Chemistry AS level Specification

Physical Chemistry

ATOMIC STRUCTURE			
1.1 Fundamental particles			
Appreciate that knowledge and understanding of atomic structure has evolved over time			
Protons, neutrons and electrons: relative charge & relative mass			
An atom consists of a nucleus containing protons and neutrons surrounded by electrons			
1.2 Mass number and isotopes			
Mass number (A) and atomic (proton) number (Z)			
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 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			
Interpret simple mass spectra of elements			
Calculate relative atomic mass from isotopic abundance, limited to mononuclear ions			
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			
Define first ionisation energy			
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			

AMOUNT OF SUBSTANCE			
1.4 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			
Define relative atomic mass (A_r)			
Define relative molecular mass (M_r)			
1.5 The mole & Avogadro's 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}			
Calculations using:			
• avogadro's constant (do not need to learn the value)			
• using mass of substance, M_r, amount in moles			
• using concentration, volume and amount of substance in a solution			
1.6 Ideal gas equation			
The ideal gas equation $pV = nRT$ with the variables in SI units			
Use the equation in calculations (do not need to learn gas constant value, R)			
1.7 Empirical & molecular formula			
Empirical formula is the simplest whole number ratio of atoms of each element in a compound			
Molecular formula is the actual number of atoms of each element in a compound			
The relationship between empirical formula and molecular formula			
Calculate empirical formula from data giving composition by mass or % by mass			
Calculate molecular formula from empirical formula & relative molecular mass			
1.8 Balanced equations and associated calculations			
Equations (full and ionic)			
Percentage atom economy = (M_r of desired product / sum of molecular masses of all reactants) x 100			
Economic, ethical and environmental advantages for society and for industry of developing chemical processes with a high atom economy			

Write balanced equations for reactions studied			
Balance equations for unfamiliar reactions when reactants and products are specified			
Use balanced equations to calculate:			
• masses			
• volumes of gases			
• percentage yields			
• percentage atom economies			
• concentrations and volumes for reactions in solutions			
Required practical 1: make up a volumetric solution and carry out a simple acid-base titration			

BONDING			
1.9 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			
Predict charge on a simple ion using the position of the element in the periodic table			
Construct formulas for ionic compounds			
1.10 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			
Represent a covalent bond using a line			
Represent a dative covalent bond using an arrow			
1.11 Metallic bonding			
Metallic bonding involves attraction between delocalised electrons and positive ions arranged in a lattice			
1.12 Bonding and physical properties			
The four types of crystal structure: ionic, metallic, macromolecular (giant covalent) & covalent molecular			

The structures of the following crystals as examples of these four types of crystal structure:			
• diamond			
• graphite			
• ice			
• iodine			
• magnesium			
• sodium chloride			
Know how 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 the structures above involving specified numbers of particles			
1.13 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			
1.14 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			
Know how to use partial charges to show that a bond is polar			
Explain why some molecules with polar bonds do not have a permanent dipole			
1.15 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			
The importance of hydrogen bonding in the low density of ice and the anomalous boiling points of compounds			
Explain the existence of these forces between familiar and unfamiliar molecules			
Explain how melting and boiling points are influenced by these intermolecular forces			

ENERGETICS			
1.16 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 $\Delta H_{298}^{\ominus}$)			
Define standard enthalpy of combustion ($\Delta_c H^{\ominus}$)			
Define standard enthalpy of formation ($\Delta_f H^{\ominus}$)			
1.17 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 (do not need to learn value of c)			
Use this equation to calculate the molar enthalpy change for a reaction			
Use this equation in related calculations			
Required practical 2: measurement of an enthalpy change			
1.18 Applications of Hess’s law			
Use Hess’s law to perform calculations including calculation of enthalpy changes for reactions from enthalpies of combustion or formation			
1.19 Bond enthalpies			
Mean bond enthalpy			
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			

KINETICS			
1.20 Collision theory			
Reactions can only occur when collisions take place between particles having sufficient energy			
This energy is called the activation energy			
Define “activation energy”			
Explain why most collisions do not lead to a reaction			
1.21 Maxwell-Boltzmann distribution			
Maxwell–Boltzmann distribution of molecular energies in gases			
Draw and interpret distribution curves for different temperatures			
1.22 Effect of temperature on reaction rate			
Meaning of the term rate of reaction			
The qualitative effect of temperature changes on the rate of reaction			
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			
Required practical 3: investigation of how the rate of a reaction changes with temperature			
1.23 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			
1.24 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			

CHEMICAL EQUILIBRIA, LE CHATELIER'S PRINCIPLE AND K_c			
1.25 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			
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			
1.26 Equilibrium constant K_c for homogeneous systems			
The equilibrium constant Kc 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			
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			

OXIDATION, REDUCTION AND REDOX EQUATIONS			
1.27 Oxidation, reduction and redox equations			
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			
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			

Inorganic Chemistry

PERIODICITY			
2.1 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			
2.2 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			
Explain the trends in atomic radius and first ionisation energy			
Explain the melting point of the elements in terms of their structure and bonding			

GROUP 2, THE ALKALINE EARTH METALS			
2.3 The alkaline earth metals			
The trends in atomic radius, first ionisation energy and melting point of the elements Mg–Ba			
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			
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			
Explain why $BaCl_2$ solution is used to test for sulfate ions and why it is acidified			

GROUP 7, THE HALOGENS			
2.4 Trends in properties			
The trends in electronegativity and boiling point of the halogens			
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			
Explain why silver nitrate solution is used to identify halide ions			
Explain why the silver nitrate solution is acidified			
Explain why ammonia solution is added			
2.5 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			
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-}*			

Organic Chemistry

INTRODUCTION TO ORGANIC CHEMISTRY			
3.1 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			
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			
3.2 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			
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			
Outline mechanisms by drawing the structures of the species involved and curly arrows to represent the movement of electron pairs			
3.3 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.			
Define the term ‘structural isomer’			
Draw the structures of chain, position and functional group isomers			
Define the term stereoisomer			
Draw the structural formulas or *E* and *Z* isomers			
Apply the CIP priority rules to *E* and *Z* isomers			

ALKANES			
3.4 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			
3.5 Modification of alkanes by cracking			
Cracking involves breaking C-C bonds in alkanes			
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)			
Explain the economic reasons for cracking alkanes			
3.6 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			
Explain why sulfur dioxide can be removed from flue gases using calcium oxide or calcium carbonate			
3.7 Chlorination of alkanes			
The reaction of methane with chlorine			
Explain this reaction as a free-radical substitution mechanism involving initiation, propagation and termination steps			

HALOALKANES			
3.8 Nucleophilic substitution			
Haloalkanes contain polar bonds			
Haloalkanes undergo substitution reactions with the nucleophiles OH^-, CN^- and NH_3			
Outline the nucleophilic substitution mechanisms of these reactions			
Explain why the carbon–halogen bond enthalpy influences the rate of reaction			
3.9 Elimination			
The concurrent substitution and elimination reactions of a haloalkane (eg 2-bromopropane with potassium hydroxide)			
Explain the role of the reagent as both nucleophile and base			
Outline the mechanisms of these reaction			
3.10 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			
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 $ClO\bullet + O_3 \rightarrow 2O_2 + Cl\bullet$			

ALKENES			
3.11 Structure, bonding and reactivity			
Alkenes are unsaturated hydrocarbons			
Bonding in alkanes involves a double covalent bond, a centre of high electron density			
3.12 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			
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			
3.13 Addition polymers			
Addition polymers are formed from alkenes and substituted alkenes			
The repeating unit of addition polymers			
IUPAC rules for naming organic 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			
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			

ALCOHOLS			
3.14 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			
explain the meaning of the term biofuel			
justify the conditions used in the production of ethanol by fermentation of glucose			
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			
3.15 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			
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			
3.16 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			
Outline the mechanism for the elimination of water from alcohols			
Required practical 5: distillation of a product from a reaction			

ORGANIC ANALYSIS			
3.17 Identification of functional groups by test-tube reactions			
The reactions of functional groups listed in the specification			
Identify the functional groups using reactions in the specification			
Required practical 6: test for alcohol, aldehyde, alkene & carboxylic acid			
3.18 Mass spectrometry			
Mass spectrometry can be used to determine the molecular formula of a compound			
Use precise atomic masses and the precise molecular mass to determine the molecular formula of a compound			
3.19 Infrared spectroscopy			
Bonds in a molecule absorb infrared radiation at characteristic wavenumbers			
‘Fingerprinting’ allows identification of a molecule by comparison of spectra			
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			