KS4 Chemistry Curriculum Coverage:

Sequenced	Atomic Structure & Periodic Table	Bonding, Structure and Properties of Matter
Key Knowledge	**To know:** ● There are about 100 different elements. Elements are shown in the periodic table. ● Compounds contain two or more elements chemically combined in fixed proportions and can be represented by formulae using the symbols of the atoms from which they were formed. ● Chemical reactions can be represented by word equations or equations using symbols and formulae. ● A mixture consists of two or more elements or compounds not chemically combined together. ● Mixtures can be separated by physical processes such as filtration, crystallisation, simple distillation, fractional distillation and chromatography. ● New experimental evidence may lead to a scientific model being changed or replaced. ● Before the discovery of the electron, atoms were thought to be tiny spheres that could not be divided. ● The plum pudding model suggested that the atom is a ball of positive charge with negative electrons embedded in it. ● The results from the alpha particle scattering experiment led to the conclusion that the mass of an atom was concentrated at the centre (nucleus) and that the nucleus was charged. ● Niels Bohr adapted the nuclear model by suggesting electrons orbit the nucleus at specific distances. ● The experimental work of James Chadwick provided the evidence to show the existence of neutrons. ● In an atom, the number of electrons is equal to the number of protons in the nucleus. ● The number of protons in an atom of an element is its atomic number. ● Atoms are very small, having a radius of about 0.1 nm. ● The radius of a nucleus is less than 1/10 000 of that of the atom. ● The sum of the protons and neutrons in an atom is its mass number. ● Atoms of the same element can have different numbers of neutrons; these atoms are called isotopes. ● The electrons in an atom occupy the lowest available energy levels (innermost available shells). The electronic structure of an atom can be represented by numbers or by a diagram. ● The elements in the periodic table are arranged in order of atomic (proton) number and so that elements with similar properties are in columns, known as groups. ● Elements in the same group in the periodic table have the same number of electrons in their outer shell (outer electrons) and this gives them similar chemical properties. ● Before the discovery of protons, neutrons and electrons, scientists attempted to classify the elements by arranging them in order of their atomic weights. ● Mendeleev overcame some of the problems by leaving gaps for elements that he thought had not been discovered and in some places changed the order based on atomic weights. ● Elements that react to form positive ions are metals. ● Elements that do not form positive ions are non-metals. ● The majority of elements are metals. Metals are found to the left and towards the bottom of the periodic table. Non-metals are found towards the right and top of the periodic table. ● The elements in Group 0 of the periodic table are called the noble gases. They are unreactive and do not easily form molecules because their atoms have stable arrangements of electrons. ● The boiling points of the noble gases increase with increasing relative atomic mass. ● The elements in Group 1 of the periodic table are known as the alkali metals and have characteristic properties because of the single electron in their outer shell. ● The reactions of the first three alkali metals with oxygen, chlorine and water. ● In Group 1, the reactivity of the elements increases going down the group. ● The elements in Group 7 of the periodic table are known as the halogens and have similar reactions because they all have seven electrons in their outer shell. The halogens are non-metals and consist of molecules made of pairs of atoms. ● In Group 7, the reactivity of the elements decreases going down the group. ● A more reactive halogen can displace a less reactive halogen from an aqueous solution of its salt. ● (CHEM only) The transition elements are metals with similar properties which are different from those of the elements in Group 1. ● Many transition elements have ions with different charges, form coloured compounds and are useful as catalysts.	**To know:** ● There are three types of strong chemical bonds: ionic, covalent and metallic. ● Ionic bonding occurs in compounds formed from metals combined with non-metals. ● Covalent bonding occurs in most non-metallic elements and in compounds of non-metals. ● Metallic bonding occurs in metallic elements and alloys. ● When a metal atom reacts with a non-metal atom electrons in the outer shell of the metal atom are transferred. Metal atoms lose electrons to become positively charged ions. Non-metal atoms gain electrons to become negatively charged ions. ● The electron transfer during the formation of an ionic compound can be represented by a dot and cross diagram, ● The charge on the ions produced by metals in Groups 1 and 2 and by non-metals in Groups 6 and 7 relates to the group number of the element in the periodic table. ● An ionic compound is a giant structure of ions. Ionic compounds are held together by strong electrostatic forces of attraction between oppositely charged ions. ● When atoms share pairs of electrons, they form covalent bonds. These bonds between atoms are strong. ● Metals consist of giant structures of atoms arranged in a regular pattern. ● The electrons in the outer shell of metal atoms are delocalised and so are free to move through the whole structure. The sharing of delocalised electrons gives rise to strong metallic bonds. ● The three states of matter are solid, liquid and gas. Melting and freezing take place at the melting point, boiling and condensing take place at the boiling point. ● (HT only) Limitations of the simple model above include that in the model there are no forces, that all particles are represented as spheres and that the spheres are solid. ● In chemical equations, the three states of matter are shown as (s), (l) and (g), with (aq) for aqueous solutions. ● Ionic compounds have regular structures (giant ionic lattices) in which there are strong electrostatic forces of attraction in all directions between oppositely charged ions. ● These compounds have high melting points and high boiling points because of the large amounts of energy needed to break the many strong bonds. ● When melted or dissolved in water, ionic compounds conduct electricity because the ions are free to move and so charge can flow. ● Substances that consist of small molecules are usually gases or liquids that have relatively low melting points and boiling points. ● These substances have only weak forces between the molecules (intermolecular forces). It is these intermolecular forces that are overcome, not the covalent bonds, when the substance melts or boils. ● The intermolecular forces increase with the size of the molecules, so larger molecules have higher melting and boiling points. ● These substances do not conduct electricity because the molecules do not have an overall electric charge. ● Polymers have very large molecules. The atoms in the polymer molecules are linked to other atoms by strong covalent bonds. ● Substances that consist of giant covalent structures are solids with very high melting points. Diamond and graphite (forms of carbon) and silicon dioxide (silica) are examples of giant covalent structures. ● Metals have giant structures of atoms with strong metallic bonding. This means that most metals have high melting and boiling points. ● In pure metals, atoms are arranged in layers, which allows metals to be bent and shaped. Pure metals are too soft for many uses and so are mixed with other metals to make alloys which are harder. ● Metals are good conductors of electricity because the delocalised electrons in the metal carry electrical charge through the metal. ● In diamond, each carbon atom forms four covalent bonds with other carbon atoms in a giant covalent structure, so diamond is very hard, has a very high melting point and does not conduct electricity. ● In graphite, each carbon atom forms three covalent bonds with three other carbon atoms, forming layers of hexagonal rings which have no covalent bonds between the layers and one electron from each carbon atom is delocalised. ● Graphene is a single layer of graphite and has properties that make it useful in electronics and composites. ● Fullerenes are molecules of carbon atoms with hollow shapes. The structure of fullerenes is based on hexagonal rings of carbon atoms but they may also contain rings with five or seven carbon atoms. ● Nanoscience refers to structures that are 1–100 nm in size, of the order of a few hundred atoms. ● Nanoparticles have many applications in medicine, in electronics, in cosmetics and sun creams, as deodorants, and as catalysts. New applications for nanoparticulate materials are an important area of research.

Key Skills	**To be able to:** ● Use the names and symbols of the first 20 elements in the periodic table, the elements in Groups 1 and 7, and other elements in this specification ● Name compounds of these elements from given formulae or symbol equations ● Write word equations for the reactions in this specification ● Write formulae and balanced chemical equations for the reactions in this specification. ● (HT only) Write balanced half equations and ionic equations where appropriate. ● Describe, explain and give examples of the specified processes of separation ● Suggest suitable separation and purification techniques for mixtures when given appropriate information. ● Explain why the new evidence from the scattering experiment led to a change in the atomic model ● Describe the difference between the plum pudding model of the atom and the nuclear model of the atom. ● calculate the numbers of protons, neutrons and electrons in an atom or ion, given its atomic number and mass number. ● Relate size and scale of atoms to objects in the physical world. ● Calculate the relative atomic mass of an element given the percentage abundance of its isotopes. ● Explain how the position of an element in the periodic table is related to the arrangement of electrons in its atoms and hence to its atomic number ● Predict possible reactions and probable reactivity of elements from their positions in the periodic table. ● Explain the differences between metals and non-metals on the basis of their characteristic physical and chemical properties. This links to Group 0 , Group 1 , Group 7 and Bonding, structure and the properties of matter ● Explain how the atomic structure of metals and non-metals relates to their position in the periodic table ● Explain how the reactions of elements are related to the arrangement of electrons in their atoms and hence to their atomic number. ● Explain how properties of the elements in Group 0 depend on the outer shell of electrons of the atoms ● Predict properties from given trends down the group. ● Explain how properties of the elements in Group 1 depend on the outer shell of electrons of the atoms ● Predict properties from given trends down the group. ● Describe the nature of the compounds formed when chlorine, bromine and iodine react with metals and non-metals. ● Explain how properties of the elements in Group 7 depend on the outer shell of electrons of the atoms ● Predict properties from given trends down the group.	To be able to: ● Explain chemical bonding in terms of electrostatic forces and the transfer or sharing of electrons. ● Draw dot and cross diagrams for ionic compounds formed by metals in Groups 1 and 2 with non-metals in Groups 6 and 7. ● Work out the charge on the ions of metals and non-metals from the group number of the element, limited to the metals in Groups 1 and 2, and non-metals in Groups 6 and 7. ● Deduce that a compound is ionic from a diagram of its structure in one of the specified forms ● Describe the limitations of using dot and cross, ball and stick, two and three-dimensional diagrams to represent a giant ionic structure ● Work out the empirical formula of an ionic compound from a given model or diagram that shows the ions in the structure. ● Recognise common substances that consist of small molecules from their chemical formula. ● draw dot and cross diagrams for the molecules of hydrogen, chlorine, oxygen, nitrogen, hydrogen chloride, water, ammonia and methane ● Represent the covalent bonds in small molecules, in the repeating units of polymers and in part of giant covalent structures, using a line to represent a single bond ● Describe the limitations of using dot and cross, ball and stick, two and three-dimensional diagrams to represent molecules or giant structures ● Deduce the molecular formula of a substance from a given model or diagram in these forms showing the atoms and bonds in the molecule. ● Predict the states of substances at different temperatures given appropriate data ● Explain the different temperatures at which changes of state occur in terms of energy transfers and types of bonding ● Recognise that atoms themselves do not have the bulk properties of materials ● (HT only) Explain the limitations of the particle theory in relation to changes of state when particles are represented by solid inelastic spheres which have no forces between them. ● Use the idea that intermolecular forces are weak compared with covalent bonds to explain the bulk properties of molecular substances. ● Explain the properties of diamond and graphite in terms of its structure and bonding. ● Know that graphite is similar to metals in that it has delocalised electrons. ● Recognise graphene and fullerenes from diagrams and descriptions of their bonding and structure ● Give examples of the uses of fullerenes, including carbon nanotubes. ● Compare 'nano' dimensions to typical dimensions of atoms and molecules. ● Evaluate the use of nanoparticles for a specified purpose ● Explain that there are possible risks associated with the use of nanoparticles.
Subject specific Vocabulary	Atom, element, compound, molecule, ion, mixture, evaporation, filtration, distillation, chromatography, crystallisation, proton, neutron, electrons, nucleus, isotopes, relative atomic mass, abundance, periodic table, alkali metal, universal indicator, halogen, displacement, reactivity, noble gas, dissolving, soluble, insoluble, exothermic, transition metal, catalyst	Ionic, covalent, metallic, electrostatic, atom, element, compound, molecule, ion, electrons, delocalised, lattice, melting, freezing, boiling, condensing, intermolecular forces, diamond, graphite, graphene, fullerenes, polymer, empirical, molecular, nanoparticles, properties

KS4 Chemistry Curriculum Coverage:

Sequenced	Quantitative Chemistry	Chemical Changes
Key Knowledge	**To know:** ● The law of conservation of mass states that no atoms are lost or made during a chemical reaction so the mass of the products equals the mass of the reactants. ● The relative formula mass (M r) of a compound is the sum of the relative atomic masses of the atoms in the numbers shown in the formula. ● In a balanced chemical equation, the sum of the relative formula masses of the reactants in the quantities shown equals the sum of the relative formula masses of the products in the quantities shown. ● Chemical amounts are measured in moles. The symbol for the unit mole is mol. ● The mass of one mole of a substance in grams is numerically equal to its relative formula mass. ● One mole of a substance contains the same number of the stated particles, atoms, molecules or ions as one mole of any other substance. ● The number of atoms, molecules or ions in a mole of a given substance is the Avogadro constant. The value of the Avogadro constant is 6.02 x 1023 per mole. ● The masses of reactants and products can be calculated from balanced symbol equations. ● Chemical equations can be interpreted in terms of moles. ● The balancing numbers in a symbol equation can be calculated from the masses of reactants and products by converting the masses in grams to amounts in moles and converting the numbers of moles to simple whole number ratios. ● (HT only) In a chemical reaction involving two reactants, it is common to use an excess of one of the reactants to ensure that all of the other reactant is used. The reactant that is completely used up is called the limiting reactant because it limits the amount of products. ● Many chemical reactions take place in solutions. The concentration of a solution can be measured in mass per given volume of solution, eg grams per dm3 (g/dm3). ● (Chem only) Even though no atoms are gained or lost in a chemical reaction, it is not always possible to obtain the calculated amount of a product because: ● the reaction may not go to completion because it is reversible ● some of the product may be lost when it is separated from the reaction mixture ● some of the reactants may react in ways different to the expected reaction. ● The amount of a product obtained is known as the yield. When compared with the maximum theoretical amount as a percentage, it is called the percentage yield. ● The atom economy (atom utilisation) is a measure of the amount of starting materials that end up as useful products. It is important for sustainable development and for economic reasons to use reactions with high atom economy. ● The concentration of a solution can be measured in mol/dm3 . ● The amount in moles of solute or the mass in grams of solute in a given volume of solution can be calculated from its concentration in mol/dm3 . ● If the volumes of two solutions that react completely are known and the concentration of one solution is known, the concentration of the other solution can be calculated. ● Students should be able to explain how the concentration of a solution in mol/dm3 is related to the mass of the solute and the volume of the solution. ● Equal amounts in moles of gases occupy the same volume under the same conditions of temperature and pressure. ● The volume of one mole of any gas at room temperature and pressure (20o C and 1 atmosphere pressure) is 24 dm3	**To know:** ● When metals react with other substances the metal atoms form positive ions. The reactivity of a metal is related to its tendency to form positive ions. Metals can be arranged in order of their reactivity in a reactivity series. The metals potassium, sodium, lithium, calcium, magnesium, zinc, iron and copper can be put in order of their reactivity from their reactions with water and dilute acids. ● The non-metals hydrogen and carbon are often included in the reactivity series. ● A more reactive metal can displace a less reactive metal from a compound. ● Unreactive metals such as gold are found in the Earth as the metal itself but most metals are found as compounds that require chemical reactions to extract the metal. ● Metals less reactive than carbon can be extracted from their oxides by reduction with carbon. ● Reduction involves the loss of oxygen. ● Oxidation is the loss of electrons and reduction is the gain of electrons. ● Acids react with some metals to produce salts and hydrogen. ● Acids are neutralised by alkalis and bases to produce salts and water, and by metal carbonates to produce salts, water and carbon dioxide. ● Soluble salts can be made from acids by reacting them with solid insoluble substances, such as metals, metal oxides, hydroxides or carbonates. ● Salt solutions can be crystallised to produce solid salts. ● Acids produce hydrogen ions (H+) in aqueous solutions and aqueous solutions of alkalis contain hydroxide ions (OH−). ● The pH scale, from 0 to 14, is a measure of the acidity or alkalinity of a solution, and can be measured using universal indicator or a pH probe. A solution with pH 7 is neutral. Aqueous solutions of acids have pH values of less than 7 and aqueous solutions of alkalis have pH values greater than 7. ● In neutralisation reactions between an acid and an alkali, hydrogen ions react with hydroxide ions to produce water. ● The volumes of acid and alkali solutions that react with each other can be measured by titration using a suitable indicator. ● A strong acid is completely ionised in aqueous solution. Examples of strong acids are hydrochloric, nitric and sulfuric acids. ● A weak acid is only partially ionised in aqueous solution. Examples of weak acids are ethanoic, citric and carbonic acids. ● For a given concentration of aqueous solutions, the stronger an acid, the lower the pH. ● As the pH decreases by one unit, the hydrogen ion concentration of the solution increases by a factor of 10. ● When an ionic compound is melted or dissolved in water, the ions are free to move about within the liquid or solution. These liquids and solutions are able to conduct electricity and are called electrolytes. ● When a simple ionic compound is electrolysed in the molten state using inert electrodes, the metal is produced at the cathode and the non-metal is produced at the anode. ● Metals can be extracted from molten compounds using electrolysis. Electrolysis is used if the metal is too reactive to be extracted by reduction with carbon or if the metal reacts with carbon. Large amounts of energy are used in the extraction process to melt the compounds and to produce the electrical current. ● During electrolysis, at the cathode (negative electrode), positively charged ions gain electrons and so the reactions are reductions and at the anode (positive electrode), negatively charged ions lose electrons and so the reactions are oxidations.

Key Skills	**To be able to:** ● Understand the use of the multipliers in equations in normal script before a formula and in subscript within a formula. ● Calculate the percentage by mass in a compound given the relative formula mass and the relative atomic masses. ● Explain any observed changes in mass in non-enclosed systems during a chemical reaction given the balanced symbol equation for the reaction and explain these changes in terms of the particle model. ● Represent the distribution of results and make estimations of uncertainty ● Use the range of a set of measurements about the mean as a measure of uncertainty. ● Understand that the measurement of amounts in moles can apply to atoms, molecules, ions, electrons, formulae and equations. ● Use the relative formula mass of a substance to calculate the number of moles in a given mass of that substance and vice versa. ● Calculate the masses of substances shown in a balanced symbol equation ● Calculate the masses of reactants and products from the balanced symbol equation and the mass of a given reactant or product. ● Balance an equation given the masses of reactants and products. ● (HT only) Explain the effect of a limiting quantity of a reactant on the amount of products it is possible to obtain in terms of amounts in moles or masses in grams. ● Calculate the mass of solute in a given volume of solution of known concentration in terms of mass per given volume of solution ● (HT only) Explain how the mass of a solute and the volume of a solution is related to the concentration of the solution and calculate the percentage yield of a product from the actual yield of a reaction ● (HT only) calculate the theoretical mass of a product from a given mass of reactant and the balanced equation for the reaction. ● Calculate the atom economy of a reaction to form a desired product from the balanced equation ● (HT only) Explain why a particular reaction pathway is chosen to produce a specified product given appropriate data such as atom economy (if not calculated), yield, rate, equilibrium position and usefulness of by-products. ● Calculate the volume of a gas at room temperature and pressure from its mass and relative formula mass ● Calculate volumes of gaseous reactants and products from a balanced equation and a given volume of a gaseous reactant or product ● Change the subject of a mathematical equation.	**To be able to:** ● Recall and describe the reactions, if any, of potassium, sodium, lithium, calcium, magnesium, zinc, iron and copper with water or dilute acids and where appropriate, to place these metals in order of reactivity ● Explain how the reactivity of metals with water or dilute acids is related to the tendency of the metal to form its positive ion ● Deduce an order of reactivity of metals based on experimental results. ● Interpret or evaluate specific metal extraction processes when given appropriate information ● Identify the substances which are oxidised or reduced in terms of gain or loss of oxygen. ● Write ionic equations for displacement reactions ● Identify in a given reaction, symbol equation or half equation which species are oxidised and which are reduced. ● (HT only) Explain in terms of gain or loss of electrons, that these are redox reactions ● Identify which species are oxidised and which are reduced in given chemical equations. ● Predict products from given reactants ● Use the formulae of common ions to deduce the formulae of salts. ● Describe the use of universal indicator or a wide range indicator to measure the approximate pH of a solution ● Use the pH scale to identify acidic or alkaline solutions. ● Describe how to carry out titrations using strong acids and strong alkalis only (sulfuric, hydrochloric and nitric acids only) to find the reacting volumes accurately ● (HT Only) Calculate the chemical quantities in titrations involving concentrations in mol/dm3 and in g/dm3 . ● Use and explain the terms dilute and concentrated (in terms of amount of substance), and weak and strong (in terms of the degree of ionisation) in relation to acids ● Describe neutrality and relative acidity in terms of the effect on hydrogen ion concentration and the numerical value of pH (whole numbers only). ● (HT only) Write half equations for the reactions occurring at the electrodes during electrolysis, and to complete and balance supplied half equations. ● Explain why a mixture is used as the electrolyte ● Explain why the positive electrode must be continually replaced. ● Predict the products of the electrolysis of aqueous solutions containing a single ionic compound.
Subject specific Vocabulary	Calculate, mass, reactants, products, conservation, concentration, uncertainty, yield, moles, volume, molar ratio, atom economy, mean, range	Metal, ion, positive, negative, oxidation, reduction, displacement, reactivity series, electrons, salt, soluble, acid, indicator, universal, nitrate, chloride, sulphate, neutralisation, pH, dilute, concentrated, concentration, hydroxide, alkali, acid hydrogen ion, strong, weak, burette, pipette, titration, electrode, electrolyte, aqueous, molten

KS4 Chemistry Curriculum Coverage:

Sequenced	**Energy Changes**	**The rate and extent of chemical change**
Key Knowledge	**To know:** ● Energy is conserved in chemical reactions. The amount of energy in the universe at the end of a chemical reaction is the same as before the reaction takes place. ● An exothermic reaction is one that transfers energy to the surroundings so the temperature of the surroundings increases. ● An endothermic reaction is one that takes in energy from the surroundings so the temperature of the surroundings decreases. ● Endothermic reactions include thermal decompositions and the reaction of citric acid and sodium hydrogencarbonate. ● Chemical reactions can occur only when reacting particles collide with each other and with sufficient energy. The minimum amount of energy that particles must have to react is called the activation energy. ● Reaction profiles can be used to show the relative energies of reactants and products, the activation energy and the overall energy change of a reaction. ● During a chemical reaction energy must be supplied to break bonds in the reactants and energy is released when bonds in the products are formed. ● The energy needed to break bonds and the energy released when bonds are formed can be calculated from bond energies. ● The difference between the sum of the energy needed to break bonds in the reactants and the sum of the energy released when bonds in the products are formed is the overall energy change of the reaction. ● In an exothermic reaction, the energy released from forming new bonds is greater than the energy needed to break existing bonds. ● In an endothermic reaction, the energy needed to break existing bonds is greater than the energy released from forming new bonds. ● The voltage produced by a cell is dependent upon a number of factors including the type of electrode and electrolyte. ● A simple cell can be made by connecting two different metals in contact with an electrolyte. ● Batteries consist of two or more cells connected together in series to provide a greater voltage. ● In non-rechargeable cells and batteries the chemical reactions stop when one of the reactants has been used up. Alkaline batteries are non-rechargeable. ● Rechargeable cells and batteries can be recharged because the chemical reactions are reversed when an external electrical current is supplied.	**To know:** ● The rate of a chemical reaction can be found by measuring the quantity of a reactant used or the quantity of product formed over time. ● The quantity of reactant or product can be measured by the mass in grams or by a volume in cm3 . ● The units of rate of reaction may be given as g/s or cm3 /s. ● (HT only) Use quantity of reactants in terms of moles and units for rate of reaction in mol/s. ● Factors which affect the rates of chemical reactions include: the concentrations of reactants in solution, the pressure of reacting gases, the surface area of solid reactants, the temperature and the presence of catalysts. ● Collision theory explains how various factors affect rates of reactions. According to this theory, chemical reactions can occur only when reacting particles collide with each other and with sufficient energy. The minimum amount of energy that particles must have to react is called the activation energy. ● Increasing the concentration of reactants in solution, the pressure of reacting gases, and the surface area of solid reactants increases the frequency of collisions and so increases the rate of reaction. ● Increasing the temperature increases the frequency of collisions and makes the collisions more energetic, and so increases the rate of reaction. ● Catalysts change the rate of chemical reactions but are not used up during the reaction. Different reactions need different catalysts. Enzymes act as catalysts in biological systems. ● Catalysts increase the rate of reaction by providing a different pathway for the reaction that has a lower activation energy. ● In some chemical reactions, the products of the reaction can react to produce the original reactants. Such reactions are called reversible reactions and are represented by $A + B \rightleftharpoons C + D$ ● The direction of reversible reactions can be changed by changing the conditions. ● When a reversible reaction occurs in apparatus which prevents the escape of reactants and products, equilibrium is reached when the forward and reverse reactions occur at exactly the same rate. ● If a system is at equilibrium and a change is made to any of the conditions, then the system responds to counteract the change. ● The effects of changing conditions on a system at equilibrium can be predicted using Le Chatelier's Principle. ● If the concentration of one of the reactants or products is changed, the system is no longer at equilibrium and the concentrations of all the substances will change until equilibrium is reached again. ● If the concentration of a reactant is increased, more products will be formed until equilibrium is reached again. ● If the concentration of a product is decreased, more reactants will react until equilibrium is reached again. ● If the temperature of a system at equilibrium is increased then the relative amount of products at equilibrium increases for an endothermic reaction and the relative amount of products at equilibrium decreases for an exothermic reaction
Key Skills	**To be able to:** ● Distinguish between exothermic and endothermic reactions on the basis of the temperature change of the surroundings ● Evaluate uses and applications of exothermic and endothermic reactions given appropriate information. ● Draw simple reaction profiles (energy level diagrams) for exothermic and endothermic reactions showing the relative energies of reactants and products, the activation energy and the overall energy change, with a curved line to show the energy as the reaction proceeds ● Use reaction profiles to identify reactions as exothermic or endothermic ● Explain that the activation energy is the energy needed for a reaction to occur. ● Calculate the energy transferred in chemical reactions using bond energies supplied. ● Interpret data for relative reactivity of different metals and evaluate the use of cells. ● Evaluate the use of hydrogen fuel cells in comparison with rechargeable cells and batteries ● (HT only) Write the half equations for the electrode reactions in the hydrogen fuel cell.	**To be able to:** ● Calculate the mean rate of a reaction from information about the quantity of a reactant used or the quantity of a product formed and the time taken ● Draw, and interpret, graphs showing the quantity of product formed or quantity of reactant used up against time ● Draw tangents to the curves on these graphs and use the slope of the tangent as a measure of the rate of reaction ● (HT only) Calculate the gradient of a tangent to the curve on these graphs as a measure of rate of reaction at a specific time. ● Recall how changing these factors affects the rate of chemical reactions. ● Predict and explain using collision theory the effects of changing conditions of concentration, pressure and temperature on the rate of a reaction ● Predict and explain the effects of changes in the size of pieces of a reacting solid in terms of surface area to volume ratio ● Explain catalytic action in terms of activation energy. ● Make qualitative predictions about the effect of changes on systems at equilibrium when given appropriate information. ● Interpret appropriate given data to predict the effect of a change in concentration of a reactant or product on given reactions at equilibrium. ● Interpret appropriate given data to predict the effect of a change in temperature on given reactions at equilibrium. ● (HT only) Interpret appropriate given data to predict the effect of pressure changes on given reactions at equilibrium.
Subject specific Vocabulary	Calculate, exothermic, endothermic, combustion, energy change, bond energy, activation energy, reactants, products, temperature, electrode, electrolyte.	Rate of reaction, product, reactant, collisions, particles, frequent, energy, temperature, pressure, concentration, surface area, catalyst, activation energy, equilibrium, exothermic, endothermic.

KS4 Chemistry Curriculum Coverage:

Sequenced	Organic Chemistry	Chemical Analysis
Key Knowledge	**To know:** ● Crude oil is a finite resource found in rocks. Crude oil is the remains of an ancient biomass consisting mainly of plankton that was buried in mud. ● Crude oil is a mixture of a very large number of compounds. Most of the compounds in crude oil are hydrocarbons, which are molecules made up of hydrogen and carbon atoms only. ● Most of the hydrocarbons in crude oil are hydrocarbons called alkanes. The general formula for the homologous series of alkanes is $C_n H_{2n+2}$ ● The first four members of the alkanes are methane, ethane, propane and butane. ● The many hydrocarbons in crude oil may be separated into fractions, each of which contains molecules with a similar number of carbon atoms, by fractional distillation. ● Many of the fuels on which we depend for our modern lifestyle, such as petrol, diesel oil, kerosene, heavy fuel oil and liquefied petroleum gases, are produced from crude oil. ● Some properties of hydrocarbons depend on the size of their molecules, including boiling point, viscosity and flammability. These properties influence how hydrocarbons are used as fuels. ● The combustion of hydrocarbon fuels releases energy. During combustion, the carbon and hydrogen in the fuels are oxidised. The complete combustion of a hydrocarbon produces carbon dioxide and water. ● Hydrocarbons can be broken down (cracked) to produce smaller, more useful molecules. ● Cracking can be done by various methods including catalytic cracking and steam cracking. ● Alkenes are more reactive than alkanes and react with bromine water, which is used as a test for alkenes. ● Alkenes are used to produce polymers and as starting materials for the production of many other chemicals. ● (Chem only) Alkenes are hydrocarbons with a double carbon-carbon bond. The general formula for the homologous series of alkenes is $C_n H_{2n}$ ● Alkene molecules are unsaturated because they contain two fewer hydrogen atoms than the alkane with the same number of carbon atoms. ● Alkenes are hydrocarbons with the functional group C=C. ● It is the generality of reactions of functional groups that determine the reactions of organic compounds. ● Alkenes react with oxygen in combustion reactions in the same way as other hydrocarbons, but they tend to burn in air with smoky flames because of incomplete combustion. ● Alkenes react with hydrogen, water and the halogens, by the addition of atoms across the carbon-carbon double bond so that the double bond becomes a single carbon-carbon bond. ● The first four members of the homologous series of alkenes are ethene, propene, butene and pentene. ● Alcohols contain the functional group –OH. ● Carboxylic acids have the functional group –COOH. ● Alkenes can be used to make polymers such as poly(ethene) and poly(propene) by addition polymerisation. ● In addition polymerisation reactions, many small molecules (monomers) join together to form very large molecules (polymers). ● Condensation polymerisation involves monomers with two functional groups. When these types of monomers react they join together, usually losing small molecules such as water, and so the reactions are called condensation reactions. ● The simplest polymers are produced from two different monomers with two of the same functional groups on each monomer. ● (HT only) Amino acids have two different functional groups in a molecule. Amino acids react by condensation polymerisation to produce polypeptides. ● DNA (deoxyribonucleic acid) is a large molecule essential for life. DNA encodes genetic instructions for the development and functioning of living organisms and viruses.	**To know:** ● A formulation is a mixture that has been designed as a useful product. Many products are complex mixtures in which each chemical has a particular purpose. Formulations are made by mixing the components in carefully measured quantities to ensure that the product has the required properties. Formulations include fuels, cleaning agents, paints, medicines, alloys, fertilisers and foods. ● Chromatography can be used to separate mixtures and can give information to help identify substances. Chromatography involves a stationary phase and a mobile phase. Separation depends on the distribution of substances between the phases. ● The ratio of the distance moved by a compound (centre of spot from origin) to the distance moved by the solvent can be expressed as its Rf value: ● Rf = distance moved by substance / distance moved by solvent ● Different compounds have different Rf values in different solvents, which can be used to help identify the compounds. The compounds in a mixture may separate into different spots depending on the solvent but a pure compound will produce a single spot in all solvents. ● The test for hydrogen uses a burning splint held at the open end of a test tube of the gas. Hydrogen burns rapidly with a pop sound. ● The test for oxygen uses a glowing splint inserted into a test tube of the gas. The splint relights in oxygen. ● The test for carbon dioxide uses an aqueous solution of calcium hydroxide (lime water). When carbon dioxide is shaken with or bubbled through limewater the limewater turns milky (cloudy). ● The test for chlorine uses litmus paper. When damp litmus paper is put into chlorine gas the litmus paper is bleached and turns white. ● Flame tests can be used to identify some metal ions (cations). Lithium, sodium, potassium, calcium and copper compounds produce distinctive colours in flame tests. ● Sodium hydroxide solution can be used to identify some metal ions (cations). ● Solutions of aluminium, calcium and magnesium ions form white precipitates when sodium hydroxide solution is added but only the aluminium hydroxide precipitate dissolves in excess sodium hydroxide solution. ● Solutions of copper(II), iron(II) and iron(III) ions form coloured precipitates when sodium hydroxide solution is added. ● Copper(II) forms a blue precipitate, iron(II) a green precipitate and iron(III) a brown precipitate. ● Carbonates react with dilute acids to form carbon dioxide gas. Carbon dioxide can be identified with limewater. ● Halide ions in solution produce precipitates with silver nitrate solution in the presence of dilute nitric acid. Silver chloride is white, silver bromide is cream and silver iodide is yellow. ● Sulfate ions in solution produce a white precipitate with barium chloride solution in the presence of dilute hydrochloric acid. ● Elements and compounds can be detected and identified using instrumental methods. Instrumental methods are accurate, sensitive and rapid. ● Flame emission spectroscopy is an example of an instrumental method used to analyse metal ions in solutions.

Key Skills	**To be able to:** ● Make models of alkane molecules using the molecular modelling kits. ● Recognise substances as alkanes given their formulae in these forms. now the names of specific alkanes other than methane, ethane, propane and butane. ● Explain how fractional distillation works in terms of evaporation and condensation. ● Write balanced equations for the complete combustion of hydrocarbons with a given formula. ● Describe in general terms the conditions used for catalytic cracking and steam cracking. ● Balance chemical equations as examples of cracking given the formulae of the reactants and products. ● Give examples to illustrate the usefulness of cracking. They should also be able to explain how modern life depends on the uses of hydrocarbons. ● Describe the reactions and conditions for the addition of hydrogen, water and halogens to alkenes ● Draw fully displayed structural formulae of the first four members of the alkenes and the products of their addition reactions with hydrogen, water, chlorine, bromine and iodine. ● Describe what happens when any of the first four alcohols react with sodium, burn in air, are added to water, react with an oxidising agent ● Recall the main uses of these alcohols. ● Know the conditions used for fermentation of sugar using yeast. ● Recognise alcohols from their names or from given formulae. ● Describe what happens when any of the first four carboxylic acids react with carbonates, dissolve in water, react with alcohols ● (HT only) Explain why carboxylic acids are weak acids in terms of ionisation and pH ● Recognise addition polymers and monomers from diagrams in the forms shown and from the presence of the functional group C=C in the monomers ● Draw diagrams to represent the formation of a polymer from a given alkene monomer ● Relate the repeating unit to the monomer. ● Explain the basic principles of condensation polymerisation by reference to the functional groups in the monomers and the repeating units in the polymers. ● Name the types of monomers from which these naturally occurring polymers are made.	**To be able to:** ● Use melting point and boiling point data to distinguish pure from impure substances. ● Identify formulations given appropriate information. ● Explain how paper chromatography separates mixtures ● Suggest how chromatographic methods can be used for distinguishing pure substances from impure substances ● Interpret chromatograms and determine Rf values from chromatograms ● The test for hydrogen uses a burning splint held at the open end of a test tube of the gas. Hydrogen burns rapidly with a pop sound. ● The test for oxygen uses a glowing splint inserted into a test tube of the gas. The splint relights in oxygen. ● The test for carbon dioxide uses an aqueous solution of calcium hydroxide (lime water). When carbon dioxide is shaken with or bubbled through limewater the limewater turns milky (cloudy). ● The test for chlorine uses litmus paper. When damp litmus paper is put into chlorine gas the litmus paper is bleached and turns white. ● Write balanced equations for the reactions to produce the insoluble hydroxides.. ● State advantages of instrumental methods compared with the chemical tests in this specification. ● Interpret an instrumental result given appropriate data in chart or tabular form, when accompanied by a reference set in the same form, limited to flame emission spectroscopy.
Subject specific Vocabulary	Alkanes, crude oil, methane, ethane, propane, butane, combustion, complete, incomplete, viscosity, flammability, boiling point, alkenes, cracking, fractional distillation, oxidising, alcohol, fermentation, methanol, ethanol, propanol, butanol, carboxylic, esters, carbonates, monomer, polymer.	Pure, impure, chromatography, Rf value, chromatogram, hydrogen, oxygen, chlorine, carbon dioxide, litmus, insoluble, soluble, compound, ion, spectroscopy.

KS4 Chemistry Curriculum Coverage:

Sequenced	Chemistry of the atmosphere	Using resources
Key Knowledge	**To know:** ● The proportions of different gases in the atmosphere today. ● Theories about what was in the Earth's early atmosphere and how the atmosphere was formed have changed and developed over time. Evidence for the early atmosphere is limited because of the time scale of 4.6 billion years. ● One theory suggests that during the first billion years of the Earth's existence there was intense volcanic activity that released gases that formed the early atmosphere and water vapour that condensed to form the oceans. At the start of this period the Earth's atmosphere may have been like the atmospheres of Mars and Venus today, consisting of mainly carbon dioxide with little or no oxygen gas. ● Volcanoes also produced nitrogen which gradually built up in the atmosphere and there may have been small proportions of methane and ammonia. ● When the oceans formed carbon dioxide dissolved in the water and carbonates were precipitated producing sediments, reducing the amount of carbon dioxide in the atmosphere. ● Algae and plants produced the oxygen that is now in the atmosphere by photosynthesis. ● Algae first produced oxygen about 2.7 billion years ago and soon after this oxygen appeared in the atmosphere. Over the next billion years plants evolved and the percentage of oxygen gradually increased to a level that enabled animals to evolve. ● Algae and plants decreased the percentage of carbon dioxide in the atmosphere by photosynthesis. ● Carbon dioxide was also decreased by the formation of sedimentary rocks and fossil fuels that contain carbon. ● Greenhouse gases in the atmosphere maintain temperatures on Earth high enough to support life. Water vapour, carbon dioxide and methane are greenhouse gases. ● Some human activities increase the amounts of greenhouse gases in the atmosphere. ● Based on peer-reviewed evidence, many scientists believe that human activities will cause the temperature of the Earth's atmosphere to increase at the surface and that this will result in global climate change.However, it is difficult to model such complex systems as global climate change. This leads to simplified models, speculation and opinions presented in the media that may be based on only parts of the evidence and which may be biased. ● An increase in average global temperature is a major cause of climate change. ● The carbon footprint is the total amount of carbon dioxide and other greenhouse gases emitted over the full life cycle of a product, service or event. ● The carbon footprint can be reduced by reducing emissions of carbon dioxide and methane. ● The combustion of fuels is a major source of atmospheric pollutants. ● Most fuels, including coal, contain carbon and/or hydrogen and may also contain some sulfur. ● The gases released into the atmosphere when a fuel is burned may include carbon dioxide, water vapour, carbon monoxide, sulfur dioxide and oxides of nitrogen. Solid particles and unburned hydrocarbons may also be released that form particulates in the atmosphere. ● Carbon monoxide is a toxic gas. It is colourless and odourless and so is not easily detected. ● Sulfur dioxide and oxides of nitrogen cause respiratory problems in humans and cause acid rain. ● Particulates cause global dimming and health problems for humans.	**To know:** ● Humans use the Earth's resources to provide warmth, shelter, food and transport. ● Natural resources, supplemented by agriculture, provide food, timber, clothing and fuels. ● Finite resources from the Earth, oceans and atmosphere are processed to provide energy and materials. ● Water of appropriate quality is essential for life. For humans, drinking water should have sufficiently low levels of dissolved salts and microbes. Water that is safe to drink is called potable water. Potable water is not pure water in the chemical sense because it contains dissolved substances. ● The methods used to produce potable water depend on available supplies of water and local conditions. ● Sterilising agents used for potable water include chlorine, ozone or ultraviolet light. ● If supplies of fresh water are limited, desalination of salty water or sea water may be required. Desalination can be done by distillation or by processes that use membranes such as reverse osmosis. These processes require large amounts of energy. ● Urban lifestyles and industrial processes produce large amounts of waste water that require treatment before being released into the environment. Sewage and agricultural waste water require removal of organic matter and harmful microbes. Industrial waste water may require removal of organic matter and harmful chemicals. ● Copper ores are becoming scarce and new ways of extracting copper from low-grade ores include phytomining, and bioleaching. These methods avoid traditional mining methods of digging, moving and disposing of large amounts of rock. ● Phytomining uses plants to absorb metal compounds. The plants are harvested and then burned to produce ash that contains metal compounds. ● Bioleaching uses bacteria to produce leachate solutions that contain metal compounds. ● The metal compounds can be processed to obtain the metal. For example, copper can be obtained from solutions of copper compounds by displacement using scrap iron or by electrolysis. ● Life cycle assessments (LCAs) are carried out to assess the environmental impact of products in each of these stages: extracting and processing raw materials; manufacturing and packaging; use and operation during its lifetime; disposal at the end of its useful life, including transport and distribution at each stage. ● Use of water, resources, energy sources and production of some wastes can be fairly easily quantified. Allocating numerical values to pollutant effects is less straightforward and requires value judgements, so LCA is not a purely objective process. ● The reduction in use, reuse and recycling of materials by end users reduces the use of limited resources, use of energy sources, waste and environmental impacts. ● Metals, glass, building materials, clay ceramics and most plastics are produced from limited raw materials. Much of the energy for the processes comes from limited resources. Obtaining raw materials from the Earth by quarrying and mining causes environmental impacts. ● Some products, such as glass bottles, can be reused. Glass bottles can be crushed and melted to make different glass products. Other products cannot be reused and so are recycled for a different use. ● Metals can be recycled by melting and recasting or reforming into different products. The amount of separation required for recycling depends on the material and the properties required of the final product. ● (Chem only) Corrosion is the destruction of materials by chemical reactions with substances in the environment. Rusting is an example of corrosion. Both air and water are necessary for iron to rust. ● Corrosion can be prevented by applying a coating that acts as a barrier, such as greasing, painting or electroplating. ● Bronze is an alloy of copper and tin. Brass is an alloy of copper and zinc. ● Gold used as jewellery is usually an alloy with silver, copper and zinc. The proportion of gold in the alloy is measured in carats. ● Steels are alloys of iron that contain specific amounts of carbon and other metals. High carbon steel is strong but brittle. Low carbon steel is softer and more easily shaped. ● Most of the glass we use is soda-lime glass, made by heating a mixture of sand, sodium carbonate and limestone. Borosilicate glass, made from sand and boron trioxide, melts at higher temperatures than soda-lime glass. ● Clay ceramics, including pottery and bricks, are made by shaping wet clay and then heating in a furnace. ● The properties of polymers depend on what monomers they are made from and the conditions under which they are made. ● Thermosoftening polymers melt when they are heated. Thermosetting polymers do not melt when they are heated. ● (Chem only) The Haber process is used to manufacture ammonia, which can be used to produce nitrogen-based fertilisers. ● The raw materials for the Haber process are nitrogen and hydrogen. ● Compounds of nitrogen, phosphorus and potassium are used as fertilisers to improve agricultural productivity. NPK fertilisers contain compounds of all three elements. ● Industrial production of NPK fertilisers can be achieved using a variety of raw materials in several integrated processes. NPK fertilisers are formulations of various salts containing appropriate percentages of the elements.

Key Skills	**To be able to:** ● Interpret evidence and evaluate different theories about the Earth's early atmosphere. ● Describe the main changes in the atmosphere over time and some of the likely causes of these changes ● Describe and explain the formation of deposits of limestone, coal, crude oil and natural gas. ● Describe the greenhouse effect in terms of the interaction of short and long wavelength radiation with matter. ● Recall two human activities that increase the amounts of each of the greenhouse gases carbon dioxide and methane. ● Evaluate the quality of evidence in a report about global climate change given appropriate information ● Describe uncertainties in the evidence base ● Recognise the importance of peer review of results and of communicating results to a wide range of audiences. ● Describe briefly four potential effects of global climate change ● Discuss the scale, risk and environmental implications of global climate change. ● Describe actions to reduce emissions of carbon dioxide and methane ● Give reasons why actions may be limited. ● Describe and explain the problems caused by increased amounts of these pollutants in the air. ● Describe how carbon monoxide, soot (carbon particles), sulfur dioxide and oxides of nitrogen are produced by burning fuels, that carbon monoxide is a toxic gas, it is colourless and odourless and so is not easily detected, and that sulfur dioxide and oxides of nitrogen cause respiratory problems in humans and cause acid rain. ● Describe and explain the problems caused by increased amounts of these pollutants in the air.	**To be able to:** ● State examples of natural products that are supplemented or replaced by agricultural and synthetic products ● Distinguish between finite and renewable resources given appropriate information. ● Extract and interpret information about resources from charts, graphs and tables ● Use orders of magnitude to evaluate the significance of data. ● Distinguish between potable water and pure water ● Describe the differences in treatment of ground water and salty water ● Give reasons for the steps used to produce potable water. ● Comment on the relative ease of obtaining potable water from waste, ground and salt water. ● Evaluate alternative biological methods of metal extraction, given appropriate information. (HT only) ● Carry out simple comparative LCAs for shopping bags made from plastic and paper. ● Evaluate ways of reducing the use of limited resources, given appropriate information. ● Describe experiments and interpret results to show that both air and water are necessary for rusting ● Explain sacrificial protection in terms of relative reactivity. ● Interpret and evaluate the composition and uses of alloys other than those specified given appropriate information. ● Explain how low density and high density poly(ethene) are both produced from ethene ● Explain the difference between thermosoftening and thermosetting polymers in terms of their structures. ● Describe that most composites are made of two materials, a matrix or binder surrounding and binding together fibres or fragments of the other material, which is called the reinforcement. ● Compare quantitatively the physical properties of glass and clay ceramics, polymers, composites and metals ● Explain how the properties of materials are related to their uses and select appropriate materials. ● (SEP only) Recall a source for the nitrogen and a source for the hydrogen used in the Haber process. ● Recall the names of the salts produced when phosphate rock is treated with nitric acid, sulfuric acid and phosphoric acid. ● Compare the industrial production of fertilisers with laboratory preparations of the same compounds, given appropriate information.
Subject specific Vocabulary	Atmosphere, nitrogen, oxygen, global dimming, global warming, greenhouse effect, gas, carbon dioxide, sulfur dioxide, health, fossil fuels, coal, oil, gas.	Pollution, disposal, waste, salt, nitric acid, sulfuric acid, phosphoric acid, Haber process, plastic, paper, water, alloys, composites, matrix, binder, fibres, fragments.