**Year 13 A Level Chemistry**

**Why this subject is important**

Chemistry is the study of matter and energy and the interaction between them. There are many reasons to study chemistry, even if you aren't pursuing a career in science.

Chemistry is everywhere in the world around you! It's in the food you eat, clothes you wear, water you drink, medicines, air, cleaners... you name it. Chemistry sometimes is called the "central science" because it connects other sciences to each other, such as biology, physics, geology, and environmental science. Here are some of the best reasons to study chemistry.

Chemistry helps you to understand the world around you. Why do leaves change colour in the fall? Why are plants green? How is cheese made? What is in soap and how does it clean? These are all questions that can be answered by applying chemistry.

Chemistry opens up career options. There are many careers in chemistry, but even if you're looking for a job in another field, the analytical skills you gained in chemistry are helpful. Chemistry applies to the food industry, retail sales, transportation, art, homemaking... really any type of work you can name.

Chemistry is fun! There are lots of interesting chemistry projects you can do using common everyday materials. Chemistry projects don't just go boom. They can glow in the dark, change colours, produces bubbles and change states.

Studying A Level Chemistry can be the gateway into great career choices and is necessary to access certain degrees at university.
## Year 13 A Level Chemistry

### What you will learn over the course of the year

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<td></td>
<td>Physical Chemistry</td>
<td>This unit of work involves thermodynamics, Kinetics, Electrode potentials and Acids, bases and pH</td>
<td>AT I Measure rates of reaction by at least two different methods, for example: • an initial rate method such as a clock reaction • a continuous monitoring method</td>
<td>• Enjoy problem solving • Creative thinker • Meticulous attention to detail • Determined • Organised • Patient • Resilient • Passionate about Chemistry • Responsible learners</td>
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<td><strong>In thermodynamics</strong>, Lattice enthalpy can be defined as either enthalpy of lattice dissociation or enthalpy of lattice formation. Born–Haber cycles are used to calculate lattice enthalpies using the following data: • enthalpy of formation • ionisation energy • enthalpy of atomisation • bond enthalpy • electron affinity. Cycles are used to calculate enthalpies of solution for ionic compounds from lattice enthalpies and enthalpies of hydration. In kinetics, $\Delta H$, whilst important, is not sufficient to explain feasible change. The concept of increasing disorder (entropy change, $\Delta S$). $\Delta S$ accounts for the above deficiency, illustrated by physical changes and chemical changes. The balance between entropy and enthalpy determines the feasibility of a reaction given by the relationship: $\Delta G = \Delta H - T\Delta S$ (derivation not required). For a reaction to be feasible, the value of $\Delta G$ must be zero or negative. The rate of a chemical reaction is related to the concentration of reactant Translate information between graphical, numerical and algebraic formats by a rate equation of the form: Rate = $k[A]^m[B]^n$ where $m$ and $n$ are the orders of reaction with respect to reactants $A$ and $B$ and $k$ is the rate constant. The orders $m$ and $n$ are restricted to the values $0$, $1$, and $2$. The rate constant $k$ varies with</td>
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temperature as shown by the equation: $k = \frac{A e^{-\frac{E_a}{RT}}}{RT}$ where $A$ is a constant, known as the Arrhenius constant, $E_a$ is the activation energy and $T$ is the temperature in K.

The rate equation is an experimentally determined relationship. The orders with respect to reactants can provide information about the mechanism of a reaction. The equilibrium constant $K_p$ is deduced from the equation for a reversible reaction occurring in the gas phase. $K_p$ is the equilibrium constant calculated from partial pressures for a system at constant temperature.

IUPAC convention for writing half-equations for electrode reactions. The conventional representation of cells. Cells are used to measure electrode potentials by reference to the standard hydrogen electrode. The importance of the conditions when measuring the electrode potential, $E$ (Nernst equation not required). Standard electrode potential, $E_\Theta$, refers to conditions of 298 K, 100 kPa and 1.00 mol dm$^{-3}$ solution of ions. Standard electrode potentials can be listed as an electrochemical series.

Electrochemical cells can be used as a commercial source of electrical energy. The simplified electrode reactions in a lithium cell: Positive electrode: $\text{Li}^+ + \text{CoO}_2 + e^- \rightarrow \text{Li}^+\text{[CoO}_2\text{]}^-$ Negative electrode: $\text{Li} \rightarrow \text{Li}^+ + e^-$. Cells can be non-rechargeable (irreversible), rechargeable or fuel cells. Fuel cells are used to generate an electric current and do not need to be electrically recharged. The electrode reactions in an alkaline hydrogen–oxygen fuel cell. The benefits and risks to society associated with using these cells.

The concentration of hydrogen ions in aqueous solution covers a very wide range. Therefore, a logarithmic scale, the pH scale, is used as a measure of hydrogen ion concentration. $\text{pH} = -\log_{10}[\text{H}^+]$
| Water is slightly dissociated. KW is derived from the equilibrium constant for this dissociation. KW = [H+]\[OH^-] The value of KW varies with temperature. Weak acids and weak bases dissociate only slightly in aqueous solution. Ka is the dissociation constant for a weak acid. pKa = –log10 Ka Titrations of acids with bases. A buffer solution maintains an approximately constant pH, despite dilution or addition of small amounts of acid or base. Acidic buffer solutions contain a weak acid and the salt of that weak acid. Basic buffer solutions contain a weak base and the salt of that weak base. Indicators used to detect acidity and alkalinity by a colour change in equivalence point |
|---|---|
| Inorganic Chemistry | The Periodic Table provides chemists with a structured organisation of the known chemical elements from which they can make sense of their physical and chemical properties. The historical development of the Periodic Table and models of atomic structure provide good examples of how scientific ideas and explanations develop over time. The reactions of the Period 3 elements with oxygen are considered. The pH of the solutions formed when the oxides react with water illustrates further trends in properties across this period. Explanations of these reactions offer opportunities to develop an in-depth understanding of how and why these reactions occur. |
The reactions of Na and Mg with water. The trends in the reactions of the elements Na, Mg, Al, Si, P and S with oxygen, limited to the formation of Na₂O, MgO, Al₂O₃, SiO₂, P₄O₁₀, SO₂ and SO₃, including trends in melting points, structures and reaction with water.

The 3d block contains 10 elements, all of which are metals. Unlike the metals in Groups 1 and 2, the transition metals Ti to Cu form coloured compounds and compounds where the transition metal exists in different oxidation states. Some of these metals are familiar as catalysts. The properties of these elements are studied in this section with opportunities for a wide range of practical investigations.

Transition metal characteristics of elements Ti–Cu arise from an incomplete d sub-level in atoms or ions. The characteristic properties include: • complex formation • formation of coloured ions • variable oxidation state • catalytic activity. A ligand is a molecule or ion that forms a co-ordinate bond with a transition metal by donating a pair of electrons. A complex is a central metal atom or ion surrounded by ligands.

Co-ordination number is number of co-ordinate bonds to the central metal atom or ion.

H₂O, NH₃ and Cl⁻ can act as monodentate ligands.

The ligands NH₃ and H₂O are similar in size and are uncharged.

Exchange of the ligands NH₃ and H₂O occurs without change of co-ordination number (eg Co²⁺ and Cu²⁺).

Substitution may be incomplete (eg the formation of [Cu(NH₃)₃]⁺).
The Cl– ligand is larger than the uncharged ligands NH$_3$ and H$_2$O.

Exchange of the ligand H$_2$O by Cl– can involve a change of co-ordination number (e.g., Co$^{2+}$, Cu$^{2+}$, and Fe$^{3+}$).

Ligands can be bidentate (e.g., H$_2$NCH$_2$CH$_2$NH$_2$ and C$_2$O$_4^{2–}$).

Ligands can be multidentate (e.g., EDTA$_4^{4–}$).

Haem is an iron(II) complex with a multidentate ligand.

Oxygen forms a co-ordinate bond to Fe(II) in haemoglobin, enabling oxygen to be transported in the blood.

Carbon monoxide is toxic because it replaces oxygen co-ordinately bonded to Fe(II) in haemoglobin.

Bidentate and multidentate ligands replace monodentate ligands from complexes. This is called the chelate effect.

Isomerism in transition metal complexes is also studied as an application in the synthesis of cancer drugs.

Transition metal ions can be identified by their colour.

Colour arises when some of the wavelengths of visible light are absorbed and the remaining wavelengths of light are transmitted or reflected.

d electrons move from the ground state to an excited state when light is absorbed.

The energy difference between the ground state and the excited state of the d electrons is given by:
ΔE = hν = hc/λ
Changes in oxidation state, co-ordination number and ligand alter ΔE and this leads to a change in colour. 
The absorption of visible light is used in spectroscopy.
A simple colorimeter can be used to determine the concentration of coloured ions in solution.

Transition metals and their compounds can act as heterogeneous and homogeneous catalysts. A heterogeneous catalyst is in a different phase from the reactants and the reaction occurs at active sites on the surface. The use of a support medium to maximise the surface area of a heterogeneous catalyst and minimise the cost. V2O5 acts as a heterogeneous catalyst in the Contact process. Fe is used as a heterogeneous catalyst in the Haber process. Heterogeneous catalysts can become poisoned by impurities that block the active sites and consequently have reduced efficiency; this has a cost implication. A homogeneous catalyst is in the same phase as the reactants. When catalysts and reactants are in the same phase, the reaction proceeds through an intermediate species.

In aqueous solution, the following metal-aqua ions are formed: [M(H2O)6]2+, limited to M = Fe and Cu [M(H2O)6]3+, limited to M = Al and Fe The acidity of [M(H2O)6]3+ is greater than that of [M(H2O)6]2+
Some metal hydroxides show amphoteric character by dissolving in both acids and bases (eg hydroxides of Al3+).

**Organic chemistry introduction**

Organic chemistry is the study of the millions of covalent compounds of the element carbon. These structurally diverse compounds vary from naturally occurring petroleum fuels to DNA and the molecules in living systems. Organic compounds also demonstrate

**AT d** Use laboratory apparatus for a variety of experimental techniques including:
- titration, using burette and pipette

**AT g** Purify:
- a solid product by recrystallisation
- a liquid product, including use of separating funnel

**AT h** Use melting
human ingenuity in the vast range of synthetic materials created by chemists. Many of these compounds are used as drugs, medicines and plastics. Organic compounds are named using the International Union of Pure and Applied Chemistry (IUPAC) system and the structure or formula of molecules can be represented in various different ways. Organic mechanisms are studied, which enable reactions to be explained. In the search for sustainable chemistry, for safer agrochemicals and for new materials to match the desire for new technology, chemistry plays the dominant role.

The characteristics of a homologous series, a series of compounds containing the same functional group. IUPAC rules for nomenclature.

**Organic chemistry**

Optical isomerism is a form of stereoisomerism and occurs as a result of chirality in molecules, limited to molecules with a single chiral centre. An asymmetric carbon atom is chiral and gives rise to optical isomers (enantiomers), which exist as non superimposable mirror images and differ in their effect on plane polarised light. A mixture of equal amounts of enantiomers is called a racemic mixture (racemate).

Aldehydes are readily oxidised to carboxylic acids. Chemical tests to distinguish between aldehydes and ketones including Fehling’s solution and ‘Tollens’ reagent. Aldehydes can be reduced to primary alcohols, and ketones to secondary alcohols, using NaBH4 in aqueous solution. These reduction reactions are examples of nucleophilic addition. The nucleophilic addition reactions of carbonyl compounds with KCN, followed by
dilute acid, to produce hydroxynitriles. Aldehydes and unsymmetrical ketones form mixtures of enantiomers when they react with KCN followed by dilute acid. The hazards of using KCN.

The structures of: • carboxylic acids • esters. Carboxylic acids are weak acids but will liberate CO₂ from carbonates. Carboxylic acids and alcohols react, in the presence of an acid catalyst, to give esters. Common uses of esters (eg in solvents, plasticisers, perfumes and food flavourings). Vegetable oils and animal fats are esters of propane-1,2,3-triol (glycerol). Esters can be hydrolysed in acid or alkaline conditions to form alcohols and carboxylic acids or salts of carboxylic acids. Vegetable oils and animal fats can be hydrolysed in alkaline conditions to give soap (salts of long-chain carboxylic acids) and glycerol. Biodiesel is a mixture of methyl esters of long-chain carboxylic acids. Biodiesel is produced by reacting vegetable oils with methanol in the presence of a catalyst. The nucleophilic addition–elimination reactions of water, alcohols, ammonia and primary amines with acyl chlorides and acid anhydrides. The industrial advantages of ethanoic anhydride over ethanol chloride in the manufacture of the drug aspirin. The nature of the bonding in a benzene ring, limited to planar structure and bond length intermediate between single and double. Delocalisation of p electrons makes benzene more stable than the theoretical molecule cyclohexa-1,3,5-triene.

Electrophilic attack on benzene rings results in substitution, limited to monosubstitutions. Nitration is an important step in synthesis, including the manufacture of explosives and formation of amines. Friedel–Crafts acylation reactions are also important steps in synthesis.

Primary aliphatic amines can be prepared by the reaction of ammonia with haloenoalkanes and by the reduction of nitriles. Aromatic amines,
prepared by the reduction of nitro compounds, are used in the manufacture of dyes. Amines are weak bases. The difference in base strength between ammonia, primary aliphatic and primary aromatic amines.

Amines are nucleophiles. The nucleophilic substitution reactions of ammonia and amines with halogenoalkanes to form primary, secondary, tertiary amines and quaternary ammonium salts. The use of quaternary ammonium salts as cationic surfactants. The nucleophilic addition–elimination reactions of ammonia and primary amines with acyl chlorides and acid anhydrides.

The study of polymers is extended to include condensation polymers. The ways in which condensation polymers are formed are studied, together with their properties and typical uses. Problems associated with the reuse or disposal of both addition and condensation polymers are considered. Condensation polymers are formed by reactions between: • dicarboxylic acids and diols • dicarboxylic acids and diamines • amino acids. The repeating units in polyesters (eg Terylene) and polyamides (eg nylon 6,6 and Kevlar) and the linkages between these repeating units.

Amino acids, proteins and DNA are the molecules of life. In this section, the structure and bonding in these molecules and the way they interact is studied. Drug action is also considered.

Proteins are sequences of amino acids joined by peptide links. The importance of hydrogen bonding and sulphur–sulphur bonds in proteins. The primary, secondary (α-helix and β–pleated sheets) and tertiary structure of proteins. Hydrolysis of the peptide link produces the constituent amino acids. Amino acids can be separated and identified by thin-layer chromatography. Amino acids can be located on a chromatogram using developing agents such as ninhydrin
or ultraviolet light and identified by their Rf factor.

The structures of the phosphate ion, 2-deoxyribose (a pentose sugar) and the four bases adenine, cytosine, guanine and thymine are given in the Chemistry Data Booklet. A nucleotide is made up from a phosphate ion bonded to 2-deoxyribose which is in turn bonded to one of the four bases adenine, cytosine, guanine and thymine. A single strand of DNA (deoxyribonucleic acid) is a polymer of nucleotides linked by covalent bonds between the phosphate group of one nucleotide and the 2-deoxyribose of another nucleotide. This results in a sugar-phosphate polymer chain with bases attached to the sugars in the chain. DNA exists as two complementary strands arranged in the form of a double helix.

The Pt(II) complex cisplatin is used as an anticancer drug. Cisplatin prevents DNA replication in cancer cells by a ligand replacement reaction with DNA in which a bond is formed between platinum and a nitrogen atom on guanine. Appreciate that society needs to assess the balance between the benefits and the adverse effects of drugs, such as the anticancer drug cisplatin.

The synthesis of an organic compound can involve several steps.

Chemists use a variety of techniques to deduce the structure of compounds. In this section, nuclear magnetic resonance spectroscopy is added to mass spectrometry and infrared spectroscopy as an analytical technique. The emphasis is on the use of analytical data to solve problems rather than on spectroscopic theory.

Nuclear magnetic spectroscopy is used to analyse organic structures.

Chromatography provides an important method of separating and identifying components in a mixture. Different types of chromatography are
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used depending on the composition of mixture to be separated.

| Year 1 Revision | Physical Chemistry 1  
| Inorganic Chemistry 1  
| Organic Chemistry 1  
| Including required practicals |

How parents/carers can help:

Ensure students have a quiet place to study
Test students on key knowledge questions
Check in for home learning
Encourage independent study at home

Who to contact if you have a query

<table>
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