Learning Outcomes Leaving Certificate Chemistry

1 Periodic table and atomic structure			
1.1 The periodic table of elements. (3 class periods) By the end of this section pupils should be able to	**Good**	**Fair**	**Poor**
describe the periodic table as a list of elements arranged so as to demonstrate trends in their physical and chemical properties define the term element associate the first 36 elements with their elemental symbols distinguish between elements and compounds state the principle resemblances of elements within each main group, in particular alkali metals, alkaline earth metals, halogens and noble gases describe the reaction between water and lithium, sodium and potassium having seen the reaction demonstrated describe by means of a chemical equation the reaction between water and lithium, sodium and potassium having seen the reaction demonstrated outline the history of the idea of elements, including the contributions of the Greeks, Boyle, Davy and Moseley outline the contributions of Mendeleev, **Dobereiner, Newlands and Moseley** to the structure of the modern periodic table compare Mendeleev's periodic table with the modern periodic table arrange elements in order of relative atomic mass and note differences with modern periodic table			
1.2 Atomic Structure (6 class periods) By the end of this section pupils should be able	**Good**	**Fair**	**Poor**
outline the historical development of atomic theory (outline principles only, mathematical treatment not required): *Dalton*: atomic theory; ***Crookes*: vacuum tubes, cathode rays;** ***Stoney:* naming of the electron**; *Thomson*: negative charge of the electron; **e/m for electrons (experimental details not required);** ***Millikan*: magnitude of charge of electrons as shown by oil drop experiment (experimental details not required);** *Rutherford***:** discovery of the nucleus as shown by the particle scattering experiment; **discovery of protons in nuclei of various atoms;** *Bohr*: model of the atom; ***Chadwick*: discovery of the neutron**. recall that matter is composed of particles, which may be atoms, molecules or ions define an atom			

appreciate that atoms are minute particles state the law of conservation of mass describe, relative mass, relative charge and location of a proton, neutron, and electron in an atom define atomic number (Z) mass number(*A*) define relative atomic mass (*A*r) using the C_{12} scale define isotope describe the composition of isotopes using hydrogen and carbon as examples describe how a mass spectrometer can be used to determine relative atomic mass describe the principles on which the Mass Spectrometer is based **explain the fundamental processes that occur in a mass spectrometer** **calculate the approximate relative atomic masses from abundance of isotopes of given mass number**			
1.3 Radioactivity (2 class periods) By the end of this section pupils should be able	**Good**	**Fair**	**Poor**
define radioactivity describe the nature and penetrating ability of alpha, beta and gamma radiation give one example each of the following: an α emitter, a β emitter and a γ-emitter explain how radiation is detected having seen a demonstration / video (principles of a geiger muller tube not required) define radioisotopes define and explain half life (non-mathematical treatment) give a historical outline of: • Becquerel's discovery of radiation from uranium salts • Marie and Pierre Curie's discovery of polonium and radium comment on the widespread occurrence of radioactivity **distinguish between a chemical reaction and a nuclear reaction (simple equations required, confine to α and β emissions)** state three uses of radioactivity, including food irradiation and the use of ^{60}Co for cancer treatment explain how ^{14}C is used for age determination (calculations not required)			

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1.4 Electronic Structure of Atoms (11 class periods) By the end of this section pupils should be able	**Good**	**Fair**	**Poor**
define and explain energy levels in atoms			
describe the organization of particles in atoms of elements numbers 1-20			
classify the first twenty elements in the periodic table on the basis of the number of outer electrons			
list the numbers of electrons in each main energy level in atoms of elements nos. 1–20			
describe and explain the emission spectrum of the hydrogen atom using the Balmer series in the emission spectrum as an example			
describe and explain the absorption spectrum			
use flame tests to provide evidence that energy is absorbed or released in discrete units when electrons move from one energy level to another			
explain how flame tests provide evidence that energy is absorbed or released in discrete units when electrons move from one energy level to another			
relate energy levels in atoms to everyday applications such as sodium street lights and fireworks			
discuss the uses of atomic absorption spectrometry (AAS) as an analytical technique			
illustrate how line spectra provide evidence for energy levels			
use a spectroscope or a spectrometer to view emission spectra of elements			
define and explain energy sub-levels			
state the Heisenberg uncertainty principle			
state the dual wave-particle nature of the electron (mathematical treatment not required)			
define and explain atomic orbitals			
describe the shapes of s and p orbitals			
build up the electronic structure of the first 36 elements			
derive the electronic configurations of ions of s- and p block elements only			
describe the arrangement of electrons in individual orbitals of p-block atoms			
define and explain atomic radius			
explain the general trends in values of atomic radii (covalent radii only)			

• down a group • across a period (main group elements only) define and explain first ionisation energy **explain the general trends in first ionisation energy values:** • **down a group** • **across a period (main group elements) and** **explain the exceptions to the general trends across a period** **define and explain second and successive ionisation energies** **describe how second and successive ionisation energies provide evidence for energy levels** **recognise the relationship and trends in successive ionisation energies of an individual element** explain how chemical properties of elements depend on their electronic structure explain how atomic radius, screening effect and nuclear charge account for general trends in properties of elements in groups I and VII			
1.5 Oxidation and Reduction (7 class periods) By the end of this section pupils should be able	**Good**	**Fair**	**Poor**
define oxidation and reduction in terms of electron transfer use simple examples , e.g. Na with Cl_2, Mg with O_2, Zn with Cu^{2+} to describe oxidation and reduction in terms of electron transfer apply knowledge of oxidation and reduction to explain the rusting of iron define oxidising agent and reducing agent arrange the electrochemical series of metals in order of their ease of oxidation (reactions, other than displacement reactions, not required) carry out an experiment to show that halogens act as oxidising agents(reactions with bromides, iodides, Fe^{2+} and sulfites; half equations only required) carry out an experiment to demonstrate the displacement reactions of metals (Zn with Cu^{2+}, Mg with Cu^{2+}) explain what happens at each electrode during the electrolysis of: • copper sulfate solution with copper electrodes • acidified water with inert electrodes **(half equations only required)** **describe and account for the observations of what happens at each electrode during the electrolysis of (teacher demo)** • **aqueous sodium sulfate (using universal indicator)** • **aqueous potassium iodide (using phenolphthalein indicator)**			

with inert electrodes (half equations only required) describe the extraction of copper by displacements using scrap iron describe and explain ionic movement as observed during teacher demonstration describe the following electrolytic processes: purification of copper, chrome and nickel plating. Give one everyday application of chrome and nickel plating e.g. cutlery			

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Chemical Bonding			
2.1 Chemical Compounds (5 class periods) By the end of this section pupils should be able to	**Good**	**Fair**	**Poor**
understand that compounds can be represented by chemical formulas relate the stability of noble gasses to their electron configurations describe bonding and valency in terms of the attainment of a stable electronic structure state the octet rule explain its limitations use the octet rule to predict the formulas of simple binary compounds of the first 36 elements (excluding d-block elements) binary compounds of the first 36 elements *(excluding d-block elements)* and the hydroxides, carbonates, **nitrates, hydrogencarbonates, sulfites and sulfates** of these elements (where such exist). **recognise that Cu, Fe, Cr and Mn have variable valencies** relate the uses of helium and argon to their chemical unreactivity			
2.2 Ionic Bonding (4 class periods) By the end of this section pupils should be able	**Good**	**Fair**	**Poor**
define ion, positive ion, negative ion appreciate the minute size of ions explain ionic bonding in terms of electron transfer represent ionic bonds using dot and cross diagrams describe the structure of a sodium chloride crystal having reviewed models associate ionic substances with their characteristics outline two uses of ionic materials in everyday life test for anions in aqueous solutions: chloride, carbonate, nitrate, sulfate, phosphate, sulfite, hydrogencarbonate			
2.3 Covalent Bonding (4 class periods) By the end of this section pupils should be able to	**Good**	**Fair**	**Poor**
define molecule appreciate the minute size of molecules explain covalent bonding in terms of the sharing of pairs of electrons (Single, double and triple covalent bonds) represent covalent bonds in molecules using dot and cross diagrams			

distinguish between sigma and pi bonding distinguish between polar and non-polar covalent bonding test a liquid for polarity using a charged plastic rod give examples of polar and non-polar materials in everyday life (two examples in each case) associate covalent substances with their characteristics test the solubility of ionic and covalent substances in different solvents			
2.4 Electronegativity (2 class periods) By the end of this section pupils should be able	**Good**	**Fair**	**Poor**
define electronegativity recognise the trends in electronegativity values down a group and across a period explain the general trends in electronegativity values • down a group • across a period. relate differences in electronegativity to polarity of bonds predict bond type using electronegativity differences			
2.5 Shapes of Molecules and Intermolecular Forces (5 class Periods) By the end of this section pupils should be able	**Good**	**Fair**	**Poor**
describe the shapes of simple molecules use appropriate modeling techniques to illustrate molecular shape **explain the basis for electron pair repulsion theory** **use electron pair repulsion theory to explain the shapes of molecules of type AB_n for up to four pairs of electrons around the central atom refer to bond angles (Shapes of molecules with pi bonds not to be considered)** **explain the relationship between symmetry and polarity in a molecule (dipole moments not required)** **describe and distinguish between intramolecular bonding and intermolecular forces (van der Waals', dipole-dipole, hydrogen bonding)** **describe the effects of intermolecular forces on the boiling point of covalent substances** **relate the differences in boiling points of H_2 and O_2, C_2H_2 and HCHO and of H_2O and H_2S to the effect of intermolecular forces**			

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2.6 Oxidation Numbers (5 class periods) By the end of this section pupils should be able	**Good**	**Fair**	**Poor**
define oxidation number, oxidation state **define oxidation and reduction in terms of change of oxidation numbers** **state the rules for oxidation numbers (exclude peroxides, except for hydrogen peroxide)** **calculate oxidation numbers of transition metals in their compounds and of other elements** **use oxidation numbers in nomenclature of transition metal compounds** **give an example of an oxidising and a reducing bleach**			

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3 Stoichiometry, Formulas and Equations			
3.1 States of Matter (1 class period) By the end of this section pupils should be able to	**Good**	**Fair**	**Poor**
describe the motion of particles in solids, liquids and gases explain diffusion demonstrate diffusion (Graham's law not required) using simple chemicals			
3.2 Gas Laws (7 class periods) By the end of this section pupils should be able	**Good**	**Fair**	**Poor**
State and explain Boyle's law describe the significance of Boyle' air pump state and explain Charles's law **state and explain Gay-Lussac's law of combining volumes** **state and explain Avogadro's law** carry out simple calculations using the combined gas law $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$ = constant **define ideal gases** **list the assumptions of the kinetic theory of gases** **explain why gases deviate from ideal gas behavior** **carry out simple calculations involving** ***PV = nRT (units: Pa m³,K)***			
3.3 The Mole (9 class periods) By the end of this section pupils should be able	**Good**	**Fair**	**Poor**
define the Avogadro constant define the mole calculate relative molecular mass from relative atomic masses define s.t.p define molar volume at s.t.p., molar mass, relative molecular mass (M_r) convert moles to grams, litres and number of particles convert grams, litres and **number of particles** to moles **convert moles to number of atoms of a molecular species** **explain how a mass spectrometer can be used to determine relative**			

molecular mass(M_r) (limited to simple treatment interpretation of mass spectra not required) determine the relative molecular mass of a volatile liquid using suitable apparatus			
3.4 Chemical Formulas (6 class periods) By the end of this section pupils should be able	**Good**	**Fair**	**Poor**
define empirical formula , molecular formula calculate empirical formulas given the percentage composition by mass **calculate empirical formulas given the masses of reactants and products** calculate molecular formulas given the empirical formulas and the relative molecular masses (examples should include simple biological substances, such as glucose and urea) calculate percentage composition by mass define structural formula deduce, describe and explain structural formulas (simple examples)			
3.5 Chemical Equations (11 class periods) By the end of this section pupils should be able	**Good**	**Fair**	**Poor**
recall that chemical equations are used to represent chemical reactions construct chemical equations balance simple chemical equations **balance redox equations (ionic equations only – ignore spectator ions)** perform calculations based on balanced equations using the mole concept (calculations in g and kg rather than tones. Calculations may involve masses and volumes) **perform calculations based on balanced equations involving excess of one reactant (calculations in g and kg rather than tones. Calculations may involve masses and volumes)** **calculate percentage yields**			

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4 Volumetric Analysis			
4.1 Concentration of Solutions (8 class period) By the end of this section pupils should be able to	**Good**	**Fair**	**Poor**
solution define concentration define molarity express concentration of solutions in mol^{-1}(molarity), g l^{-1} and also in **% (w/v)**, % (v/v), **% (w/w)** appreciate the everyday use of % v/v e.g. in alcoholic beverages calculate molarity from concentration in grams per litre and vice versa calculate number of moles from molarity and volume **perform simple calculations involving percentage concentrations** **calculate the effect of dilution on concentration** apply knowledge of concentrations of solutions to everyday examples describe how colour intensity can be used as an indicator of concentration Define a primary standard and a standard solution prepare standard solution of sodium carbonate			
4.2 Acids and Bases (4 class periods) By the end of this section pupils should be able	**Good**	**Fair**	**Poor**
relate the properties of acids and bases to their household applications recall that neutralisation is the formation of a salt from an acid and a base relate their knowledge of neutralisation to everyday examples e.g. use of lime in agriculture , use of stomach powders state the Arrhenius and **Brønsted-Lowry** theories of acids and bases **define what is meant by a conjugate acid/base pair** apply the Arrhenius and **Brønsted-Lowry** theories of acids and bases for aqueous solutions only			
4.3 Volumetric Analysis (22 class Periods) By the end of this section pupils should be able	**Good**	**Fair**	**Poor**
identify appropriate apparatus used in volumetric analysis use correct titrimetric procedure when carrying out titrations			

solve volumetric problems, using the formula method **solve volumetric problems from first principles** carry out a titration between hydrochloric acid and sodium hydroxide solutions and use this titration to make a sample of sodium chloride (OL only) standardise a hydrochloric acid solution using a standard solution of sodium carbonate **calculate the relative molecular mass of a compound and of the amount of water of crystallisation in a compound from titration data** (balanced equations will be given in all volumetric problems) **determine the concentration of ethanoic acid in vinegar** **determine the amount of water of crystallisation in hydrated sodium carbonate** **carry out a potassium manganate(VII)/ammonium iron(II) sulfate titration** **determine the amount of iron in an iron tablet** **carry out an iodine/thiosulfate titration** **determine the percentage (w/v) of hypochlorite in bleach**			

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5 Fuels and Heats of Reaction			
5.1 Source of Hydrocarbons (1 class period) By the end of this section pupils should be able to	**Good**	**Fair**	**Poor**
define hydrocarbon recall that coal, natural gas and petroleum are sources of hydrocarbons recall that decomposing animal and vegetable wastes are sources of methane recognise the hazards of methane production in slurry pits coalmines and refuse dumps discuss the contribution of methane to the greenhouse effect			
5.2 Structure of Aliphatic Hydrocarbons (5 class periods) By the end of this section pupils should be able	**Good**	**Fair**	**Poor**
define aliphatic hydrocarbon know what a homologous series is know that alkanes alkenes and alkynes are examples of homologous series apply the IUPAC system of nomenclature to the following homologous series: alkanes (to C5), alkenes (to C4) and alkynes. *(only ethyne (acetylene) to be considered)* define structural isomers draw the structural formulas and structural isomers of alkanes to C-5 construct models of the alkanes (to C5), alkenes (to C4) alkynes *(only ethyne (acetylene) to be considered)* draw the structural formulas of hexane, heptane, octane, cyclohexane and 2,2,4-trimethylpentane (iso-octane) (isomers not required) draw the structural formulas and structural isomers of alkenes to C-4 state the physical properties of aliphatic hydrocarbons [physical state, solubility (qualitative only) in water and in non-polar solvents describe and explain what is observed during a demonstration of the solubility properties of methane ethane and ethyne (acetylene) in polar and non-polar solvents			
5.3 Aromatic Hydrocarbons (1 class period) By the end of this section pupils should be able	**Good**	**Fair**	**Poor**
define aromatic hydrocarbon describe the structure of benzene, methylbenzene and ethylbenzene state the physical properties of aromatic hydrocarbons [physical state, solubility (qualitative only) in water and in non-polar solvents			

	Good	Fair	Poor
describe and explain what is observed during a demonstration of the solubility properties of methylbenzene in polar and non-polar solvents			
5.4 Exothermic and Endothermic Reactions (9 class periods) By the end of this section pupils should be able	**Good**	**Fair**	**Poor**
recall that chemical reactions can have an associated change in temperature of the system define endothermic and exothermic reactions describe and explain what is observed during a demonstration of an endothermic and exothermic reaction explain why changes of state can be endothermic or exothermic define heat of reaction determine the heat of reaction of hydrochloric acid with sodium hydroxide define heat of combustion recognise that the combustion of alkanes and other hydrocarbons releases carbon dioxide, water and energy write balanced chemical equations for the combustion of simple hydrocarbons relate the sign of enthalpy changes to exothermic and endothermic reactions **relate energy changes to bond breaking and formation** **explain the concept of bond energy using the calculation of the C-H bond energy in methane as an illustration** define heat of combustion describe the use of the bomb calorimeter in determining calorific values of foods relate the kilogram calorific values of fuels to their uses **define heat of formation** **state the law of conservation of energy** **state Hess's law** **calculate heat of reaction using heats of formation of reactants and products** **calculate heat of formation using other heats of formation and one heat of reaction. (Other kinds of heat of reaction calculation not required)**			
5.5 Oil Refining and its Products (4 class periods) By the end of this section pupils should be able	**Good**	**Fair**	**Poor**

describe the fractional distillation of crude oil			
explain where the main fractions of crude oil (refinery gas, light gasoline, naphtha, kerosene, gas oil and residue fractions) are produced on the fractionating column			
state the uses of refinery gas, light gasoline, naphtha, kerosene, and gas oil and residue fraction			
appreciate the rationale for the addition of mercaptans to natural gas			
recall the composition of natural gas, liquid petroleum gas (LPG) and petrol			
describe and explain: auto-ignition, knocking, octane number			
relate the octane number of a fuel to its tendency to cause knocking in the internal combustion engine			
describe the effect of chain length, degree of branching and cyclic structure on the tendency of petrol towards auto-ignition in the internal combustion engine			
describe the role played by lead compounds as petrol additives in the past			
explain isomerisation, dehydrocyclisation, catalytic cracking			
describe the role of isomerisation, dehydrocyclisation, and catalytic cracking in the increase of the octane rating of fuel			
oxygenates			
5.6 Other Chemical Fuels (1 class period) By the end of this section pupils should be able	**Good**	**Fair**	**Poor**
prepare a sample of ethyne (acetylene)			
recognise oxyacetylene welding and cutting as principle uses of ethyne (acetylene) .			
carry out an experiment to demonstrate the properties of ethyne (acetylene) *[combustion, tests for unsaturation using bromine water and acidified potassium manganate(VII) solution]*			
describe the manufacture of hydrogen by: • electrolysis of water • steam reforming of natural gas (simple treatment only)			
list some industrial uses of hydrogen including its potential as a fuel			

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6 Rates of Reaction			
Each topic has a set of boxes which the pupil can tick to show how well they understanding or how well they know the topic. This is useful for revision. **Bold text** indicates Higher Level.			
6.1 Reaction Rates (3 class periods) By the end of this section pupils should be able to	**Good**	**Fair**	**Poor**
define rate of reaction define catalysis monitor the rate of production of oxygen from hydrogen peroxide, using manganese dioxide as a catalyst plot reaction rate graphs interpret reaction rate graphs **distinguish between average and instantaneous rate** **calculate instantaneous rate from graph**s			
6.2 Factors Affecting Rates of Reaction (8 class periods) By the end of this section pupils should be able	**Good**	**Fair**	**Poor**
explain what is meant by the nature of reactants describe and explain how concentration, particle size, temperature, nature of reactants, and the presence of a catalyst effects the rate of reaction describe how to investigate the effect of (i) particle size and (ii) catalysts on reaction rate explain why dust explosions occur identify two examples of catalysts produced by living cells (enzymes) describe catalytic converters in terms of; nature of catalysts, reactions catalysed, environmental benefits and catalyst poisons investigate the effects on the reaction rate of (i) concentration and (ii) temperature, using sodium thiosulfate solution and hydrochloric acid describe and explain an experiment to show the oxidation of methanol (methyl alcohol) using a hot platinum or nichrome catalyst define activation energy **describe and explain the influence of temperature change to changes in reaction rate** **draw and interpret reaction profile diagrams** **use reaction profile diagrams to explain the influence of catalyst on the rate of reaction**			

explain the mechanism of catalysis with reference to surface adsorption and intermediate formation theories of catalysis describe and explain an experiment that demonstrates the oxidation of potassium sodium tartrate by hydrogen peroxide, catalysed by cobalt(II) salts			

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7 Organic Chemistry			
7.1 Tetrahedral Carbon (4 class periods) By the end of this section pupils should be able to	**Good**	**Fair**	**Poor**
define tetrahedral carbon explain what is meant by a saturated organic compound construct models to illustrate the structure of saturated organic compounds describe alkanes as a homologous series of aliphatic hydrocarbons discuss the use of alkanes as fuels **explain what is meant by the term alcohol** describe the alcohols as a homologous series of organic compounds **explain what is meant by the term chloroalkane** name the , **chloroalkanes** and alcohols (primary and secondary alcohols only) up to C4 **discuss the use of chloroalkanes as solvents** draw the structural formulas of, **chloroalkanes** and alcohols (primary and secondary alcohols only) up to C4 account for the physical properties [physical state, solubility (qualitative only) in water and in non-polar solvents]of the alkanes and **chloroalkanes** and alcohols up to C4 relate the physical properties of alcohols and water through comparison of their structures account for the solubility of (a) methanol (methyl alcohol) and (b) butan-1-ol in (i) cyclohexane and (ii) water. discuss the use of ethanol (ethyl alcohol) as a solvent outline the use of methanol (methyl alcohol) as a denaturing agent recall that fermentation is a source of ethanol (ethyl alcohol) discuss the use of fermentation in the brewing and distilling industries			
7.2 Planar Carbon (11 class periods) By the end of this section pupils should be able	**Good**	**Fair**	**Poor**

define planar carbon explain what is meant by an unsaturated organic compound describe alkenes as a homologous series of aliphatic hydrocarbons construct models to illustrate the structure of alkenes name the alkenes to C4 draw the structural formulas of the alkenes up to C4 outline the role of alkenes as raw materials in the industrial manufacture of plastic define carbonyl compound describe the bonding in the carbonyl group describe aldehydes as a homologous series of compounds construct models to illustrate the structure of aldehydes name the aldehydes to C4 draw the structural formulas of the aldehydes up to C4 account for the physical properties [physical state, solubility (qualitative only) in water and in non-polar solvents]of the aldehydes up to C4 account for the solubility of ethanal (acetaldehyde)in (i) cyclohexane and in (ii) water **recall that benzaldehyde is a constituent of almond kernels (structure of benzaldehyde not required)** **describe ketones as a homologous series of compounds** **construct models to illustrate the structure of, ketones** **name the ketones to C4** **draw the structural formulas of the ketones to C4** **account for the physical properties [physical state, solubility (qualitative only) in water and in non-polar solvents]of the ketones up to C4** **account for the solubility of propanone (acetone) in (i) cyclohexane and in (ii) water** **give an example of the use of propanone (acetone) as a solvent e.g. in nail varnish remover** describe carboxylic acids as a homologous series of compounds construct models to illustrate the structure of carboxylic acids name the carboxylic acids to C4			

draw the structural formulas of the carboxylic acids to C4 describe the bonding in the carbonyl group of carboxylic acids account for the solubility of ethanoic (acetic) acid in (i) cyclohexane and in (ii) water account for the physical properties [physical state, solubility (qualitative only) in water and in non-polar solvents] of the carboxylic acids up to C4 give examples of carboxylic acids in everyday life e.g. methanoic acid (formic acid) in nettles and ants, ethanoic acid (acetic acid) in vinegar **recall the use of ethanoic acid** (acetic acid) **in the manufacture of cellulose acetate (structure of cellulose acetate not required)** **recall the use of propanoic and benzoic acid and their salts as food preservatives (structure of benzoic acid not required)** purify a sample of benzoic acid by recrystallisation outline the use of melting point to confirm purity determine the melting point of benzoic acid **describe esters as a homologous series of compounds** **construct models to illustrate the structure of esters** **name the esters to C4** **draw the structural formulas of the esters to C** **account for the physical properties of esters [physical state, solubility (qualitative only) in water and in non-polar solvents]** **account for the solubility of ethyl ethanoate (ethyl acetate) in (i) cyclohexane and in (ii) water** **recall that fats are natural esters** **appreciate that esters have a characteristic aroma** **recall the use of ethyl ethanoate (ethyl acetate) as a solvent** explain what is meant by an aromatic compound explain in simple terms the use of the circle to represent the identical bonds in benzene, intermediate between double and single **describe the bonding in benzene with reference to sigma and pi bonds** account for the solubility of methylbenzene in (i) cyclohexane and in (ii) water discuss the use of methylbenzene as an industrial solvent			

give an indication of the range and scope of aromatic chemistry (Structures not required) identify the benzene ring in the structural formulas of a range of consumer products give one example in each case of: • aromatic compounds as the basis of dyestuffs, detergents, herbicides and many pharmaceutical compounds (structures not required) • aromatic acid-base indicators: phenolphthalein, methyl orange (structures not required) recognise the carcinogenic nature of some aromatic compounds e.g. benzene recognise that not all aromatic compounds are carcinogenic, e.g. aspirin (structure of aspirin not required)			
7.3 Organic Chemical Reaction Types (21 class periods) By the end of this section pupils should be able	**Good**	**Fair**	**Poor**
Students are not, in general, required to know the conditions (temperature, pressure, catalyst, solvent) for these reactions except where specified elsewhere in this syllabus. They are required to write balanced equations using structural formulas, unless otherwise stated. **Addition Reactions** explain what is meant by an addition reaction write balanced equations using structural formula for the reactions of the alkenes with hydrogen, chlorine, bromine, water and hydrogen chloride outline the production of alkenes in the petrochemical industry c.f section 5.5 outline the industrial importance of: • products of the addition reactions of ethene (ethylene) with chlorine, bromine, water and hydrogen chloride • hydrogenation of vegetable oils **describe the mechanisms of ionic addition (addition of HCl, Br_2, Cl_2, only to ethene (ethylene))** **describe the evidence for this mechanism as: the reaction of ethene (ethylene) with bromine water containing sodium chloride results in the formation of 2-bromoethanol (ethyl alcohol) 1-bromo-2-chloroethane and 1,2-dibromoethane** explain what is meant by addition polymerisation outline the polymerisation reaction of ethene(ethylene) and propene (reaction mechanism not required).			

account for the unreactivity of benzene with regard to addition reactions relative to ethene (ethylene)

account for the use of alkenes as raw materials in the industrial manufacture of plastics

outline the range and scope of the petrochemical industry

list two synthetic products of the petrochemical industry (structures not required unless specified elsewhere on the syllabus)

<u>Substitution Reaction</u>
define substitution reaction

recognise halogenation of alkanes as a substitution reaction

write balanced equations using structural formula for the halogenations of alkanes

describe the mechanism of free radical substitution (monochlorination of methane and ethane only)

discuss the evidence for the mechanism of free radical substitution
- **use of ultraviolet light even for a very short period causes a chain reaction**
- **formation of trace quantities of ethane and butane in the monochlorination of methane and ethane, respectively**
- **these reactions are speeded up by the addition of a known source of free radicals, such as tetraethyllead**

explain what is meant by esterification

explain what is meant by base hydrolysis of esters

write balanced equations using structural formulas to illustrate base hydrolysis of esters

prepare a sample of soap **(structures of reactants and products required)**

discuss the manufacture of soap **(structures of reactants and products required)**

<u>Elimination Reactions</u>
explain what is meant by an elimination reaction

explain what is meant by a dehydration reaction

write balanced equations using structural formula for the dehydration of alcohols

prepare a sample of ethene(ethylene)

demonstrate the properties of ethene(ethylene) combustion, tests for unsaturation using acidified potassium manganate(VII) solution and bromine water.(*equations and structures of products not required unless specified elsewhere on the syllabus)*

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Redox Reactions write balanced half equations using structural formula for the oxidation (using $KMnO_4$ or $Na_2Cr_2O_7$) of: • alcohols to(i) aldehydes and (ii) acids • aldehydes to acids prepare a sample of ethanal (acetaldehyde)from ethanol (ethyl alcohol) **carry out calculations involving percentage yield of ethanal (the balanced equation will be given)** demonstrate the properties of ethanal (acetaldehyde) (limited to reactions with (i) acidified potassium manganate(VII) solution, (ii) Fehling's reagent and (iii) ammoniacal silver nitrate) relate the production of ethanal to the metabolism of ethanol (ethyl alcohol) in the human body prepare a sample of ethanoic acid (acetic acid) from ethanol (ethyl alcohol) **carry out calculations involving percentage yield of ethanoic acid (the balanced equation will be given)** carry out diagnostic tests on ethanoic acid (limited to reactions with sodium carbonate, magnesium and **ethanol (ethyl alcohol)**) **account for the lower susceptibility of ketones than aldehydes to oxidation** **write balanced equations using structural formulas for the reduction of carbonyl compounds using a H_2/Ni catalyst** recall that combustion is a reaction common to most organic compounds recall that the fully halogenated alkanes are non-flammable, relate this property to their use in flame retardants and fire extinguishers write balanced equations using structural formulas for the combustion of alcohols discuss the application of alcohols as motor fuels **Reactions as acids** write balanced equations using structural formulas for the reactions of alcohols with sodium **account for the acidic nature of the carboxylic acid group** write balanced equations using structural formulas for the reactions of carboxylic acids with magnesium, with sodium hydroxide and with sodium carbonate **Organic synthesis: principles and examples** recall that chemical synthesis involves (i) bond breaking and (ii) bond forming describe the organic synthesis of PVC from ethene (ethylene) (structures and synthetic route not required)			

work out reaction schemes of up to three conversions recalling familiar reactions			
7.4 Organic Natural Products (4 class periods) By the end of this section pupils should be able	**Good**	**Fair**	**Poor**
describe some commonly used extraction techniques, e.g. solvent extraction, steam distillation extract clove oil from cloves (or similar alternative) by steam distillation indicate the range and scope of organic natural product chemistry using two examples of useful organic natural products (structures not required*)*			
7.5 Chromatography and Instrumentation in Organic Chemistry (3 class periods) By the end of this section pupils should be able	**Good**	**Fair**	**Poor**
describe chromatography as a separation technique in which a mobile phase carrying a mixture is caused to move in contact with a selectively absorbent stationary phase separate a mixture of indicators using paper chromatography or thin-layer chromatography or column chromatography describe the use of thin-layer chromatography (TLC) in the separation of dyes taken from fibres in forensic work describe GC and HPLC as more advanced separation techniques give examples of instrumental methods of separation or analysis referring briefly to the principles involved in each case for the following: • mass spectrometry- analysis of gases from a waste dump, trace organic pollutants in water • gas chromatography (GC)- drug tests on athletes, blood alcohol tests • high-performance liquid chromatography (HPLC)- growth-promoters in meat, vitamins in foods • **infra-red absorption spectrometry (IR)- identification of organic compounds, e.g. plastics and drugs** • **ultraviolet absorption spectrometry- quantitative determination of organic compounds (e.g. drug metabolites, plant pigments)** Brief reference to the principles of each method. interpretation of spectra etc. not required (It should be noted that these techniques are applicable not only to organic chemistry but also to many other areas of chemistry)			

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Chemical Equilibrium			
8.1 Chemical Equilibrium (8 class periods) By the end of this section pupils should be able to	**Good**	**Fair**	**Poor**
explain what is meant by a reversible reaction explain what is meant by dynamic equilibrium explain what is meant by chemical equilibrium state the equilibrium law ($K_c$only) write expressions for K_c **perform calculations involving equilibrium constants (K_c)**			
8.2 Le Chatelier's Principle (5 class periods) By the end of this section pupils should be able	**Good**	**Fair**	**Poor**
state Le Chatelier's principle use Le Chatelier's principle to predict the effect (if any) on equilibrium position of concentration, pressure, temperature and catalyst perform simple experiments to demonstrate Le Chatelier's principle using the following equilibrium mixtures • $CoCl_4^{2-} + 6H_20 \Leftrightarrow Co(H_20)_6^{2+} + 4Cl^-$ (to demonstrate the effects of both temperature changes and concentration changes on an equilibrium mixture) • $Cr_2O_7^{2-} + H_2O \Leftrightarrow 2CrO_4^{2-} + 2H^+$ • $Fe^{3+} + CNS^- \Leftrightarrow Fe(CNS)^{2+}$ (to demonstrate the effects of concentration changes on an equilibrium mixture) discuss the Industrial application of Le Chatelier's principle in the catalytic oxidation of sulfur dioxide to sulfur trioxide and in the Haber process			

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9 Environmental Chemistry: Water			
Each topic has a set of boxes which the pupil can tick to show how well they understanding or how well they know the topic. This is useful for revision. **Bold text** indicates Higher Level.			
9.1 pH Scale (6 class periods) By the end of this section pupils should be able to	**Good**	**Fair**	**Poor**
define pH describe the use of the pH scale as a measure of the degree of acidity/alkalinity discuss the limitations of the pH scale **explain self-ionisation of water** write an expression for K_w use universal indicator paper or solution to determine pH calculate the pH of dilute aqueous solutions of strong acids and bases **distinguish between the terms weak, strong,** concentrated and dilute **in relation to acids and bases** **calculate the pH of weak acids and bases (approximate method of calculation to be used – assuming that ionisation does not alter the total concentration of the non-ionised form)** **define acid-base indicator** **explain the theory of acid-base indicators** justify the selection of an indicator for acid base titrations			
9.2 Hardness in Water (3 class periods) By the end of this section pupils should be able	**Good**	**Fair**	**Poor**
define hardness in water define temporary hardness in water define permanent hardness in water identify the causes temporary and permanent hardness in water explain how deionisation is achieved using ion exchange resins describe a test that can be carried out on scale deposits in a kettle describe how hardness can be removed by boiling and by ion exchange **account the relative purity of deionised and distilled water**			
9.3 Water Treatment (5 class periods) By the end of this section pupils should be able	**Good**	**Fair**	**Poor**
describe the treatment of water under the following headings:			

sedimentation, flocculation, filtration, chlorination, fluoridation and pH adjustment describe how sewage is treated (primary, e.g. settlement, screening; secondary, e.g. bacterial breakdown; tertiary, e.g. reduction of level of phosphates and nitrates) be aware of the high cost of tertiary treatment of water discuss the role of nutrients in the eutrophication of water **discuss how pollution can be caused by uncontrolled use of nitrate fertilizers** **describe the polluting potential of heavy metals from batteries in the absence of recycling** **discuss pollution by heavy metal ions in water – especially Pb^{2+}, Hg^{2+} and Cd^{2+}** **describe how heavy metal ions in water – especially Pb^{2+}, Hg^{2+} and Cd^{2+} can be removed from industrial effluent by precipitation** recall that there are EU limits for various chemical species in water (two examples, e.g. nitrates, phosphates, specific metal ions)			
9.4 Water Analysis (11 class periods) By the end of this section pupils should be able	**Good**	**Fair**	**Poor**
outline the basic principles of the following instrumental methods of water analysis: • pH meter (analysis of river and lake water) • **AAS [cf. flame tests, absorption spectra (unit 1.4)]** (analysis of heavy metals in water e.g. lead, cadmium) • colorimetry (analysis of (i) lead in water (ii) fertilisers carry out a colorimetric experiment to estimate free chlorine in swimming-pool water or bleach (using a colorimeter or a comparator) determine the total suspended and total dissolved solids (expressed as p.p.m.) by filtration and evaporation respectively determine pH and test water for anions (cf.unit 2.2) estimate the total hardness of water using ethylenediaminetetraacetic acid (edta) (balanced ionic equation required) **define biochemical oxygen demand (BOD**) **estimate dissolved oxygen by redox titration** describe the effect of organic chemical pollutants e.g. sewage industrial waste, silage, milk			

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Option 1A: Additional Industrial Chemistry			
1A.1 General Principles (3 class periods) By the end of this section pupils should be able to	**Good**	**Fair**	**Poor**
distinguish between batch, continuous and semi-continuous industrial chemical processes. Understand and discuss the following characteristics of effective and successful industrial chemical processes (i) feedstock (raw materials, preparation) (ii) rate (temperature and pressure variables, catalyst) (iii) product yield (temperature and pressure variables, catalyst) (iv) co-products (separation, disposal or sale) (v) waste disposal and effluent control (waste water treatment, emission control) (vi) quality control (vii) safety (location of site, on-site training, monitoring of hazards, safety features) (viii) costs (fixed costs, variable costs; cost reduction by use of heat exchangers, catalysts, recycling and selling of useful co-products; costs of waste disposal) (ix) site location (x) Suitable materials for the construction of chemical plant (unreactive, resistant to corrosion). be aware of the contributions of chemistry to society, e.g. provision of pure water, fuels, metals, medicines, detergents, enzymes, dyes, paints, semiconductors, liquid crystals and alternative materials, such as plastics and synthetic fibres; increasing crop yields by the use of fertilisers, herbicides and pesticides; food-processing			
1A.2 Case Studies (5 class periods) By the end of this section pupils should be able	**Good**	**Fair**	**Poor**
conduct a case study of one of the following processes used in the Irish chemical industry **(a) Ammonia manufacture from natural gas, water vapour and air, and its conversion to urea.** know equations for (i) hydrogen production (ii) removal of carbon dioxide (iii) ammonia formation (iv) Urea synthesis. **(b) Nitric acid manufacture from ammonia, and its use to make fertilisers.** use of urea as a fertiliser know equations required for (i) oxidation of ammonia (ii) oxidation of nitrogen monoxide			

(iii) formation of nitric acid (iv) Formation of ammonium nitrate. Use of ammonium nitrate as a fertiliser. **(c) Magnesium oxide manufacture from sea water.** know equations required for (i) conversion of calcium carbonate to calcium oxide (ii) conversion of calcium oxide to calcium hydroxide (iii) formation of magnesium hydroxide (iv) Formation of magnesium oxide. Use of magnesium oxide as a heat-resistant material in the walls of furnaces. be aware of the range and scope of the Irish chemical industry (two examples of products produced by this industry, other than those referred to in the case study chosen).			

Option 1B: Atmospheric Chemistry			
1B.1 Oxygen (1 class period) By the end of this section pupils should be able to	**Good**	**Fair**	**Poor**
describe the manufacture of oxygen using liquefaction and fractional distillation of air state two uses of oxygen and liquid nitrogen			
1B.2 Nitrogen (2 class periods) By the end of this section pupils should be able	**Good**	**Fair**	**Poor**
describe the structure of the nitrogen molecule describe how nitrogen is fixed naturally and in an electric discharge explain why the nitrogen molecule is inert and give two uses derived from this			
1B.3 Carbon Dioxide (4 class periods) By the end of this section pupils should be able	**Good**	**Fair**	**Poor**

describe the conditions under which carbon monoxide and carbon dioxide are produced by combustion describe and explain the effect of carbon dioxide on universal indicator solution state the effect of carbon dioxide and carbon monoxide on universal indicator solution explain how carbon dioxide works as a poison **write balanced chemical equations for reactions of carbon dioxide with water- free and combined as carbonate and hydrogencarbonate** describe fermentation in ethanol production as a source of carbon dioxide explain the use of carbon dioxide in carbonated drinks describe the carbon cycle explain the greenhouse effect discuss the influence of human activity on the greenhouse effect describe the effects of the greenhouse gasses [especially carbon dioxide and water vapour, **also methane and chlorofluorocarbons (CFCs)]** explain how atmospheric carbon dioxide is reduced by dissolving in the ocean discuss the possible implications of the increased greenhouse effect			
1B.4 Atmospheric Pollution (2 class periods) By the end of this section pupils should be able	**Good**	**Fair**	**Poor**
explain how oxides of nitrogen and sulphur are formed list sources of pollution (natural, domestic, industrial, internal combustion engine) explain how acid rain is formed describe and explain the effect of sulphur dioxide on universal indicator solution list the effects of acid rain on the environment describe how sulphur dioxide emissions from coal-fired power stations are reduced by scrubbing of waste gasses using limestone			
1B.5 The Ozone Layer (4 class periods) By the end of this section pupils should be able	**Good**	**Fair**	**Poor**
define ozone define chlorofluorocarbon describe the effect of CFCs on ozone in the stratosphere explain how ozone is formed in the stratosphere **(equation required)**			

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explain how the ozone layer is beneficial **explain the photo-dissociation of ozone (equation required)** describe what use is made of CFCs explain why they have been replaced by HCFCs **explain the significance of the residence time of CFCs** **describe how CFCs are broken down in the stratosphere** **describe how ozone is removed from the stratosphere by Cl atoms (equation required), O atoms and NO molecules** **describe the role of methane in absorbing Cl atoms** comment on the damaging effect of CFCs on the ozone layer **name a type of compound used as a replacement for CFCs**			