solutions have pH below 7 and alkaline solutions pH above 7?



Can you explain qualitative differences between strong and weak acids using reactions with reactive metals and pH measured by pH meter, universal indicator or conductivity?



Neutralisation and titrations

Can you describe neutralisation as the reaction $\text{H}^+(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow \text{H}_2\text{O}(\text{l})$?



Can you state that salts are formed in neutralisation reactions?



Can you sketch pH titration curves for strong acid/strong alkali, strong acid/weak alkali, weak acid/strong alkali and weak acid/weak alkali?



Can you select suitable indicators for acid-alkali titrations from given data?



8.1 Rate of reaction

Can you explain and use the terms rate of reaction, frequency of collisions, effective collisions and non-effective collisions?



Can you explain qualitatively, in terms of the frequency of effective collisions, the effect of concentration or pressure changes on the rate of reaction?



Can you calculate a rate of reaction from experimental data?

**8.2 Effect of temperature and activation energy**

Can you define activation energy, EA, as the minimum energy needed for a collision to be effective?



Can you sketch and use the Boltzmann distribution to explain the significance of activation energy?



Can you explain qualitatively, using the Boltzmann distribution and frequency of effective collisions, the effect of temperature change on the rate of reaction?

**8.3 Catalysis**

Can you explain that a catalyst increases the rate of a reaction by providing an alternative mechanism with a lower activation energy?



Can you explain catalysis using the Boltzmann distribution?



Can you construct and interpret reaction pathway diagrams for reactions with and without a catalyst?



9.1 Periodicity of physical properties in Period 3

Can you describe qualitatively the variation in atomic radius, ionic radius, melting point and electrical conductivity across Period 3 (sodium to argon)?



Can you explain the variation in melting point and electrical conductivity across Period 3 in terms of structure and bonding?

**9.2 Reactions of the Period 3 elements**

Can you describe, and write equations for, the reactions of the Period 3 elements with oxygen (to give Na_2O , MgO , Al_2O_3 , P_4O_{10} , SO_2)?



Can you describe, and write equations for, the reactions of the Period 3 elements with chlorine (to give NaCl , MgCl_2 , AlCl_3 , SiCl_4 , PCl_5)?



Can you describe, and write equations for, the reactions of sodium and magnesium with water?

**9.2 Period 3 oxides and chlorides**

Can you state and explain the variation in the oxidation number of the Period 3 oxides and chlorides in terms of their outer shell electrons?



Can you describe, and write equations for, the reactions of the Period 3 oxides with water, including the likely pH of the solutions?



Can you describe, explain and write equations for the acid/base behaviour of the Period 3 oxides and hydroxides, including amphoteric behaviour in reactions with acids and sodium hydroxide?



Can you describe, explain and write equations for the reactions of the Period 3 chlorides with water, including the likely pH of the solutions?



Can you explain the variations and trends in the oxides and chlorides of Period 3 in terms of bonding and electronegativity?



Can you suggest the types of chemical bonding present in chlorides and oxides from observations of their chemical and physical properties?

**9.3 Chemical periodicity of other elements**

Can you predict the characteristic properties of an element in a given group using knowledge of chemical periodicity?



Can you deduce the nature, possible position in the Periodic Table and identity of unknown elements from given information?



Properties of Group 2 metals, magnesium to barium, and their compounds

Can you describe, and write equations for, the reactions of the Group 2 elements with oxygen?



Can you describe, and write equations for, the reactions of the Group 2 elements with water?



Can you describe, and write equations for, the reactions of the Group 2 elements with dilute hydrochloric acid and dilute sulfuric acid?



Can you describe, and write equations for, the reactions of the Group 2 oxides, hydroxides and carbonates with water, dilute hydrochloric acid and dilute sulfuric acid?



Can you describe, and write equations for, the thermal decomposition of the Group 2 nitrates and carbonates, including the trend in their thermal stabilities?



Can you describe and predict the trends in physical and chemical properties of the Group 2 elements and their compounds?



Can you state the variation in the solubilities of the Group 2 hydroxides and sulfates?



11.1 Physical properties

Can you describe the colours of chlorine, bromine and iodine and the trend in their volatility?



Can you describe and explain the trend in bond strength of the halogen molecules?



Can you interpret the volatility of the halogens in terms of instantaneous dipole-induced dipole forces?

**11.2 Halogens and hydrogen halides**

Can you describe the relative reactivity of the halogens as oxidising agents?



Can you describe the reactions of the halogens with hydrogen and explain their relative reactivity?



Can you describe the relative thermal stabilities of the hydrogen halides and explain them in terms of bond strengths?

**11.3 Reactions of the halide ions**

Can you describe the relative reactivity of halide ions as reducing agents?



Can you describe and explain the reactions of halide ions with aqueous silver ions followed by aqueous ammonia?



Can you describe and explain the reactions of halide ions with concentrated sulfuric acid, including balanced equations?

**11.4 Reactions of chlorine**

Can you describe and interpret, in terms of changes in oxidation number, the reaction of chlorine with cold aqueous sodium hydroxide as disproportionation?



Can you describe and interpret, in terms of changes in oxidation number, the reaction of chlorine with hot aqueous sodium hydroxide as disproportionation?



Can you explain, with an equation, the use of chlorine in water purification, including the formation of HOCl and ClO⁻ which kill bacteria?



Nitrogen and ammonia

Can you explain the lack of reactivity of nitrogen in terms of the strength of the triple bond and its lack of polarity?



Can you describe and explain the basicity of ammonia using Brønsted-Lowry theory?



Can you describe and explain the structure of the ammonium ion and its formation by an acid-base reaction?



Can you describe and explain the displacement of ammonia from ammonium salts by an acid-base reaction?

**Oxides of nitrogen and sulfur in the atmosphere**

Can you state and explain the natural and man-made occurrences of oxides of nitrogen and their catalytic removal from car engine exhaust gases?



Can you explain how NO and NO₂ react with unburned hydrocarbons to form peroxyacetyl nitrate, PAN, a component of photochemical smog?



Can you describe the role of NO and NO₂ in the formation of acid rain, both directly and in their catalytic role in the oxidation of atmospheric sulfur dioxide?



13.1-13.2

Formulae, naming and organic reactions

Formulae, functional groups and naming

Can you define the term hydrocarbon as a compound made up of carbon and hydrogen only?	☐	☐	☐
Can you recognise alkanes as simple hydrocarbons with no functional group?	☐	☐	☐
Can you explain that the functional group in alkenes, halogenoalkanes, alcohols, aldehydes, ketones, carboxylic acids, esters, amines and nitriles determines their physical and chemical properties?	☐	☐	☐
Can you interpret and use general, structural, displayed and skeletal formulae for the classes of compound in the syllabus?	☐	☐	☐
Can you name simple aliphatic organic molecules systematically, up to six carbon atoms (straight chains only for esters and nitriles)?	☐	☐	☐
Can you deduce the molecular and/or empirical formula of a compound from its structural, displayed or skeletal formula?	☐	☐	☐

Characteristic organic reactions

Can you use the terms homologous series, saturated and unsaturated?	☐	☐	☐
Can you use the terms homolytic fission and heterolytic fission?	☐	☐	☐
Can you use the terms free radical, initiation, propagation and termination?	☐	☐	☐
Can you use the terms nucleophile and electrophile?	☐	☐	☐
Can you use the reaction types addition, substitution, elimination, hydrolysis and condensation?	☐	☐	☐
Can you use the terms oxidation and reduction in organic chemistry, using [O] and [H] in equations?	☐	☐	☐
Can you describe the mechanism types free-radical substitution, electrophilic addition, nucleophilic substitution and nucleophilic addition?	☐	☐	☐
Can you draw curly arrows correctly, starting from a bond or a lone pair of electrons?	☐	☐	☐

13.3-13.4

Shapes of organic molecules and isomerism

Shapes of organic molecules; σ and π bonds

Can you describe organic molecules as straight-chained, branched or cyclic?	☐	☐	☐
Can you explain the shape of, and bond angles in, molecules containing sp , sp^2 and sp^3 hybridised atoms?	☐	☐	☐

Can you describe the arrangement of σ and π bonds in molecules containing sp, sp² and sp³ hybridised atoms?



Can you use the term planar to describe the arrangement of atoms in organic molecules, e.g. ethene?



Structural isomerism and stereoisomerism

Can you describe structural isomerism, including chain, positional and functional group isomerism?



Can you describe stereoisomerism, including geometrical (cis/trans) and optical isomerism?



Can you explain cis/trans isomerism in alkenes in terms of restricted rotation due to the presence of π bonds?



Can you explain what is meant by a chiral centre and explain that such a centre gives rise to two optical isomers (enantiomers)?



Can you identify chiral centres and cis/trans isomerism in a molecule from its structural formula, including cyclic compounds?



Can you deduce the possible isomers for an organic molecule of known molecular formula?



14.1

Alkanes

Production and reactions of alkanes

Can you recall the production of alkanes by hydrogenation of alkenes using H_2 and a Pt or Ni catalyst with heat?



Can you recall the production of alkanes by cracking a longer chain alkane using heated Al_2O_3 ?



Can you describe the complete and incomplete combustion of alkanes?



Can you describe the free-radical substitution of alkanes by Cl_2 or Br_2 in the presence of ultraviolet light, e.g. ethane?



Can you describe the mechanism of free-radical substitution with reference to the initiation, propagation and termination steps?



Can you explain how cracking produces more useful lower M_r alkanes and alkenes from heavier crude oil fractions?



Can you explain the general unreactivity of alkanes in terms of the strength and low polarity of the C-H bond?



Can you recognise the environmental consequences of CO, oxides of nitrogen and unburnt hydrocarbons from alkane combustion, and their catalytic removal from exhaust gases?



14.2

Alkenes

Production of alkenes

Can you recall the production of alkenes by elimination of HX from a halogenoalkane using ethanolic NaOH and heat?



Can you recall the production of alkenes by dehydration of an alcohol using heated Al_2O_3 or concentrated acid?



Can you recall the production of alkenes by cracking a longer chain alkane?



Reactions of alkenes

Can you describe the electrophilic addition of hydrogen to alkenes using a Pt or Ni catalyst and heat?



Can you describe the electrophilic addition of steam to alkenes using an H_3PO_4 catalyst?



Can you describe the electrophilic addition of a hydrogen halide, $HX(g)$, to alkenes at room temperature?



Can you describe the electrophilic addition of a halogen, X_2 , to alkenes?



Can you describe the oxidation of alkenes by cold dilute acidified KMnO_4 to form a diol?



Can you describe the oxidation of alkenes by hot concentrated acidified KMnO_4 , and use the products to find the position of the $\text{C}=\text{C}$ in larger molecules?



Can you describe the addition polymerisation of ethene and propene?



Can you use aqueous bromine to show the presence of a $\text{C}=\text{C}$ bond?



Mechanism and Markovnikov addition

Can you describe the mechanism of electrophilic addition in alkenes, using bromine with ethene and hydrogen bromide with propene as examples?



Can you describe and explain the inductive effects of alkyl groups on the stability of primary, secondary and tertiary carbocations?



Can you use carbocation stability to explain Markovnikov addition?



Production of halogenoalkanes

Can you recall the production of halogenoalkanes by free-radical substitution of alkanes with Cl_2 or Br_2 in ultraviolet light?



Can you recall the production of halogenoalkanes by electrophilic addition of X_2 or HX(g) to an alkene at room temperature?



Can you recall the production of halogenoalkanes from alcohols using HX(g) , KCl and concentrated H_2SO_4 or H_3PO_4 , PCl_3 and heat, PCl_5 , or SOCl_2 ?



Can you classify halogenoalkanes as primary, secondary or tertiary?

**Reactions of halogenoalkanes**

Can you describe the nucleophilic substitution of halogenoalkanes with NaOH(aq) and heat to form an alcohol?



Can you describe the nucleophilic substitution of halogenoalkanes with KCN in ethanol and heat to form a nitrile?



Can you describe the nucleophilic substitution of halogenoalkanes with NH_3 in ethanol heated under pressure to form an amine?



Can you describe the reaction of halogenoalkanes with aqueous silver nitrate in ethanol to identify the halogen present, e.g. bromoethane?



Can you describe the elimination reaction of halogenoalkanes with NaOH in ethanol and heat to form an alkene, e.g. bromoethane?

**Mechanisms and reactivity**

Can you describe the SN_1 and SN_2 mechanisms of nucleophilic substitution, including the inductive effects of alkyl groups?



Can you recall that primary halogenoalkanes tend to react by SN_2 , tertiary by SN_1 , and secondary by a mixture of the two depending on structure?



Can you explain the different reactivities of halogenoalkanes in terms of C-X bond strengths, e.g. with aqueous silver nitrate?



Production of alcohols

Can you recall the production of alcohols by electrophilic addition of steam to an alkene with an H_3PO_4 catalyst?



Can you recall the production of diols by reaction of alkenes with cold dilute acidified KMnO_4 ?



Can you recall the production of alcohols by substitution of a halogenoalkane using NaOH(aq) and heat?



Can you recall the production of alcohols by reduction of an aldehyde or ketone using NaBH_4 or LiAlH_4 ?



Can you recall the production of alcohols by reduction of a carboxylic acid using LiAlH_4 ?



Can you recall the production of alcohols by hydrolysis of an ester using dilute acid or dilute alkali and heat?

**Reactions of alcohols**

Can you describe the combustion of alcohols?



Can you describe the substitution of alcohols to form halogenoalkanes?



Can you describe the reaction of alcohols with Na(s) to produce hydrogen gas and sodium alkoxide?



Can you describe the oxidation of alcohols with acidified $\text{K}_2\text{Cr}_2\text{O}_7$ or acidified KMnO_4 to form carbonyl compounds by distillation?



Can you describe the oxidation of alcohols with acidified $\text{K}_2\text{Cr}_2\text{O}_7$ or acidified KMnO_4 to form carboxylic acids by refluxing?



Can you describe the dehydration of alcohols to form an alkene using heated Al_2O_3 or concentrated acid?



Can you describe the formation of esters by reaction of alcohols with carboxylic acids and a concentrated H_2SO_4 catalyst, e.g. ethanol?

**Classifying and testing alcohols**

Can you classify alcohols as primary, secondary or tertiary, including polyhydric alcohols?



Can you state the characteristic distinguishing reactions of primary, secondary and tertiary alcohols, e.g. the orange to green colour change with acidified $\text{K}_2\text{Cr}_2\text{O}_7$?



Can you use the reaction with alkaline $\text{I}_2(\text{aq})$ to give a yellow precipitate of tri-iodomethane to detect a $\text{CH}_3\text{CH(OH)-}$ group, forming RCO_2^- ?



Can you explain the acidity of alcohols compared with water?



Production and reactions

Can you recall the production of aldehydes by oxidation of primary alcohols using acidified $\text{K}_2\text{Cr}_2\text{O}_7$ or acidified KMnO_4 and distillation?



Can you recall the production of ketones by oxidation of secondary alcohols using acidified $\text{K}_2\text{Cr}_2\text{O}_7$ or acidified KMnO_4 and distillation?



Can you describe the reduction of aldehydes and ketones using NaBH_4 or LiAlH_4 to form alcohols?



Can you describe the reaction of aldehydes and ketones with HCN , KCN as catalyst, and heat to form hydroxynitriles, e.g. ethanal and propanone?



Can you describe the mechanism of nucleophilic addition reactions of HCN with aldehydes and ketones?

**Tests for carbonyl compounds**

Can you use 2,4-dinitrophenylhydrazine (2,4-DNPH) reagent to detect the presence of carbonyl compounds?



Can you deduce the nature of a carbonyl compound (aldehyde or ketone) using Fehling's and Tollens' reagents and ease of oxidation?



Can you use the reaction with alkaline $\text{I}_2(\text{aq})$ to give a yellow precipitate of triiodomethane to detect a CH_3CO^- group, forming RCO_2^- ?



18.1 Carboxylic acids

Can you recall the production of carboxylic acids by oxidation of primary alcohols and aldehydes with acidified $\text{K}_2\text{Cr}_2\text{O}_7$ or acidified KMnO_4 and refluxing?



Can you recall the production of carboxylic acids by hydrolysis of nitriles with dilute acid or dilute alkali followed by acidification?



Can you recall the production of carboxylic acids by hydrolysis of esters with dilute acid or dilute alkali and heat followed by acidification?



Can you describe the redox reaction of carboxylic acids with reactive metals to form a salt and H_2 ?



Can you describe the neutralisation reaction of carboxylic acids with alkalis to form a salt and H_2O ?



Can you describe the reaction of carboxylic acids with carbonates to form a salt, H_2O and CO_2 ?



Can you describe the esterification of carboxylic acids with alcohols using a concentrated H_2SO_4 catalyst?



Can you describe the reduction of carboxylic acids by LiAlH_4 to form a primary alcohol?

**18.2 Esters**

Can you recall the production of esters by condensation of an alcohol and a carboxylic acid with a concentrated H_2SO_4 catalyst?



Can you describe the hydrolysis of esters by dilute acid and by dilute alkali with heat?



19.1 Primary amines

Can you recall the production of amines by reaction of a halogenoalkane with NH_3 in ethanol heated under pressure?

**19.2 Nitriles and hydroxynitriles**

Can you recall the production of nitriles by reaction of a halogenoalkane with KCN in ethanol and heat?



Can you recall the production of hydroxynitriles by reaction of aldehydes and ketones with HCN, KCN as catalyst, and heat?



Can you describe the hydrolysis of nitriles with dilute acid or dilute alkali followed by acidification to form a carboxylic acid?



Addition polymerisation

Can you describe addition polymerisation, e.g. poly(ethene) and poly(chloroethene), PVC?



Can you deduce the repeat unit of an addition polymer from a given monomer?



Can you identify the monomer(s) present in a given section of an addition polymer molecule?



Can you recognise the difficulty of disposing of poly(alkene)s, including non-biodegradability and harmful combustion products?



Organic synthesis

Can you identify the functional groups in an organic molecule containing several functional groups using reactions in the syllabus?



Can you predict the properties and reactions of an organic molecule containing several functional groups?



Can you devise multi-step synthetic routes for preparing organic molecules using reactions in the syllabus?



Can you analyse a given synthetic route in terms of the type of reaction and reagents used for each step, and possible by-products?



22.1 Infrared spectroscopy

Can you analyse an infrared spectrum of a simple molecule to identify functional groups using the Data section of the syllabus?

**22.2 Mass spectrometry**

Can you analyse mass spectra in terms of m/e values and isotopic abundances (knowledge of how the mass spectrometer works is not needed)?



Can you calculate the relative atomic mass of an element from the relative abundances of its isotopes or from its mass spectrum?



Can you deduce the molecular mass of an organic molecule from the molecular ion peak in a mass spectrum?



Can you suggest the identity of molecules formed by simple fragmentation in a given mass spectrum?



Can you deduce the number of carbon atoms, n , in a compound using the $[M+1]^+$ peak and $n = (100 \times \text{abundance of } [M+1]^+) / (1.1 \times \text{abundance of } M^+)$?



Can you deduce the presence of bromine and chlorine atoms in a compound using the $[M+2]^+$ peak?



23.1

Lattice energy and Born-Haber cycles

A-LEVEL ONLY

Lattice energy and Born-Haber cycles

- | | |
|---|---|
| Can you define and use the term enthalpy change of atomisation, ΔH_{at} ? | ☐ ☐ ☐ |
| Can you define and use the term lattice energy, ΔH_{latt} , as the enthalpy change when 1 mole of an ionic compound is formed from its gaseous ions? | ☐ ☐ ☐ |
| Can you define and use the term first electron affinity, EA? | ☐ ☐ ☐ |
| Can you explain the factors affecting the electron affinities of elements? | ☐ ☐ ☐ |
| Can you describe and explain the trends in the electron affinities of the Group 16 and Group 17 elements? | ☐ ☐ ☐ |
| Can you construct and use Born-Haber cycles for ionic solids (limited to +1 and +2 cations and -1 and -2 anions)? | ☐ ☐ ☐ |
| Can you carry out calculations involving Born-Haber cycles? | ☐ ☐ ☐ |
| Can you explain, in qualitative terms, the effect of ionic charge and ionic radius on the numerical magnitude of a lattice energy? | ☐ ☐ ☐ |

23.2

Enthalpies of solution and hydration

A-LEVEL ONLY

Enthalpies of solution and hydration

- | | |
|---|---|
| Can you define and use the term enthalpy change of hydration, ΔH_{hyd} ? | ☐ ☐ ☐ |
| Can you define and use the term enthalpy change of solution, ΔH_{sol} ? | ☐ ☐ ☐ |
| Can you construct and use an energy cycle involving enthalpy change of solution, lattice energy and enthalpy change of hydration? | ☐ ☐ ☐ |
| Can you carry out calculations involving these energy cycles? | ☐ ☐ ☐ |
| Can you explain, in qualitative terms, the effect of ionic charge and ionic radius on the numerical magnitude of an enthalpy change of hydration? | ☐ ☐ ☐ |

23.3-23.4

Entropy and Gibbs free energy

A-LEVEL ONLY

Entropy change, ΔS

- | | |
|--|---|
| Can you define the term entropy, S , as the number of possible arrangements of the particles and their energy in a given system? | ☐ ☐ ☐ |
| Can you predict and explain the sign of the entropy change for changes in state, dissolving of a solid and the reverse processes? | ☐ ☐ ☐ |

Can you predict and explain the sign of the entropy change when the temperature of a system changes?



Can you predict and explain the sign of the entropy change for a reaction in which there is a change in the number of gaseous molecules?



Can you calculate the entropy change for a reaction, ΔS , given the standard entropies, $S^\ominus$, of the reactants and products?



Gibbs free energy change, ΔG

Can you state and use the Gibbs equation $\Delta G^\ominus = \Delta H^\ominus - T\Delta S^\ominus$?



Can you perform calculations using $\Delta G^\ominus = \Delta H^\ominus - T\Delta S^\ominus$?



Can you state whether a reaction or process will be feasible by using the sign of ΔG ?



Can you predict the effect of temperature change on the feasibility of a reaction, given standard enthalpy and entropy changes?



24.1

Electrolysis

A-LEVEL ONLY

Electrolysis

Can you predict the identities of substances liberated during electrolysis from the state of the electrolyte, position in the redox series (electrode potential) and concentration?



Can you state and apply the relationship $F = Le$ between the Faraday constant, the Avogadro constant and the charge on the electron?



Can you calculate the quantity of charge passed during electrolysis using $Q = It$?



Can you calculate the mass and/or volume of substance liberated during electrolysis?



Can you describe the determination of a value of the Avogadro constant by an electrolytic method?



24.2

Electrode potentials and the Nernst equation

A-LEVEL ONLY

Standard electrode potentials and cells

Can you define the terms standard electrode (reduction) potential and standard cell potential?



Can you describe the standard hydrogen electrode?



Can you describe methods used to measure the standard electrode potentials of metals or non-metals in contact with their ions in aqueous solution?



Can you describe methods used to measure the standard electrode potentials of ions of the same element in different oxidation states?



Can you calculate a standard cell potential by combining two standard electrode potentials?



Can you use standard cell potentials to deduce the polarity of each electrode and the direction of electron flow in the external circuit?



Can you use standard cell potentials to predict the feasibility of a reaction?



Can you deduce from $E^\ominus$ values the relative reactivity of elements, compounds and ions as oxidising agents or reducing agents?



Can you construct redox equations using the relevant half-equations?



Concentration effects and free energy

Can you predict qualitatively how the value of an electrode potential, E , varies with the concentration of the aqueous ion?



Can you use the Nernst equation, e.g. $E = E^\ominus + (0.059/z) \log([\text{oxidised species}]/[\text{reduced species}])$, to predict quantitatively how E varies with ion concentration, e.g. for Cu^{2+}/Cu and $\text{Fe}^{3+}/\text{Fe}^{2+}$?



Can you understand and use the equation $\Delta G^\ominus = -nE^\ominus_{\text{cell}}F$?



25.1

Acids and bases

A-LEVEL ONLY

Conjugate pairs and pH calculations

- | | | | |
|--|-----------------------|-----------------------|-----------------------|
| Can you understand and use the terms conjugate acid and conjugate base? | ☐ | ☐ | ☐ |
| Can you define conjugate acid-base pairs and identify such pairs in reactions? | ☐ | ☐ | ☐ |
| Can you define mathematically the terms pH, K_a , pK_a and K_w , and use them in calculations? | ☐ | ☐ | ☐ |
| Can you calculate $[H^+(aq)]$ and pH values for strong acids? | ☐ | ☐ | ☐ |
| Can you calculate $[H^+(aq)]$ and pH values for strong alkalis? | ☐ | ☐ | ☐ |
| Can you calculate $[H^+(aq)]$ and pH values for weak acids? | ☐ | ☐ | ☐ |

Buffer solutions

- | | | | |
|--|-----------------------|-----------------------|-----------------------|
| Can you define a buffer solution? | ☐ | ☐ | ☐ |
| Can you explain how a buffer solution can be made? | ☐ | ☐ | ☐ |
| Can you explain how buffer solutions control pH, using chemical equations? | ☐ | ☐ | ☐ |
| Can you describe and explain the uses of buffer solutions, including the role of HCO_3^- in controlling pH in blood? | ☐ | ☐ | ☐ |
| Can you calculate the pH of buffer solutions, and the concentrations needed, from given data? | ☐ | ☐ | ☐ |

Solubility product

- | | | | |
|---|-----------------------|-----------------------|-----------------------|
| Can you understand and use the term solubility product, K_{sp} ? | ☐ | ☐ | ☐ |
| Can you write an expression for K_{sp} ? | ☐ | ☐ | ☐ |
| Can you calculate K_{sp} from concentrations and vice versa? | ☐ | ☐ | ☐ |
| Can you understand and use the common ion effect to explain the different solubility of a compound in a solution containing a common ion? | ☐ | ☐ | ☐ |
| Can you perform calculations using K_{sp} values and the concentration of a common ion? | ☐ | ☐ | ☐ |

25.2

Partition coefficients

A-LEVEL ONLY

Partition coefficients

- | | | | |
|---|-----------------------|-----------------------|-----------------------|
| Can you state what is meant by the term partition coefficient, K_{pc} ? | ☐ | ☐ | ☐ |
|---|-----------------------|-----------------------|-----------------------|

Can you calculate and use a partition coefficient for a system in which the solute is in the same physical state in the two solvents?



Can you explain how the relative polarities of the solute and solvents affect the numerical value of a partition coefficient?



26.1

Rate equations, orders and rate constants

A-LEVEL ONLY

Rate equations and orders

Can you explain and use the terms rate equation, order of reaction, overall order of reaction, rate constant, half-life, rate-determining step and intermediate?



Can you understand and use rate equations of the form $\text{rate} = k[\text{A}]^m[\text{B}]^n$, where m and n are 0, 1 or 2?



Can you deduce the order of a reaction from concentration-time graphs or from experimental data on initial rates and half-lives?



Can you interpret experimental data in graphical form, including concentration-time and rate-concentration graphs?



Can you calculate an initial rate using concentration data?



Can you construct a rate equation?



Half-life and rate constants

Can you show understanding that the half-life of a first-order reaction is independent of concentration?



Can you use the half-life of a first-order reaction in calculations?



Can you calculate the numerical value of a rate constant using initial rates and the rate equation?



Can you calculate the numerical value of a rate constant using the half-life and $k = 0.693/t_{1/2}$?



Can you describe qualitatively the effect of temperature change on the rate constant and hence the rate of reaction?



Mechanisms and rate-determining steps

Can you suggest a multi-step reaction mechanism that is consistent with the rate equation and the overall equation?



Can you predict the order of a reaction from a given multi-step mechanism and its rate-determining step?



Can you deduce a rate equation from a given multi-step mechanism with a rate-determining step?



Can you identify an intermediate or a catalyst from a given reaction mechanism?



Can you identify the rate-determining step from a rate equation and a given reaction mechanism?



26.2

Homogeneous and heterogeneous catalysts

A-LEVEL ONLY

Catalysts

Can you explain that catalysts can be homogeneous or heterogeneous?



Can you describe heterogeneous catalysis in terms of adsorption of reactants, bond weakening and desorption of products, e.g. iron in the Haber process?



Can you describe heterogeneous catalysis by palladium, platinum and rhodium in the catalytic removal of oxides of nitrogen from car exhaust gases?



Can you describe homogeneous catalysis as the catalyst being used in one step and reformed in a later step, e.g. atmospheric oxides of nitrogen in the oxidation of atmospheric sulfur dioxide?



Can you describe homogeneous catalysis by Fe^{2+} or Fe^{3+} in the reaction between I^- and $\text{S}_2\text{O}_8^{2-}$?



Thermal stability and solubility

Can you describe and explain qualitatively the trend in the thermal stability of Group 2 nitrates and carbonates, including the effect of ionic radius on the polarisation of the large anion?



Can you describe and explain qualitatively the variation in solubility and ΔH_{sol} of the Group 2 hydroxides and sulfates in terms of the relative sizes of enthalpy change of hydration and lattice energy?



28.1

General properties of the first row transition elements

A-LEVEL ONLY

General properties, titanium to copper

Can you define a transition element as a d-block element that forms one or more stable ions with incomplete d orbitals?	☐	☐	☐
Can you sketch the shape of a 3dxy orbital and a 3dz ² orbital?	☐	☐	☐
Can you state that transition elements have variable oxidation states?	☐	☐	☐
Can you state that transition elements behave as catalysts?	☐	☐	☐
Can you state that transition elements form complex ions?	☐	☐	☐
Can you state that transition elements form coloured compounds?	☐	☐	☐
Can you explain why transition elements have variable oxidation states in terms of the similarity in energy of the 3d and 4s sub-shells?	☐	☐	☐
Can you explain why transition elements behave as catalysts in terms of having more than one stable oxidation state and vacant d orbitals that can form dative bonds with ligands?	☐	☐	☐
Can you explain why transition elements form complex ions in terms of vacant d orbitals that are energetically accessible?	☐	☐	☐

28.2

Chemical properties of the first row transition elements

A-LEVEL ONLY

Ligands and complexes

Can you describe and explain the reactions of transition elements with ligands to form complexes, including Cu(II) and Co(II) ions with water, ammonia, hydroxide and chloride ions?	☐	☐	☐
Can you define a ligand as a species that contains a lone pair of electrons that forms a dative covalent bond to a central metal atom or ion?	☐	☐	☐
Can you use the term monodentate ligand, e.g. H ₂ O, NH ₃ , Cl ⁻ and CN ⁻ ?	☐	☐	☐
Can you use the term bidentate ligand, e.g. 1,2-diaminoethane (en) and the ethanedioate ion, C ₂ O ₄ ²⁻ ?	☐	☐	☐
Can you use the term polydentate ligand, e.g. EDTA ⁴⁻ ?	☐	☐	☐
Can you define a complex as a molecule or ion formed by a central metal atom or ion surrounded by one or more ligands?	☐	☐	☐
Can you describe the geometry of linear, square planar, tetrahedral and octahedral complexes?	☐	☐	☐

Can you state what is meant by coordination number?



Can you predict the formula and charge of a complex ion from the metal ion, ligand and coordination number?



Can you explain qualitatively that ligand exchange can occur, including the complexes of Cu(II) and Co(II) ions?



Redox chemistry of transition elements

Can you predict, using $E^\ominus$ values, the feasibility of redox reactions involving transition elements and their ions?



Can you describe the reaction, and carry out calculations, involving MnO_4^- and $\text{C}_2\text{O}_4^{2-}$ in acid solution?



Can you describe the reaction, and carry out calculations, involving MnO_4^- and Fe^{2+} in acid solution?



Can you describe the reaction, and carry out calculations, involving Cu^{2+} and I^- ?



Can you perform calculations involving other redox systems given suitable information?



28.3

Colour of complexes

A-LEVEL ONLY

Colour of complexes

Can you define and use the terms degenerate and non-degenerate d orbitals?



Can you describe the splitting of degenerate d orbitals into two energy levels in octahedral complexes (two higher, three lower) using ΔE ?



Can you describe the splitting of degenerate d orbitals into two energy levels in tetrahedral complexes (three higher, two lower) using ΔE ?



Can you explain the origin of colour in transition element complexes in terms of absorption of light when an electron is promoted between non-degenerate d orbitals?



Can you describe, in qualitative terms, the effects of different ligands on ΔE , the frequency of light absorbed and hence the complementary colour observed?



Can you use the complexes of Cu(II) and Co(II) ions with water, ammonia, hydroxide and chloride ions as examples of ligand exchange affecting the colour observed?



Stereoisomerism in transition element complexes

Can you describe the types of stereoisomerism shown by complexes, including geometrical (cis/trans) isomerism in square planar complexes such as $[\text{Pt}(\text{NH}_3)_2\text{Cl}_2]$ and octahedral complexes such as $[\text{Co}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+}$ and $[\text{Ni}(\text{en})_2(\text{H}_2\text{O})_2]^{2+}$?



Can you describe optical isomerism in octahedral complexes such as $[\text{Ni}(\text{en})_3]^{2+}$ and $[\text{Ni}(\text{en})_2(\text{H}_2\text{O})_2]^{2+}$?



Can you deduce the overall polarity of complexes such as those described above?

**Stability constants, Kstab**

Can you define the stability constant, Kstab, of a complex as the equilibrium constant for the formation of the complex ion in a solvent from its constituent ions or molecules?



Can you write an expression for Kstab, excluding $[\text{H}_2\text{O}]$?



Can you perform calculations involving Kstab?



Can you describe and explain ligand exchanges in terms of Kstab values, understanding that a large Kstab is due to the formation of a stable complex ion?



29.1 Formulae, functional groups and naming

Can you explain that the functional groups in arenes, halogenoarenes, phenols, acyl chlorides, amides, amino acids and the other classes in the syllabus determine their properties?



Can you interpret and use general, structural, displayed and skeletal formulae for these classes of compound?



Can you name simple aliphatic molecules containing these functional groups, up to six carbon atoms, including cyclic compounds with one ring?



Can you name simple aromatic molecules with one benzene ring and one or more simple substituents, e.g. 3-nitrobenzoic acid and 2,4,6-tribromophenol?

**29.2 Characteristic organic reactions**

Can you understand and use the mechanism terms electrophilic substitution and addition-elimination?

**29.3 Shapes of aromatic organic molecules; σ and π bonds**

Can you describe and explain the shape of benzene and other aromatic molecules, including sp^2 hybridisation, σ bonds and a delocalised π system?

**29.4 Isomerism: optical**

Can you explain that enantiomers have identical physical and chemical properties apart from their ability to rotate plane-polarised light and their potential biological activity?



Can you understand and use the terms optically active and racemic mixture?



Can you describe the effect of each of two optical isomers on plane-polarised light?



Can you explain the relevance of chirality to drug action, including that the two enantiomers may have very different biological activity?



Can you explain the need to separate racemic mixtures in drug production?



Can you explain the use of chiral catalysts to produce a single pure optical isomer?



Reactions of arenes

Can you describe the substitution of benzene and methylbenzene by Cl_2 or Br_2 with an AlCl_3 or AlBr_3 catalyst to form halogenoarenes?



Can you describe the nitration of benzene and methylbenzene with a mixture of concentrated HNO_3 and concentrated H_2SO_4 at 25-60 °C?



Can you describe Friedel-Crafts alkylation of benzene and methylbenzene using CH_3Cl and an AlCl_3 catalyst with heat?



Can you describe Friedel-Crafts acylation of benzene and methylbenzene using CH_3COCl and an AlCl_3 catalyst with heat?



Can you describe the complete oxidation of the side-chain of alkylbenzenes using hot alkaline KMnO_4 followed by dilute acid to give benzoic acid?



Can you describe the hydrogenation of the benzene ring using H_2 and a Pt or Ni catalyst with heat to form a cyclohexane ring?

**Mechanism and directing effects**

Can you describe the mechanism of electrophilic substitution in arenes, using the formation of nitrobenzene and bromobenzene as examples?



Can you explain why the delocalised π system in benzene makes arenes undergo substitution rather than addition reactions?



Can you predict whether halogenation will occur in the side-chain or in the benzene ring of an arene depending on the reaction conditions?



Can you apply knowledge of the directing effects of $-\text{NH}_2$, $-\text{OH}$, $-\text{R}$, $-\text{NO}_2$, $-\text{COOH}$ and $-\text{COR}$ substituents to predict the position of electrophilic substitution in aromatic compounds?



Halogenoarenes

Can you recall the production of halogenoarenes by reaction of benzene or methylbenzene with Cl_2 or Br_2 and a catalyst, including the formation of 2- and 4-chloromethylbenzene?



Can you explain the difference in reactivity between a halogenoalkane and a halogenoarene, e.g. chloroethane and chlorobenzene?



32.1 Alcohols

Can you describe the formation of esters by reaction of alcohols with acyl chlorides, e.g. ethyl ethanoate?

**32.2 Phenol**

Can you recall the production of phenol from phenylamine via a diazonium salt, followed by warming with water?



Can you recall the reaction of phenol with bases, e.g. NaOH(aq), to produce sodium phenoxide?



Can you recall the reaction of phenol with Na(s) to produce sodium phenoxide and H₂(g)?



Can you recall the reaction of phenol in NaOH(aq) with diazonium salts to give azo compounds?



Can you recall the nitration of phenol's aromatic ring with dilute HNO₃(aq) at room temperature to give a mixture of 2-nitrophenol and 4-nitrophenol?



Can you recall the bromination of phenol with Br₂(aq) to form 2,4,6-tribromophenol?



Can you explain the acidity of phenol?



Can you describe and explain the relative acidities of water, phenol and ethanol?



Can you explain why the reagents and conditions for nitration and bromination of phenol are different from those for benzene?



Can you recall that the hydroxyl group of phenol directs substitution to the 2-, 4- and 6-positions?



Can you apply the chemistry of phenol to related compounds, e.g. naphthol?



33.1-33.2

Carboxylic acids and esters

A-LEVEL ONLY

33.1 Carboxylic acids

Can you recall the production of benzoic acid by oxidation of an alkylbenzene with hot alkaline KMnO_4 followed by dilute acid?



Can you describe the formation of acyl chlorides from carboxylic acids using PCl_3 and heat, PCl_5 or SOCl_2 ?



Can you recognise that methanoic acid can be further oxidised?



Can you recognise that ethanedioic acid can be further oxidised?



Can you describe and explain the relative acidities of carboxylic acids, phenols and alcohols?



Can you describe and explain the relative acidities of chlorine-substituted carboxylic acids?



33.2 Esters

Can you recall the production of esters by reaction of alcohols or phenols with acyl chlorides, e.g. ethyl ethanoate and phenyl benzoate?



33.3

Acyl chlorides

A-LEVEL ONLY

Acyl chlorides

Can you recall the production of acyl chlorides from carboxylic acids using PCl_3 and heat, PCl_5 or SOCl_2 ?



Can you describe the hydrolysis of acyl chlorides with water at room temperature to give a carboxylic acid and HCl ?



Can you describe the reaction of acyl chlorides with alcohols at room temperature to give an ester and HCl ?



Can you describe the reaction of acyl chlorides with phenols at room temperature to give an ester and HCl ?



Can you describe the reaction of acyl chlorides with ammonia at room temperature to give an amide and HCl ?



Can you describe the reaction of acyl chlorides with primary or secondary amines at room temperature to give an amide and HCl ?



Can you describe the addition-elimination mechanism for the reactions of acyl chlorides?



Can you explain the relative ease of hydrolysis of acyl chlorides, alkyl chlorides and halogenoarenes (aryl chlorides)?



34.1-34.2

Amines and phenylamine

A-LEVEL ONLY

34.1 Primary and secondary amines

Can you recall the production of alkyl amines by reaction of ammonia with halogenoalkanes (in ethanol, heated under pressure)?	☐	☐	☐
Can you recall the production of secondary amines by reaction of primary amines with halogenoalkanes?	☐	☐	☐
Can you recall the production of alkyl amines by reduction of amides with LiAlH_4 ?	☐	☐	☐
Can you recall the production of alkyl amines by reduction of nitriles with LiAlH_4 or H_2 and a Ni catalyst?	☐	☐	☐
Can you describe the formation of amides by reaction of ammonia or amines with acyl chlorides at room temperature?	☐	☐	☐
Can you describe and explain the basicity of aqueous solutions of amines?	☐	☐	☐

34.2 Phenylamine and azo compounds

Can you describe the preparation of phenylamine by nitration of benzene followed by reduction with hot Sn/concentrated HCl and then NaOH(aq) ?	☐	☐	☐
Can you describe the reaction of phenylamine with $\text{Br}_2(\text{aq})$ at room temperature?	☐	☐	☐
Can you describe the reaction of phenylamine with HNO_2 (NaNO_2 and dilute acid) below 10°C to form a diazonium salt, followed by warming to give phenol?	☐	☐	☐
Can you describe and explain the relative basicities of aqueous ammonia, ethylamine and phenylamine?	☐	☐	☐
Can you recall the coupling of benzenediazonium chloride with phenol in NaOH(aq) to form an azo compound?	☐	☐	☐
Can you identify the azo group in a molecule?	☐	☐	☐
Can you state that azo compounds are often used as dyes?	☐	☐	☐
Can you suggest other azo dyes that could be formed by this coupling method?	☐	☐	☐

34.3-34.4

Amides and amino acids

A-LEVEL ONLY

34.3 Amides

Can you recall the production of amides by reaction of ammonia or primary amines with acyl chlorides at room temperature?	☐	☐	☐
Can you describe the hydrolysis of amides on heating with aqueous acid or aqueous alkali?	☐	☐	☐

Can you describe the reduction of the $\text{C}=\text{O}$ in amides to CH_2 using LiAlH_4 to form an amine?



Can you state and explain why amides are much weaker bases than amines?



34.4 Amino acids

Can you describe the acid/base properties of amino acids and the formation of zwitterions, including the isoelectric point?



Can you describe the formation of amide (peptide) bonds between amino acids to give di- and tripeptides?



Can you interpret and predict the results of electrophoresis on mixtures of amino acids and dipeptides at different pHs?



35.1 Condensation polymerisation

Can you describe the formation of polyesters from a diol and a dicarboxylic acid or dioyl chloride?



Can you describe the formation of polyesters from a hydroxycarboxylic acid?



Can you describe the formation of polyamides from a diamine and a dicarboxylic acid or dioyl chloride?



Can you describe the formation of polyamides from an aminocarboxylic acid?



Can you describe the formation of polyamides from amino acids?



Can you deduce the repeat unit of a condensation polymer from a given monomer or pair of monomers?



Can you identify the monomer(s) present in a given section of a condensation polymer molecule?

**35.2 Predicting the type of polymerisation**

Can you predict the type of polymerisation reaction for a given monomer or pair of monomers?



Can you deduce the type of polymerisation reaction that produces a given section of a polymer molecule?

**35.3 Degradable polymers**

Can you recognise that poly(alkenes) are chemically inert and therefore difficult to biodegrade?



Can you recognise that some polymers can be degraded by the action of light?



Can you recognise that polyesters and polyamides are biodegradable by acidic and alkaline hydrolysis?



Organic synthesis

Can you identify the functional groups in an organic molecule containing several functional groups, using the reactions in the syllabus?



Can you predict the properties and reactions of an organic molecule containing several functional groups?



Can you devise multi-step synthetic routes for preparing organic molecules using the reactions in the syllabus?



Can you analyse a given synthetic route in terms of the type of reaction and reagents used for each step, and possible by-products?



37.1-37.2

Chromatography

A-LEVEL ONLY

Thin-layer chromatography

Can you describe and use the terms stationary phase (e.g. aluminium oxide on a solid support) and mobile phase (a polar or non-polar solvent) in thin-layer chromatography?



Can you describe and use the terms R_f value, solvent front and baseline?



Can you interpret R_f values?



Can you explain differences in R_f values in terms of interaction with the stationary phase and relative solubility in the mobile phase?

**Gas/liquid chromatography**

Can you describe and use the terms stationary phase (a high boiling point non-polar liquid on a solid support), mobile phase (an unreactive gas) and retention time in gas/liquid chromatography?



Can you interpret gas/liquid chromatograms in terms of the percentage composition of a mixture?



Can you explain retention times in terms of interaction with the stationary phase?



37.3-37.4

NMR spectroscopy

A-LEVEL ONLY

Carbon-13 NMR spectroscopy

Can you analyse a carbon-13 NMR spectrum of a simple molecule to deduce the different environments of the carbon atoms present?



Can you analyse a carbon-13 NMR spectrum of a simple molecule to deduce possible structures for the molecule?



Can you predict or explain the number of peaks in a carbon-13 NMR spectrum for a given molecule?

**Proton (^1H) NMR spectroscopy**

Can you analyse a ^1H NMR spectrum to deduce the different types of proton present from chemical shift values?



Can you analyse a ^1H NMR spectrum to deduce the relative numbers of each type of proton from relative peak areas?



Can you use the $n + 1$ rule to deduce the number of equivalent protons on adjacent carbon atoms from splitting patterns (singlet, doublet, triplet, quartet and multiplet)?



Can you analyse a ^1H NMR spectrum of a simple molecule to deduce possible structures for the molecule?



Can you predict the chemical shifts and splitting patterns of the protons in a given molecule?



Can you describe the use of tetramethylsilane, TMS, as the standard for chemical shift measurements?



Can you state the need for deuterated solvents, e.g. CDCl_3 , when obtaining a ^1H NMR spectrum?



Can you describe the identification of O-H and N-H protons by proton exchange using D_2O ?

