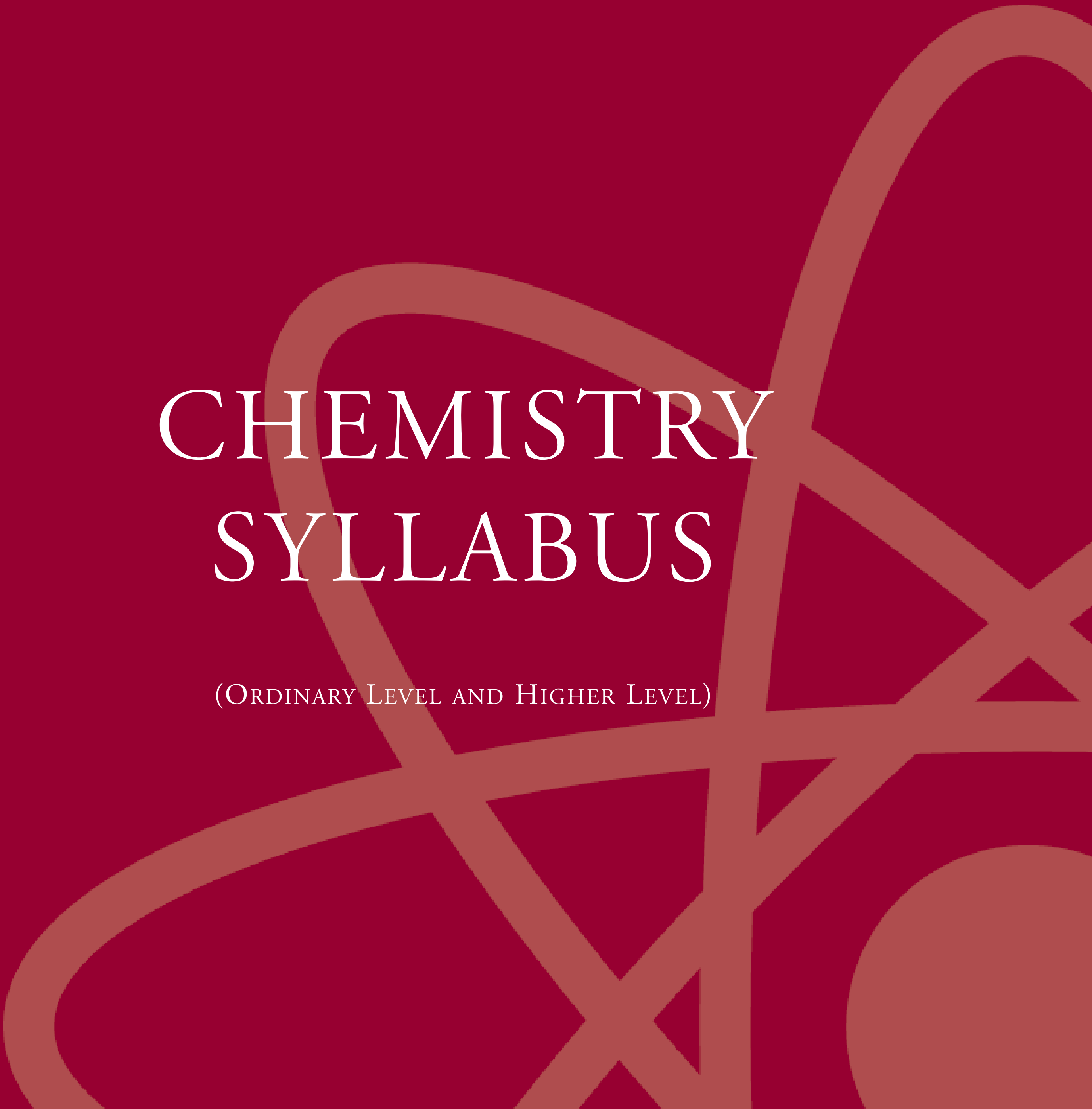
An Roinn Oideachais agus Eolaíochta

Leaving Certificate

CHEMISTRY SYLLABUS

(Ordinary Level and Higher Level)



LEAVING CERTIFICATE PROGRAMMES

Aims and Principles

1. The general aim of education is to contribute towards the development of all aspects of the individual, including aesthetic, creative, critical, cultural, emotional, expressive, intellectual, for personal and home life, for working life, for living in the community and for leisure.

2. Leaving Certificate programmes are presented within this general aim, with a particular emphasis on the preparation of students for the requirements of further education or training, for employment and for their role as participative, enterprising citizens.

3. All Leaving Certificate programmes aim to provide continuity with and progression from the Junior Certificate programme. The relative weighting given to the various components — e.g. personal and social (including moral and spiritual) development, vocational studies and preparation for further education and for adult and working life — within the programmes may vary.

4. Programmes leading to the award of the Leaving Certificate are of two years duration and are offered in three forms:

   i. The Leaving Certificate (Established)

   ii. The Leaving Certificate Vocational Programme

   iii. The Leaving Certificate Applied

5. All Leaving Certificate programmes, in contributing to a high quality education, emphasise the importance of :

   - self-directed learning and independent thought

   - a spirit of inquiry, critical thinking, problem solving, self-reliance, initiative and enterprise

   - preparation for further education, for adult and working life

   - lifelong learning.

The Leaving Certificate (Established)

The Leaving Certificate (Established) programme offers students a broad and balanced education while allowing for some specialisation. Syllabuses are provided in a wide range of subjects. All subjects are offered at Ordinary and Higher levels. In addition, Mathematics and Irish are also offered at Foundation level.

The certificate is used for purposes of selection into further education, employment, training and higher education.

The Leaving Certificate Vocational Programme (LCVP)

The Leaving Certificate Vocational Programme is an intervention within the Leaving Certificate (Established). LCVP students study a minimum of five subjects (at Higher, Ordinary or Foundation levels), including Irish and two subjects from specified vocational subject groupings. They are also required to take a recognised course in a Modern European language, other than Irish or English. In addition LCVP students take three Link Modules on Enterprise Education, Preparation for Work and Work Experience.

In particular, the LCVP aims to foster in students a spirit of enterprise and initiative and to develop their interpersonal, vocational and technological skills.

The Leaving Certificate Applied

The Leaving Certificate Applied is a distinct, self-contained Leaving Certificate programme. It is designed for those students who do not wish to proceed directly to third level education or for those whose needs, aspirations and aptitudes are not adequately catered for by the other two Leaving Certificate programmes. The Leaving Certificate Applied is structured around three main elements – Vocational Preparation, Vocational Education and General Education - which are interrelated and interdependent. This programme is characterised by educational experiences of an active, practical and student-centred nature.

LEAVING CERTIFICATE

CHEMISTRY

(ORDINARY AND HIGHER LEVEL)

Preamble

Policy Context

Science education in the senior cycle should reflect the changing needs of students and the growing significance of science for strategic development in Ireland.

Leaving Certificate science syllabuses are designed to incorporate the following components:

- science for the enquiring mind, or pure science, to include the principles, procedures and concepts of the subject as well as its cultural and historical aspects
- science for action, or the applications of science and its interface with technology
- science, which is concerned with issues – political, social and economic – of concern to citizens.

The three components should be integrated within each science syllabus, with the first component having a 70% weighting. The remaining 30% should be allocated to the other two components in the ratio 3 to 1.

The syllabuses, which are offered at two levels, Higher and Ordinary, will have approximately 180 hours of class contact time over a two-year period. They should be practically and experimentally based in their teaching.

CONTENTS

Ordinary Level Core

Ordinary Level: Option 1

Ordinary Level: Option 2

Higher Level Core

Higher Level: Option 1

Higher Level: Option 2

Introduction

Aims

The aims of the syllabus, common to both levels, are:

- To stimulate and sustain students' interest in, and enjoyment of, chemistry
- To provide a relevant course for those students who will complete their study of chemistry at this level
- To provide a foundation course in chemistry for those students who will continue their studies in chemistry or in related subjects
- To encourage an appreciation of the scientific, social, economic, environmental and technological aspects of chemistry and an understanding of the historical development of chemistry
- To illustrate generally how humanity has benefited from the study and practice of chemistry
- To develop an appreciation of scientific method and rational thought
- To develop skills in laboratory procedures and techniques, carried out with due regard for safety, together with the ability to assess the uses and limitations of these procedures
- To develop skills of observation, analysis, evaluation, communication and problem-solving.

Structure of the Syllabus

The syllabus consists of a core and options. Each option is an expansion of material that is contained in the core. The entire Ordinary level syllabus is presented first, followed by the entire Higher level syllabus. In both cases, an expanded syllabus format has been adopted.

The syllabus is presented in four columns, giving

(i) the content

(ii) the depth of treatment

(iii) suitable activities

(iv) references to relevant social and applied aspects, where appropriate.

The third column includes mandatory experiments (twenty-one for Ordinary level and twenty-eight for Higher level). These are numbered in order, within sections, and each experiment has the same number in the Ordinary level syllabus as in the Higher level syllabus.

The format in which the syllabus is presented does not imply any particular order of teaching. Teaching strategies should promote, in a positive manner, the aims and objectives of the syllabus.

The syllabus consists of approximately 70% pure chemistry; the remaining 30% deals with the social and applied aspects of chemistry. **All material within the syllabus is examinable.**

The syllabus is designed for 180 hours of class contact time (the equivalent of 270 class periods of 40 minutes each, or five class periods per week). A specific number of class periods for each sub-section of the syllabus is recommended. At Ordinary level, 187 class periods in total are recommended for all the specific sub-sections of the syllabus; the remaining 83 class periods may be used for supplementary work, including revision. At Higher level, 258 class periods in total are recommended for all the specific sub-sections of the syllabus, including time for revision. The remaining 12 class periods may be used for supplementary work, including further revision. These specifications are intended only to indicate the **approximate** amount of time needed.

Practical Work

In all experimental work, safety should be a major concern. Safety equipment, such as fume cupboards, safety glasses and pipette fillers, should be used where appropriate. The mandatory experiments included in the syllabus must be carried out by the students. An adequate record of their practical work must be retained for the period of the course. In addition, the students' practical work should be supplemented by teacher demonstrations where indicated throughout the syllabus. There should be an appreciation of the errors inherent in an experiment and of the precautions that can be taken to reduce such errors.

Students will be given full recognition for carrying out mandatory experiments using computer interfacing and other modern methods of computer-aided technology. However, this is not obligatory.

Differentiation between Ordinary level and Higher level

There are two main differences between Ordinary level and Higher level:

(i) Range of topics

All the Ordinary level material, except mandatory experiment 4.2A in the Ordinary level syllabus (see page 14), forms part of the Higher level syllabus. The Higher level syllabus contains additional material. Ordinary level students will study one option from 1A, 1B, 2A, or 2B. Higher level students must study, in their entirety, either Option 1 or Option 2.

(ii) Depth of treatment

The Ordinary level syllabus provides an overview of chemistry and its applications to everyday life. At Higher level, a deeper and more quantitative treatment of chemistry is required.

Assessment

The syllabus will be assessed in relation to its objectives. All material within the syllabus is examinable. Practical work is an integral part of the study of chemistry; it will initially be assessed through the medium of the written examination paper. An element of practical assessment may be included as part of the overall assessment at a later stage.

LEAVING CERTIFICATE CHEMISTRY

ORDINARY LEVEL SYLLABUS

Ordinary Level Syllabus Objectives

The objectives of the syllabus are:

1. Knowledge

Students should have a knowledge of

- basic chemical terminology, facts, principles and methods
- scientific theory
- social, historical, environmental, technological and economic aspects of chemistry.

2. Understanding

Students should understand

- how chemistry relates to everyday life
- scientific information in verbal, graphical and mathematical form
- basic chemical principles
- how chemical problems can be solved
- how the scientific method applies to chemistry.

3. Skills

Students should be able to

- follow instructions given in a suitable form
- perform experiments safely and co-operatively
- select and manipulate suitable apparatus to perform specified tasks
- make accurate observations and measurements
- interpret experimental data and assess the accuracy of experimental results.

4. Competence

Students should be able to

- translate scientific information in verbal, graphical and mathematical form
- organise chemical ideas and statements
- report experimental procedures and results in a concise, accurate and comprehensible manner
- use chemical facts and principles to make qualitative chemical predictions
- perform simple chemical calculations
- discuss public issues relating to chemistry.

5. Attitudes

Students should appreciate

- advances in chemistry and their influence on our lives
- that the understanding of chemistry contributes to the social and economic development of society
- the range of vocational opportunities that use chemistry, and how chemists work.

CORE

1. PERIODIC TABLE AND ATOMIC STRUCTURE

Content	Depth of Treatment	Activities	Social and Applied Aspects
1.1 Periodic Table (Time needed: 4 class periods)	Elements. Symbols of elements 1–36.		History of the idea of elements, including the contributions of the Greeks, Boyle, Davy and Moseley.
	The periodic table as a list of elements arranged so as to demonstrate trends in their physical and chemical properties.	Arranging elements in order of relative atomic mass; note differences compared with the modern periodic table.	History of the periodic table, including the contribution of Mendeleev. Comparison of Mendeleev's table with the modern periodic table.
	Brief statement of the principal resemblances of elements within each main group, in particular alkali metals, alkaline earth metals, halogens and noble gases.	Demonstration of the reaction with water of lithium, sodium and potassium.	
1.2 Atomic Structure (Time needed: 5 class periods)	Matter is composed of particles, which may be atoms, molecules or ions. Atoms. Minute size of atoms. Law of conservation of mass.		Very brief outline of the historical development of atomic theory (outline principles only; mathematical treatment not required): Dalton: atomic theory; Thomson: negative charge of the electron; Rutherford: discovery of the nucleus as shown by the α–particle scattering experiment; and Bohr: model of the atom.
	Properties of electrons, protons and neutrons (relative mass, relative charge, location within atom). Atomic number (Z), mass number (A), isotopes; hydrogen and carbon as examples of isotopes.		
	Relative atomic mass (A_r). The ^{12}C scale for relative atomic masses.		Use of the mass spectrometer in determining relative atomic mass.

1. PERIODIC TABLE AND ATOMIC STRUCTURE (CONTINUED)

Content	Depth of Treatment	Activities	Social and Applied Aspects
1.3 Radioactivity (Time needed: 3 class periods)	Alpha, beta and gamma radiation (nature and penetrating ability). One example each of: an α-emitter, e.g. ^{241}Am a β-emitter, e.g. ^{14}C a γ-emitter, e.g. ^{60}Co.	Demonstration of properties – detection and penetrating power (this can be shown using an appropriate videotape, if desired). (Principle of Geiger-Müller tube not required.)	Historical outline of radioactivity: work of Becquerel (discovery of radiation from uranium salts); Marie and Pierre Curie (discovery of polonium and radium). Widespread occurrence of radioactivity.
	Radioisotopes.		Uses of radioisotopes (three examples).
	Half-life (non-mathematical treatment).		^{14}C age determination (calculations not required). ^{60}Co for cancer treatment. Food irradiation.
1.4 Electronic Structure of Atoms (Time needed: 7 class periods)	Energy levels in atoms. Organisation of particles in atoms of elements nos. 1–20 (numbers of electrons in each main energy level). Classification of the first twenty elements in the periodic table on the basis of the number of outer electrons. Atomic radii (covalent radii only). Explanations for general trends in values: (i) down a group (ii) across a period (covalent radii of main group elements only).	Mandatory experiment 1.1*	Sodium street lights, fireworks.

*Mandatory experiments are defined at the end of each section of the syllabus

1. PERIODIC TABLE AND ATOMIC STRUCTURE (CONTINUED)

Content	Depth of Treatment	Activities	Social and Applied Aspects
1.4 Electronic Structure of Atoms (continued)	Dependence of chemical properties of elements on their electronic structure.		
	Explanations in terms of atomic radius, screening effect and nuclear charge for general trends in properties of elements in groups I and VII.	See mandatory experiment 1.2 below (reactivity of halogens).	
1.5 Oxidation and Reduction (Time needed: 7 class periods)	Introduction to oxidation and reduction: simple examples only, e.g. Na with Cl_2, Mg with O_2, Zn with Cu^{2+}. Oxidation and reduction in terms of loss and gain of electrons.		Rusting of iron.
	Oxidising and reducing agents.		Swimming-pool water treatment.
	The electrochemical series as a series of metals arranged in order of their ability to be oxidised (reactions, other than displacement reactions, not required).	Mandatory experiment 1.2 (half equations only required, e.g. $2Br^- - 2e^- \longrightarrow Br_2$).	Use of scrap iron to extract copper.
	Electrolysis of (i) copper sulfate solution with copper electrodes and (ii) acidified water with inert electrodes.	Demonstration of ionic movement.	Electroplating. Purification of copper. Chrome and nickel plating. Cutlery.

Mandatory Experiments

1.1 Flame tests (Li, Na, K, Ba, Sr and Cu only).

1.2 Redox reactions of group VII elements: halogens as oxidising agents (reactions with bromides, iodides, Fe^{2+} and sulfites).
Displacement reactions of metals (Zn with Cu^{2+}, Mg with Cu^{2+}).

2. CHEMICAL BONDING

Content	Depth of Treatment	Activities	Social and Applied Aspects
2.1 Chemical Compounds (Time needed: 6 class periods)	Compounds. Simple chemical formulas.		
	Stability of noble gas electron configurations.		Uses of helium and argon related to their chemical unreactivity.
	Bonding and valency in terms of the attainment of a stable electronic structure. Octet rule and its limitations.	Using the octet rule to predict the formulas of simple compounds – binary compounds of the first 36 elements (excluding d-block elements) and the hydroxides and carbonates of these elements (where such exist).	
2.2 Ionic Bonding (Time needed: 4 class periods)	Positive and negative ions. Minute size of ions.	Representation of ionic bonds using dot and cross diagrams.	
	Ionic bonding as electron transfer.		
	Sodium chloride crystal structure.	Examination of a model of the $NaCl$ crystal.	
	Characteristics of ionic substances.	Mandatory experiment 2.1	Ionic materials in everyday life (two uses, e.g. salt tablets to replace salt lost by sweating).
2.3 Covalent Bonding (Time needed: 4 class periods)	Molecules. Minute size of molecules.		
	Covalent bonding as the sharing of pairs of electrons. Single, double and triple covalent bonds.	Representation of covalent bonds using dot and cross diagrams.	
	Polar and non-polar covalent bonding.	Polarity test for liquids (use of charged plastic rod).	Polar and non-polar materials in everyday life (two examples of each).
	Characteristics of covalent substances.	Testing solubility in different solvents of ionic and covalent substances.	

2. CHEMICAL BONDING (CONTINUED)

Content	Depth of Treatment	Activities	Social and Applied Aspects
2.4 Electronegativity (Time needed: 2 class periods)	Electronegativity. Periodic variation of electronegativity – explanation for general trends in values: (i) down a group (ii) across a period.		
	Electronegativity differences and polarity of bonds.	Prediction of bond type using electronegativity differences.	
2.5 Shapes of Molecules and Intermolecular Forces (Time needed: 1 class period)	Shapes of some simple molecules.	Use of models or balloons to illustrate molecular shapes.	

Mandatory Experiments

2.1 Tests for anions in aqueous solutions: chloride, carbonate, nitrate, sulfate.

3. STOICHIOMETRY, FORMULAS AND EQUATIONS

Content	Depth of Treatment	Activities	Social and Applied Aspects
3.1 States of Matter (Time needed: 1 class period)	Motion of particles in solids, liquids and gases.		
	Diffusion (Graham’s law not required).	NH_3 and HCl, ink and water, smoke and air.	
3.2 Gas Laws (Time needed: 3 class periods)	Boyle's law.	Calculations not required.	Boyle’s air pump.
	Charles’s law.	Calculations not required.	
	Combined gas law: $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} =$ constant.	Simple calculations, including correction of gas volumes to s.t.p. (units: Pa, cm^3, K).	
3.3 The Mole (Time needed: 9 class periods)	Avogadro constant. The mole as the SI unit for amount of substance containing the Avogadro number of particles. Standard temperature and pressure (s.t.p.). Molar volume at s.t.p., molar mass, relative molecular mass (M_r).	Calculation of relative molecular mass from relative atomic masses. Converting moles to grams, litres and number of particles. Converting grams and litres to moles.	
		Mandatory experiment 3.1	
3.4 Chemical Formulas (Time needed: 6 class periods)	Empirical and molecular formulas.	Calculations of empirical formulas, given the percentage composition by mass. Calculation of molecular formulas, given the empirical formulas and the relative molecular masses (examples should include simple biological substances, such as glucose and urea).	
	Percentage composition by mass.	Calculations.	
	Structural formulas.	Simple examples.	

3. STOICHIOMETRY, FORMULAS AND EQUATIONS (CONTINUED)

Content	Depth of Treatment	Activities	Social and Applied Aspects
3.5 Chemical Equations (Time needed: 9 class periods)	Chemical equations. Balancing chemical equations. Calculations based on balanced equations using the mole concept (balanced equations will be given for all calculations).	Simple examples. Calculations in g and kg rather than tonnes. Calculations involving masses and volumes.	

Mandatory Experiments

3.1 Determination of the relative molecular mass of a volatile liquid (conical flask or gas syringe may be used).

4. VOLUMETRIC ANALYSIS

Content	Depth of Treatment	Activities	Social and Applied Aspects
4.1 Concentration of Solutions (Time needed: 6 class periods)	Solutions. Expression of solution concentration in mol l^{-1} (molarity), g l^{-1} and also in % (v/v). Colour intensity as a function of concentration (simple treatment only). Primary standards. Standard solutions.	Calculation of molarity from concentration in grams per litre and vice versa. Calculation of number of moles from molarity and volume. Mandatory experiment 4.1	Use of % (v/v), e.g. wine.
4.2 Acids and Bases (Time needed: 3 class periods)	Acids, bases and salts. Neutralisation – formation of a salt from an acid and a base. Arrhenius theory of acids and bases (for aqueous solutions only).		Household acids and bases (two examples of each). Everyday examples of neutralisation, e.g. use of lime in agriculture, use of stomach powders for acid indigestion.
4.3 Volumetric Analysis (Time needed: 10 class periods)	Apparatus used in volumetric analysis. Correct titrimetric procedure. Acid-base titrations.	Solving volumetric problems, using the formula method. (Balanced equations will be given in all volumetric problems.) Mandatory experiment 4.2 Mandatory experiment 4.2A	

Mandatory Experiments

4.1 Preparation of standard solution of sodium carbonate.
4.2 Standardisation of a hydrochloric acid solution using a standard solution of sodium carbonate.
4.2A A hydrochloric acid/sodium hydroxide titration, and the use of this titration in making the salt sodium chloride.

5. FUELS AND HEATS OF REACTION

Content	Depth of Treatment	Activities	Social and Applied Aspects
5.1 Sources of Hydrocarbons (Time needed: 1 class period)	Coal, natural gas and petroleum as sources of hydrocarbons.		Decomposition of animal waste and vegetation as methane sources. Hazards of methane production in slurry pits, coal mines and refuse dumps. Methane as a contributor to the greenhouse effect.
5.2 Structure of Aliphatic Hydrocarbons (Time needed: 5 class periods)	Alkanes, alkenes and alkynes as homologous series. For alkynes, only ethyne to be considered.		
	Systematic names, structural formulas and structural isomers of alkanes to C-5. Structures, but not isomers, of hexane, heptane, octane, cyclohexane and 2,2,4-trimethylpentane (iso-octane) to be considered.	Use of models.	
	Systematic names, structural formulas and structural isomers of alkenes to C-4.	Use of models.	
	Physical properties [physical state, solubility (qualitative only) in water and in non-polar solvents].	Demonstration of the solubility properties of methane, ethene and ethyne.	
5.3 Aromatic Hydrocarbons (Time needed: 1 class period)	Structure of benzene, methylbenzene and ethylbenzene as examples of aromatic compounds.	Use of models.	See aromatic compounds (page 20).
	Physical properties [physical state, solubility (qualitative only) in water and in non-polar solvents].	Demonstration of the solubility properties of methylbenzene.	

5. FUELS AND HEATS OF REACTION (CONTINUED)

Content	Depth of Treatment	Activities	Social and Applied Aspects
5.4 Exothermic and Endothermic Reactions (Time needed: 5 class periods)	Chemical reactions can result in a change in temperature. Exothermic and endothermic reactions (and changes of state).	Demonstration of an exothermic and an endothermic reaction.	
	Combustion of alkanes and other hydrocarbons.		
	Heat of reaction (general term).	Mandatory experiment 5.1	
	Sign of ΔH.		
	Heat of combustion. Bomb calorimeter as an instrument for accurately measuring heats of combustion. Heats of combustion of different fuels.		Use of the bomb calorimeter in determining calorific values of foods. Kilogram calorific values of fuels, and their uses (calculations not required).
5.5 Oil Refining and its Products (Time needed: 4 class periods)	Fractionation of crude oil.		
	Production of the refinery gas, light gasoline, naphtha, kerosene, gas oil and residue fractions.		Uses of the refinery gas, light gasoline, naphtha, kerosene, gas oil and residue fractions.
			Composition of natural gas and liquid petroleum gas (LPG). Addition of mercaptans to natural gas for safety reasons. Composition of petrol.
			Auto-ignition. Octane numbers as a measure of the tendency of a fuel to cause knocking.
			Lead in petrol. Alternatives to lead: improving octane number by (i) isomerisation (ii) dehydrocyclisation (iii) catalytic cracking.

5. FUELS AND HEATS OF REACTION (CONTINUED)

Content	Depth of Treatment	Activities	Social and Applied Aspects
5.6 Other Chemical Fuels (Time needed: 3 class periods)	Ethyne: preparation, combustion, tests for unsaturation.	Mandatory experiment 5.2 (equations and structures of products not required for the tests for unsaturation).	Oxyacetylene welding and cutting.
	Hydrogen: manufacture by (i) electrolysis of water (ii) steam reforming of natural gas (simple treatment only).		Industrial uses. Potential as a fuel.

Mandatory Experiments

5.1 Determination of the heat of reaction of hydrochloric acid with sodium hydroxide.

5.2 Preparation and properties of ethyne [combustion, tests for unsaturation using bromine water and acidified potassium manganate(VII) solution].

6. RATES OF REACTION

Content	Depth of Treatment	Activities	Social and Applied Aspects
6.1 Reaction Rates (Time needed: 3 class periods)	Rate of reaction.	Mandatory experiment 6.1 Plotting and simple interpretation of reaction rate graphs.	
6.2 Factors Affecting Rates of Reaction (Time needed: 7 class periods)	Concentration. Particle size.	Demonstration of the effects on reaction rate of (i) particle size (ii) catalysts.	Dust explosions.
	Temperature.		Enzymes as catalysts produced by living cells (two examples).
	Nature of reactants. Catalysts.		Catalytic converters: (i) nature of catalysts (ii) reactions catalysed (iii) environmental benefits. Catalyst poisons.
		Mandatory experiment 6.2 Demonstration of the oxidation of methanol using a hot platinum or nichrome catalyst. Demonstration of the oxidation of potassium sodium tartrate by hydrogen peroxide, catalysed by cobalt(II) salts.	

Mandatory Experiments

6.1 Monitoring the rate of production of oxygen from hydrogen peroxide, using manganese dioxide as a catalyst.

6.2 Studying the effects on the reaction rate of (i) concentration and (ii) temperature, using sodium thiosulfate solution and hydrochloric acid.

7. ORGANIC CHEMISTRY

Content	Depth of Treatment	Activities	Social and Applied Aspects
7.1 Tetrahedral Carbon (Time needed: 3 class periods)	Saturated organic compounds.	Use of models, as appropriate.	
	Alkanes.		Use as fuels.
	Alcohols: structure and nomenclature up to C-4 (primary and secondary alcohols only). Physical properties [physical state, solubility (qualitative only) in water and in non-polar solvents].	Comparison of structure with water. Solubility of (a) methanol and (b) butan-1-ol in (i) cyclohexane and (ii) water.	Ethanol as a solvent. Fermentation as a source of ethanol; use of fermentation in the brewing and distilling industries. Methanol as a denaturing agent.
7.2 Planar Carbon (Time needed: 9 class periods)	Unsaturated organic compounds.	Use of models, as appropriate.	
	Alkenes: non-polar double bond. Structure and nomenclature up to C-4.		Use in making plastics.
	Carbonyl compounds (aldehydes only): polar double bond. Structure and nomenclature up to C-4.	Solubility of ethanal in (i) cyclohexane and (ii) water.	
	Physical properties [physical state, solubility (qualitative only) in water and in non-polar solvents].		
	Carboxylic acids: polar double bond. Structure and nomenclature up to C-4.	Solubility of ethanoic acid in (i) cyclohexane and (ii) water.	Methanoic acid in nettles and ants; ethanoic acid in vinegar.
	Physical properties [physical state, solubility (qualitative only) in water and in non-polar solvents].	Mandatory experiment 7.1	
	Simple explanation of the use of the circle to represent the identical bonds in benzene, intermediate between double and single.		

7. ORGANIC CHEMISTRY (CONTINUED)

Content	Depth of Treatment	Activities	Social and Applied Aspects
7.2 Planar Carbon (continued)	Aromatic compounds.	Solubility of methylbenzene in (i) cyclohexane and (ii) water.	Use of methylbenzene as an industrial solvent.
	An indication of the range and scope of aromatic chemistry (structures not required).	Inspect structural formulas of a range of consumer products to show the presence of benzene rings.	Aromatic compounds form the basis of dyestuffs, detergents, herbicides and many pharmaceutical compounds (one example in each case; structures not required). Aromatic acid-base indicators: phenolphthalein, methyl orange (structures not required).
			Carcinogenic nature of some aromatic compounds, e.g. benzene. Not all aromatic compounds are carcinogenic, e.g. aspirin (structure of aspirin not required).
7.3 Organic Chemical Reaction Types (Time needed: 14 class periods)	Students are not, in general, required to know the conditions (temperature, pressure, catalyst, solvent) for these reactions, except where specified elsewhere in the syllabus. They are required to be able to write balanced equations for the reactions, using structural formulas, unless otherwise indicated.		
	(a) Addition reactions Alkenes – reactions with hydrogen, chlorine, bromine, water and hydrogen chloride.		Industrial sources. Industrial importance of (i) products of the addition reactions of ethene with chlorine, bromine, water and hydrogen chloride (ii) hydrogenation of vegetable oils.

7. ORGANIC CHEMISTRY (CONTINUED)

Content	Depth of Treatment	Activities	Social and Applied Aspects
7.3 Organic Chemical Reaction Types (continued)	Polymerisation reaction (of ethene and propene only – reaction mechanism not required).		Alkenes as raw materials in the industrial manufacture of plastics.
	Unreactivity of benzene with regard to addition reactions, relative to ethene.		An indication of the range and scope of the petrochemical industry (two examples of synthetic products of this industry; structures not required, unless specified elsewhere in the syllabus).
	(b) Substitution reactions Halogenation of alkanes.		
		Mandatory experiment 7.2	Soap manufacture.
	(c) Elimination reactions Dehydration of alcohols.	Mandatory experiment 7.3 (equations and structures of products not required, unless specified elsewhere in the syllabus).	
	(d) Redox reactions Alcohols: Oxidation using $KMnO_4$ or $Na_2Cr_2O_7$ to (i) aldehydes and (ii) acids (half equations only required).	Mandatory experiment 7.4	Ethanal formation in the metabolism of ethanol in the human body.
	Oxidation of aldehydes to acids (half equations only required).	Mandatory experiment 7.5	
	Combustion – a reaction common to most organic compounds. Combustion of alcohols.		Alcohols as motor fuels.
	Non-flammability of fully halogenated alkanes.		Flame retardants, fire extinguishers.

7. ORGANIC CHEMISTRY (CONTINUED)

Content	Depth of Treatment	Activities	Social and Applied Aspects
7.3 Organic Chemical Reaction Types (continued)	**(e) Reactions as acids** Reactions of alcohols with sodium. Reactions of carboxylic acids with magnesium, with sodium hydroxide and with sodium carbonate.		
	(f) Organic synthesis: principles and examples Chemical synthesis involves (i) bond breaking and (ii) bond forming.		Useful products of organic synthesis (two examples, e.g. aspirin, paracetamol; structures and synthetic routes not required).
	Example of organic synthesis: PVC from ethene (structures and synthetic route required).		
7.4 Organic Natural Products (Time needed: 4 class periods)	Extraction techniques, e.g. solvent extraction, steam distillation.	Mandatory experiment 7.6	An indication of the range and scope of organic natural product chemistry (two examples of useful organic natural products; structures not required).
7.5 Chromatography and Instrumentation in Organic Chemistry (Time needed: 3 class periods)	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.	Mandatory experiment 7.7	Use of thin-layer chromatography (TLC) in the separation of dyes taken from fibres in forensic work. GC and HPLC as more advanced separation techniques.

7. ORGANIC CHEMISTRY (CONTINUED)

Content	Depth of Treatment	Activities	Social and Applied Aspects
7.5 Chromatography and Instrumentation in Organic Chemistry (continued) (Time needed: 3 class periods)	Instrumental methods of separation or analysis, or both:		Examples of uses:
	Mass spectrometry (cf.1.2, page 7).		Analysis of (i) gases from a waste dump and (ii) 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.
	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.)		

Mandatory Experiments

7.1 Recrystallisation of benzoic acid and determination of its melting point.
7.2 Preparation of soap.
7.3 Preparation and properties of ethene [combustion, tests for unsaturation using acidified potassium manganate(VII) solution and bromine water].
7.4 Preparation and properties of ethanal [properties limited to reactions with (i) acidified potassium manganate(VII) solution, (ii) Fehling's reagent and (iii) ammoniacal silver nitrate].
7.5 Preparation and properties of ethanoic acid (properties limited to reactions with sodium carbonate and magnesium).
7.6 Extraction of clove oil from cloves (or similar alternative) by steam distillation.
7.7 Separation of a mixture of indicators using paper chromatography or thin-layer chromatography or column chromatography.

8. CHEMICAL EQUILIBRIUM

Content	Depth of Treatment	Activities	Social and Applied Aspects
8.1 Chemical Equilibrium (Time needed: 4 class periods)	Reversible reactions – dynamic equilibrium. At equilibrium, the rate of the forward reaction equals the rate of the reverse reaction. Equilibrium law and constant (K_c only).		
8.2 Le Chatelier's Principle (Time needed: 5 class periods)	Le Chatelier's principle. Effect (if any) on equilibrium position of concentration, pressure, temperature and catalyst.	Mandatory experiment 8.1	Industrial application of Le Chatelier's principle in the catalytic oxidation of sulfur dioxide to sulfur trioxide and in the Haber process.

Mandatory Experiments

8.1 Simple experiments to illustrate Le Chatelier's principle:

(i) $CoCl_4^{2-} + 6H_2O \rightleftharpoons Co(H_2O)_6^{2+} + 4Cl^-$ (to demonstrate the effects of both temperature changes and concentration changes on an equilibrium mixture).

(ii) $Cr_2O_7^{2-} + H_2O \rightleftharpoons 2CrO_4^{2-} + 2H^+$

(iii) $Fe^{3+} + CNS^- \rightleftharpoons Fe(CNS)^{2+}$

(to demonstrate the effects of concentration changes on an equilibrium mixture).

9. ENVIRONMENTAL CHEMISTRY: WATER

Content	Depth of Treatment	Activities	Social and Applied Aspects
It is strongly recommended that students visit a water treatment plant — industrial or municipal.			
9.1 pH Scale (Time needed: 4 class periods)	pH scale. Use of universal indicator paper or solution. Limitations of the pH scale — usefulness confined to dilute aqueous solutions.		
		Calculation of pH of dilute aqueous solutions of strong acids and bases (calculation of pH of mixtures of strong acids and bases not required).	
9.2 Hardness in Water (Time needed: 3 class periods)	Hardness in water.		
	Causes of temporary and permanent hardness.	Tests on scale deposits in a kettle.	Removal of hardness by boiling and ion exchange.
	Deionisation.		
9.3 Water Treatment (Time needed: 4 class periods)	Water treatment — sedimentation, flocculation, filtration, chlorination, fluoridation and pH adjustment.		
	Sewage treatment (primary, e.g. settlement, screening; secondary, e.g. bacterial breakdown; tertiary, i.e. reduction of level of phosphates and nitrates). Cost of tertiary treatment.		
	The role of nutrients in the eutrophication of water.		Awareness that there are EU limits for various chemical species in water (two examples, e.g. nitrates, phosphates, specific metal ions).

9. ENVIRONMENTAL CHEMISTRY: WATER (CONTINUED)

Content	Depth of Treatment	Activities	Social and Applied Aspects
9.4 Water Analysis (Time needed: 6 class periods)	Instrumental methods of analysis:		Examples of uses:
	pH meter		Analysis of river and lake water.
	Colorimetry	Mandatory experiment 9.1	Analysis of (i) lead in water and (ii) fertilisers.
	Brief reference to principles of each method.		
	Tests for anions (cf. mandatory experiment 2.1).	Mandatory experiment 9.2	
			Organic chemical pollutants, e.g. sewage, industrial waste, silage, milk.

Mandatory Experiments

9.1 Colorimetric experiment to estimate free chlorine in swimming-pool water or bleach (using a colorimeter or a comparator).

9.2 Determination of total suspended and total dissolved solids (expressed as p.p.m.) by filtration and evaporation respectively. Determination of pH.

Options: Ordinary level students to choose ONE from options 1A, 1B, 2A and 2B.

OPTION 1A: ADDITIONAL INDUSTRIAL CHEMISTRY

Content	Depth of Treatment	Activities	Social and Applied Aspects
It is strongly recommended that students visit a particulat local chemical plant. This visit should be a structured one.			
1A.1 General Principles (Time needed: 4 class periods)	Batch, continuous and semi-continuous industrial chemical processes.		
	Characteristics of effective and successful industrial chemical processes, such as (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).	See above.	Awareness 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.

OPTION 1A: ADDITIONAL INDUSTRIAL CHEMISTRY (CONTINUED)

Content	Depth of Treatment	Activities	Social and Applied Aspects
1A.2 Case Study (Time needed: 5 class periods)	A case study based on the Irish chemical industry. ONE of the three following processes should be studied, using the principles outlined in 1A.1 as far as they are relevant to the process:		Awareness 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).
	(a) Ammonia manufacture from natural gas, water vapour and air, and its conversion to urea. Equation required for ammonia formation.		
	(b) Nitric acid manufacture from ammonia, and its use to make fertilisers. Equation required for oxidation of nitrogen monoxide.		
	(c) Magnesium oxide manufacture from sea water. Equation required for formation of magnesium oxide.		Use of magnesium oxide as a heat-resistant material in the walls of furnaces.

OPTION 1B: ATMOSPHERIC CHEMISTRY

Content	Depth of Treatment	Activities	Social and Applied Aspects
1B.1 Oxygen (Time needed: 1 class period)	Manufacture of oxygen using liquefaction and fractional distillation of air.		Uses of oxygen and of liquid nitrogen (two examples in each case).
1B.2 Nitrogen (Time needed: 1 class period)	Structure and inertness.		Any two uses, e.g. keeping foods fresh, flushing out dangerous vapours from oil tankers.
	Atmospheric abundance.		
	Natural fixation of nitrogen; nitrogen and oxygen in an electric discharge. Nitrogen cycle.		
1B.3 Carbon Dioxide (Time needed: 3 class periods)	Combustion of carbon to give carbon monoxide and carbon dioxide.		
	Carbon monoxide as a neutral oxide.		Carbon monoxide as a poison. Carbon monoxide in cigarette smoke and vehicle exhaust fumes.
	Carbon dioxide as an acidic oxide.	Demonstration of the effect of carbon dioxide on universal indicator solution.	
	Fermentation in ethanol production as a source of carbon dioxide.		Carbon dioxide in carbonated drinks.
	The carbon cycle.		The greenhouse effect and the influence of human activity on it. Greenhouse gases and their relative effects (especially carbon dioxide and water vapour). Reduction of atmospheric carbon dioxide levels by dissolving in the ocean. Possible implications of the increased greenhouse effect.

OPTION 1B: ATMOSPHERIC CHEMISTRY (CONTINUED)

Content	Depth of Treatment	Activities	Social and Applied Aspects
1B.4 Atmospheric Pollution (Time needed: 2 class periods)	Oxides of nitrogen and sulfur: sources of pollution (natural, domestic, industrial, internal combustion engine).		
	Dissolving of nitrogen dioxide and sulfur dioxide to form acids.	Demonstration of the effect of sulfur dioxide on universal indicator solution.	Acid rain and its effects on the environment. Scrubbing of waste gases using limestone.
1B.5 The Ozone Layer (Time needed: 2 class periods)	Chloroalkanes: preparation from alkanes, e.g. chlorination of methane.		Chlorofluorocarbons and the ozone layer.
			Formation of ozone in the stratosphere. Beneficial effect of the ozone layer.
			CFCs and HCFCs. Uses of CFCs.
			CFCs are believed to be the main cause of damage to the ozone layer.
			Effects of damage to the ozone layer.

OPTION 2A: MATERIALS

Content	Depth of Treatment	Activities	Social and Applied Aspects
2A.1 Crystals (Time needed: 3 class periods)	Ionic, molecular, metallic and covalent macromolecular crystals – physical properties related to the crystal binding forces. Crystal structure is determined by scattering of X-rays by the crystal (non-mathematical treatment only).	Use of models.	Contributions of (i) Braggs: development of the X-ray technique for determining crystal structure; (ii) Dorothy Hodgkin: determination of the crystal structure of complex organic molecules, e.g. vitamin B_{12}, penicillin (structures not required). The discovery of buckminsterfullerene (structure not required).
2A.2 Addition Polymers (Time needed: 5 class periods)	Addition polymers. Monomers.		
	Polymerisation of alkenes: poly(ethene) (low-density), poly(chloroethene), poly(phenylethene).	Demonstration of physical properties (density, flexibility, hardness) of poly(ethene), poly(chloroethene) and poly(phenylethene).	The industrial and domestic importance and advantages of these polymers in plastics and fibres (two examples of uses of each polymer). Brief history of the discovery of low-density poly(ethene). Recycling of plastics, exemplified by the recycling of polystyrene (stages: sorting, shredding, washing, drying and re-extrusion).
2A.3 Metals (Time needed: 1 class period)	Comparison between metals and non-metals (hardness, lustre, malleability, ductility, heat conductivity and electrical conductivity).		
	Alloys.		Carbon in steel and hardness.

OPTION 2B: ADDITIONAL ELECTROCHEMISTRY AND THE EXTRACTION OF METALS

Content	Depth of Treatment	Activities	Social and Applied Aspects
2B.1 The Electrochemical Series (Time needed: 1 class period)	Different combinations of metals produce different voltages in a simple cell. The electrochemical series (reactions of metals with acids, water and oxygen not required).		Contributions of Galvani, Volta, Davy and Faraday.
2B.2 Electrolysis of Molten Salts (Time needed: 1 class period)	Electrolysis of molten lead bromide, using inert electrodes.		
2B.3 Corrosion (Time needed: 1 class period)	Corrosion of metals. Relative corrodibility of metals.		Corrosion prevention (application of a protective layer on a metal: galvanising and surface coating).
2B.4 Strongly Electropositive Metals (Na and Al) (Time needed: 2 class periods)	Extraction by electrochemical methods.		Uses (two examples in each case). Recycling of aluminium.
2B.5 d-Block Metals (Time needed: 4 class periods)	Transition elements: general chemical properties (colour, use as catalysts).		
	Manufacture of iron (blast furnace – chemical aspects) and steel. Steels as alloys of iron.		Uses of iron and steel (two examples in each case).
	Electric arc process for steel manufacture (outline of main stages).		Environmental aspects of iron and steel production.

APPENDIX 1

Only the systematic names for organic compounds will be used on examination papers, except where the traditional name continues to enjoy widespread use, particularly in industrial and everyday life. In these cases, the traditional name will also be given in parentheses immediately after the systematic name. Knowledge of these traditional names is not examinable. A representative list of such compounds follows:

Systematic Name	Traditional Name
ethanal	acetaldehyde
ethanoic acid	acetic acid
ethyne	acetylene
ethanol	ethyl alcohol
ethene	ethylene
2,2,4-trimethylpentane	iso-octane
chloromethane	methyl chloride
poly(ethene)	polyethylene
poly(phenylethene)	polystyrene
poly(chloroethene)	polyvinyl chloride
methylbenzene	toluene

The systematic names for inorganic compounds are not required.

LEAVING CERTIFICATE CHEMISTRY

HIGHER LEVEL
SYLLABUS

Higher Level Syllabus Objectives

The objectives of the syllabus are:

1. Knowledge

Students should have a knowledge of

- basic chemical terminology, facts, principles and methods
- scientific theories and their limitations
- social, historical, environmental, technological and economic aspects of chemistry.

2. Understanding

Students should understand

- how chemistry relates to everyday life
- scientific information in verbal, graphical and mathematical form
- basic chemical principles
- how chemical problems can be solved
- how the scientific method applies to chemistry.

3. Skills

Students should be able to

- follow instructions given in a suitable form
- perform experiments safely and co-operatively
- select and manipulate suitable apparatus to perform specified tasks
- make accurate observations and measurements
- interpret experimental data and assess the accuracy of experimental results.

4. Competence

Students should be able to

- translate scientific information in verbal, graphical and mathematical form
- organise chemical ideas and statements and write clearly about chemical concepts and theories
- report experimental procedures and results in a concise, accurate and comprehensible manner
- explain both familiar and unfamiliar phenomena by applying known laws and principles
- use chemical facts and principles to make chemical predictions
- perform simple chemical calculations
- identify public issues and misconceptions relating to chemistry and analyse them critically.

5. Attitudes

Students should appreciate

- advances in chemistry and their influence on our lives
- that the understanding of chemistry contributes to the social and economic development of society
- the range of vocational opportunities that use chemistry, and how chemists work.

CORE

(Black text is for Higher level only.)

1. PERIODIC TABLE AND ATOMIC STRUCTURE

Content	Depth of Treatment	Activities	Social and Applied Aspects
1.1 Periodic Table (Time needed: 3 class periods)	Elements. Symbols of elements 1–36.		History of the idea of elements, including the contributions of the Greeks, Boyle, Davy and Moseley.
	The periodic table as a list of elements arranged so as to demonstrate trends in their physical and chemical properties.	Arranging elements in order of relative atomic mass; note differences compared with the modern periodic table.	History of the periodic table, including the contributions of Dobereiner, Newlands, Mendeleev and Moseley. Comparison of Mendeleev's table with the modern periodic table.
	Brief statement of the principal resemblances of elements within each main group, in particular alkali metals, alkaline earth metals, halogens and noble gases.	Demonstration of the reaction with water of lithium, sodium and potassium.	
1.2 Atomic Structure (Time needed: 6 class periods)	Matter is composed of particles, which may be atoms, molecules or ions.		Very brief outline of 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 α–particle scattering experiment; discovery of protons in nuclei of various atoms; Bohr: model of the atom; Chadwick: discovery of the neutron.
	Atoms. Minute size of atoms. Law of conservation of mass.		
	Properties of electrons, protons and neutrons (relative mass, relative charge, location within atom).		

1. PERIODIC TABLE AND ATOMIC STRUCTURE (CONTINUED)

Content	Depth of Treatment	Activities	Social and Applied Aspects
1.2 Atomic Structure (continued)	Atomic number (Z), mass number (A), isotopes; hydrogen and carbon as examples of isotopes.		
	Relative atomic mass (A_r). The ^{12}C scale for relative atomic masses.	Calculation of approximate relative atomic masses from abundance of isotopes of given mass number (e.g. calculation of approximate relative atomic mass of chlorine).	Use of the mass spectrometer in determining relative atomic mass. Fundamental processes that occur in a mass spectrometer: vaporisation of substance, production of positive ions, acceleration, separation, detection (mathematical treatment excluded).
1.3 Radioactivity (Time needed: 2 class periods)	Alpha, beta and gamma radiation (nature and penetrating ability). One example each of: an α-emitter, e.g. ^{241}Am a β-emitter, e.g. ^{14}C a γ-emitter, e.g. ^{60}Co.	Demonstration of properties – detection and penetrating power (this can be shown using an appropriate videotape, if desired). (Principle of Geiger-Müller tube not required.)	Historical outline of radioactivity: work of Becquerel (discovery of radiation from uranium salts); Marie and Pierre Curie (discovery of polonium and radium). Widespread occurrence of radioactivity.
	Distinction between chemical reaction and nuclear reaction (simple equations required – confine examples to alpha and beta emissions).		
	Radioisotopes.		Uses of radioisotopes (three examples).
	Half-life (non-mathematical treatment).		^{14}C age determination (calculations not required). ^{60}Co for cancer treatment. Food irradiation.

1. PERIODIC TABLE AND ATOMIC STRUCTURE (CONTINUED)

Content	Depth of Treatment	Activities	Social and Applied Aspects
1.4 Electronic Structure of Atoms (Time needed: 11 class periods)	Energy levels in atoms. Organisation of particles in atoms of elements nos. 1–20 (numbers of electrons in each main energy level).		
	Classification of the first twenty elements in the periodic table on the basis of the number of outer electrons.		
	Emission and absorption spectra of the hydrogen atom – Balmer series in the emission spectrum as an example.	Mandatory experiment 1.1*	Atomic absorption spectrometry (AAS). Sodium street lights, fireworks.
	Line spectra as evidence for energy levels.	Viewing of emission spectra of elements using a spectroscope or a spectrometer.	
	Energy sub-levels.		
	Heisenberg uncertainty principle. Wave nature of the electron. (Non-mathematical treatment in both cases.)		
	Atomic orbitals. Shapes of s and p orbitals.		
	Building up of electronic structure of the first 36 elements.		
	Electronic configurations of ions of s- and p-block elements only. Arrangement of electrons in individual orbitals of p-block atoms.		

*Mandatory experiments are defined at the end of each section of the syllabus.

1. PERIODIC TABLE AND ATOMIC STRUCTURE (C0NTINUED)

Content	Depth of Treatment	Activities	Social and Applied Aspects
1.4 Electronic Structure of Atoms (continued)	Atomic radii (covalent radii only). Explanations for general trends in values: (i) down a group (ii) across a period (covalent radii of main group elements only).		
	First ionisation energies. Explanations for general trends in values: (i) down a group (ii) across a period (main group elements) and for exceptions to the general trends across a period.		
	Second and successive ionisation energies.		
	Evidence for energy levels provided by successive ionisation energy values.		
1.4 Electronic Structure of Atoms (continued)	Dependence of chemical properties of elements on their electronic structure.		
	Explanations in terms of atomic radius, screening effect and nuclear charge for general trends in properties of elements in groups I and VII.	See mandatory experiment 1.2 below (reactivity of halogens).	

1. PERIODIC TABLE AND ATOMIC STRUCTURE (CONTINUED)

Content	Depth of Treatment	Activities	Social and Applied Aspects
1.5 Oxidation and Reduction (Time needed: 7 class periods)	Introduction to oxidation and reduction: simple examples only, e.g. Na with Cl_2, Mg with O_2, Zn with Cu^{2+}. Oxidation and reduction in terms of loss and gain of electrons.		Rusting of iron.
	Oxidising and reducing agents.		Swimming-pool water treatment.
	The electrochemical series as a series of metals arranged in order of their ability to be oxidised (reactions, other than displacement reactions, not required).	Mandatory experiment 1.2 (half equations only required, e.g. $2Br^- - 2e^- \rightarrow Br_2$).	Use of scrap iron to extract copper.
	Electrolysis of (i) copper sulfate solution with copper electrodes and (ii) acidified water with inert electrodes. (Half equations only required.)	Demonstration of ionic movement. Demonstration of electrolysis of aqueous sodium sulfate (using universal indicator) and of aqueous potassium iodide (using phenolphthalein indicator) with inert electrodes. (Half equations only required.)	Electroplating. Purification of copper. Chrome and nickel plating. Cutlery.

Mandatory Experiments

1.1 Flame tests (Li, Na, K, Ba, Sr and Cu only).

1.2 Redox reactions of group VII elements – halogens as oxidising agents (reactions with bromides, iodides, Fe^{2+} and sulfites).
Displacement reactions of metals (Zn with Cu^{2+}, Mg with Cu^{2+}).

2. CHEMICAL BONDING

Content	Depth of Treatment	Activities	Social and Applied Aspects
2.1 Chemical Compounds (Time needed: 5 class periods)	Compounds. Simple chemical formulas.		
	Stability of noble gas electron configurations.		Uses of helium and argon related to their chemical unreactivity.
	Bonding and valency in terms of the attainment of a stable electronic structure. Octet rule and its limitations.	Using the octet rule to predict the formulas of simple compounds – 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).	
	Variable valency of transition elements (Cu, Fe, Cr and Mn only).		
2.2 Ionic Bonding (Time needed: 4 class periods)	Positive and negative ions. Minute size of ions.	Representation of ionic bonds using dot and cross diagrams.	
	Ionic bonding as electron transfer.		
	Sodium chloride crystal structure.	Examination of a model of the $NaCl$ crystal.	
	Characteristics of ionic substances.	Mandatory experiment 2.1	Ionic materials in everyday life (two uses, e.g. salt tablets to replace salt lost by sweating).
2.3 Covalent Bonding (Time needed: 4 class periods)	Molecules. Minute size of molecules.		
	Covalent bonding as the sharing of pairs of electrons. Single, double and triple covalent bonds. Distinction between sigma and pi bonding.	Representation of covalent bonds using dot and cross diagrams.	
	Polar and non-polar covalent bonding.	Polarity test for liquids (use of charged plastic rod).	Polar and non-polar materials in everyday life (two examples of each).
	Characteristics of covalent substances.	Testing solubility in different solvents of ionic and covalent substances.	

2. CHEMICAL BONDING (CONTINUED)

Content	Depth of Treatment	Activities	Social and Applied Aspects
2.4 Electronegativity (Time needed: 2 class periods)	Electronegativity. Periodic variation of electronegativity – explanation for general trends in values: (i) down a group (ii) across a period.		
	Electronegativity differences and polarity of bonds.	Prediction of bond type using electronegativity differences.	
2.5 Shapes of Molecules and Intermolecular Forces (Time needed: 5 class periods)	Shapes of some simple molecules.	Use of models or balloons to illustrate molecular shapes.	
	Using electron pair repulsion theory to explain 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.) Relationship between symmetry and polarity in a molecule (dipole moments not required).		
	Distinction between intramolecular bonding and intermolecular forces. Intermolecular forces: van der Waals', dipole-dipole, hydrogen bonding. Effect of the intermolecular forces on the boiling point of a covalent substance.	Comparison of the boiling points of H_2 and O_2, of C_2H_4 and HCHO, and of H_2O and H_2S.	

2. CHEMICAL BONDING (CONTINUED)

Content	Depth of Treatment	Activities	Social and Applied Aspects
2.6 Oxidation Numbers (Time needed: 5 class periods)	Oxidation states and numbers. Rules for oxidation numbers (exclude peroxides, except for hydrogen peroxide).	Calculation of oxidation numbers of transition metals (in their compounds). Use of oxidation numbers in nomenclature of transition metal compounds. Calculation of oxidation numbers of other elements.	
	Oxidation and reduction in terms of oxidation numbers.		Bleaches as examples of oxidising agents (e.g. NaOCl) or reducing agents (e.g. SO_2).

Mandatory Experiments

2.1 Tests for anions in aqueous solutions: chloride, carbonate, nitrate, sulfate, phosphate, sulfite, hydrogencarbonate.

3. STOICHIOMETRY, FORMULAS AND EQUATIONS

Content	Depth of Treatment	Activities	Social and Applied Aspects
3.1 States of Matter (Time needed: 1 class period)	Motion of particles in solids, liquids and gases.		
	Diffusion (Graham's law not required).	NH_3 and HCl, ink and water, smoke and air.	
3.2 Gas Laws (Time needed: 7 class periods)	Boyle's law.	Calculations not required.	Boyle's air pump.
	Charles's law.	Calculations not required.	
	Gay-Lussac's law of combining volumes.		
	Avogadro's law.		
	Combined gas law: $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} =$ constant.	Simple calculations, including correction of gas volumes to s.t.p. (units: Pa, cm^3, K).	
	The kinetic theory of gases (non-mathematical treatment): ideal gases; assumptions of kinetic theory.	Calculations involving $PV = nRT$ (units: Pa, m^3, K).	
	Equation of state for an ideal gas: $PV = nRT$ (units: Pa, m^3, K).		
	Reasons why gases deviate from ideal gas behaviour.		
3.3 The Mole (Time needed: 9 class periods)	Avogadro constant. The mole as the SI unit for amount of substance containing the Avogadro number of particles. Standard temperature and pressure (s.t.p.). Molar volume at s.t.p., molar mass, relative molecular mass (M_r).	Calculation of relative molecular mass from relative atomic masses. Converting moles to grams, litres and number of particles. Converting grams and litres to moles, and number of particles to moles. Converting moles to number of atoms of a molecular species. Mandatory experiment 3.1	M_r determination using a mass spectrometer (simple treatment only – interpretation of mass spectra not required).

3. STOICHIOMETRY, FORMULAS AND EQUATIONS (CONTINUED)

Content	Depth of Treatment	Activities	Social and Applied Aspects
3.4 Chemical Formulas (Time needed: 6 class periods)	Empirical and molecular formulas.	Calculations of empirical formulas, given the percentage composition by mass. Calculation of empirical formulas, given the masses of reactants and products. Calculation of molecular formulas, given the empirical formulas and the relative molecular masses (examples should include simple biological substances, such as glucose and urea).	
	Percentage composition by mass.	Calculations.	
	Structural formulas.	Simple examples.	
3.5 Chemical Equations (Time needed: 11 class periods)	Chemical equations. Balancing chemical equations.	Simple examples.	
		Balancing redox equations (ionic equations only – ignore spectator ions).	
	Calculations based on balanced equations using the mole concept (balanced equations will be given for all calculations).	Calculations in g and kg rather than tonnes. Calculations involving masses and volumes.	
		Calculations involving excess of one reactant.	
	Percentage yields.	Calculation of percentage yields.	

Mandatory Experiments

3.1 Determination of the relative molecular mass of a volatile liquid (conical flask or gas syringe may be used).

4. VOLUMETRIC ANALYSIS

Content	Depth of Treatment	Activities	Social and Applied Aspects
4.1 Concentration of Solutions (Time needed: 8 class periods)	Solutions. Expression of solution concentration in mol l^{-1} (molarity), g l^{-1} and also in % (w/v), % (v/v), % (w/w).	Calculation of molarity from concentration in grams per litre and vice versa. Calculation of number of moles from molarity and volume. Simple calculations involving percentage concentrations.	Use of % (v/v), e.g. wine.
	Colour intensity as a function of concentration (simple treatment only).	Calculation of the effect of dilution on concentration.	
	Primary standards. Standard solutions.	Mandatory experiment 4.1	
4.2 Acids and Bases (Time needed: 4 class periods)	Acids, bases and salts. Neutralisation – formation of a salt from an acid and a base.		Household acids and bases (two examples of each). Everyday examples of neutralisation, e.g. use of lime in agriculture, use of stomach powders for acid indigestion.
	Arrhenius and Brønsted-Lowry theories of acids and bases (for aqueous solutions only). Conjugate acid-base pairs.		

4. VOLUMETRIC ANALYSIS (CONTINUED)

Content	Depth of Treatment	Activities	Social and Applied Aspects
4.3 Volumetric Analysis (Time needed: 22 class periods)	Apparatus used in volumetric analysis. Correct titrimetric procedure. Acid-base titrations.	Solving volumetric problems, using the formula method. Solving volumetric problems from first principles, where the formula method is not applicable. (Either method may be used when both methods are applicable.) Calculation of 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.) Mandatory experiment 4.2 Mandatory experiment 4.3 Mandatory experiment 4.4	
	Redox titrations.	Mandatory experiment 4.5 Mandatory experiment 4.6 Mandatory experiment 4.7 Mandatory experiment 4.8 Calculations based on mandatory experiments 4.5–4.8	

Mandatory Experiments

4.1 Preparation of a standard solution of sodium carbonate.
4.2 Standardisation of a hydrochloric acid solution using a standard solution of sodium carbonate.
4.3 Determination of the concentration of ethanoic acid in vinegar.
4.4 Determination of the amount of water of crystallisation in hydrated sodium carbonate.
4.5 A potassium manganate(VII)/ammonium iron(II) sulfate titration.
4.6 Determination of the amount of iron in an iron tablet.
4.7 An iodine/thiosulfate titration.
4.8 Determination of the percentage (w/v) of hypochlorite in bleach.

5. FUELS AND HEATS OF REACTION

Content	Depth of Treatment	Activities	Social and Applied Aspects
5.1 Sources of Hydrocarbons (Time needed: 1 class period)	Coal, natural gas and petroleum as sources of hydrocarbons.		Decomposition of animal waste and vegetation as methane sources. Hazards of methane production in slurry pits, coal mines and refuse dumps. Methane as a contributor to the greenhouse effect.
5.2 Structure of Aliphatic Hydrocarbons (Time needed: 5 class periods)	Alkanes, alkenes and alkynes as homologous series. For alkynes, only ethyne to be considered.		
	Systematic names, structural formulas and structural isomers of alkanes to C-5. Structures, but not isomers, of hexane, heptane, octane, cyclohexane and 2,2,4-trimethylpentane (iso-octane) to be considered.	Use of models.	
	Systematic names, structural formulas and structural isomers of alkenes to C-4.	Use of models.	
	Physical properties [physical state, solubility (qualitative only) in water and in non-polar solvents].	Demonstration of the solubility properties of methane, ethene and ethyne.	
5.3 Aromatic Hydrocarbons (Time needed: 1 class period)	Structure of benzene, methylbenzene and ethylbenzene as examples of aromatic compounds.	Use of models.	See aromatic compounds, page 55.
	Physical properties [physical state, solubility (qualitative only) in water and in non-polar solvents].	Demonstration of the solubility properties of methylbenzene.	

5. FUELS AND HEATS OF REACTION (CONTINUED)

Content	Depth of Treatment	Activities	Social and Applied Aspects
5.4 Exothermic and Endothermic Reactions (Time needed: 9 class periods)	Chemical reactions can result in a change in temperature. Exothermic and endothermic reactions (and changes of state).	Demonstration of an exothermic and an endothermic reaction.	
	Combustion of alkanes and other hydrocarbons.		
	Heat of reaction (general term).	Mandatory experiment 5.1	
	Sign of ΔH.		
	Bond energy (concept only – no calculations except for the illustrative example indicated).	Illustrating bond energies by showing how the C–H bond energy in methane is calculated.	
	Heat of combustion. Bomb calorimeter as an instrument for accurately measuring heats of combustion. Heats of combustion of different fuels.		Use of the bomb calorimeter in determining calorific values of foods. Kilogram calorific values of fuels, and their uses (calculations not required).
	Heat of formation.		
	Law of conservation of energy.	Simple calculations of heat of reaction, using heats of formation of reactants and products. Simple calculations of heat of formation, using other heats of formation and one heat of reaction. (Other kinds of heat of reaction calculation not required.)	
	Hess's law.		

5. FUELS AND HEATS OF REACTION (CONTINUED)

Content	Depth of Treatment	Activities	Social and Applied Aspects
5.5 Oil Refining and its Products (Time needed: 4 class periods)	Fractionation of crude oil. Production of the refinery gas, light gasoline, naphtha, kerosene, gas oil and residue fractions.		Uses of the refinery gas, light gasoline, naphtha, kerosene, gas oil and residue fractions. Composition of natural gas and liquid petroleum gas (LPG). Addition of mercaptans to natural gas for safety reasons. Composition of petrol. Auto-ignition. Octane numbers as a measure of the tendency of a fuel to cause knocking. Internal combustion engine in relation to auto-ignition. Relationship between octane number and (i) chain length (ii) degree of branching (iii) cyclic structure. Lead in petrol. Alternatives to lead: improving octane number by (i) isomerisation (ii) dehydrocyclisation (iii) catalytic cracking. Adding oxygenates (notably methyl *tert*-butyl ether) to increase the octane number and reduce pollution (structure of methyl *tert*-butyl ether not required).

5. FUELS AND HEATS OF REACTION (CONTINUED)

Content	Depth of Treatment	Activities	Social and Applied Aspects
5.6 Other Chemical Fuels (Time needed: 3 class periods)	Ethyne: preparation, combustion, tests for unsaturation. Hydrogen: manufacture by (i) electrolysis of water (ii) steam reforming of natural gas (simple treatment only).	Mandatory experiment 5.2 (equations and structures of products not required for the tests for unsaturation).	Oxyacetylene welding and cutting. Industrial uses. Potential as a fuel.

Mandatory Experiments

5.1 Determination of the heat of reaction of hydrochloric acid with sodium hydroxide.

5.2 Preparation and properties of ethyne [combustion, tests for unsaturation using bromine water and acidified potassium manganate(VII) solution].

6. RATES OF REACTION

Content	Depth of Treatment	Activities	Social and Applied Aspects
6.1 Reaction Rates (Time needed: 3 class periods)	Rate of reaction.	Mandatory experiment 6.1	
		Plotting and simple interpretation of reaction rate graphs.	
	Distinction between average and instantaneous rate.	Calculation of instantaneous rate from graphs.	
6.2 Factors Affecting Rates of Reaction (Time needed: 8 class periods)	Concentration. Particle size.	Demonstration of the effects on reaction rate of (i) particle size (ii) catalysts.	Dust explosions.
	Temperature.		Enzymes as catalysts produced by living cells (two examples).
	Nature of reactants. Catalysts.		Catalytic converters: (i) nature of catalysts (ii) reactions catalysed (iii) environmental benefits.
			Catalyst poisons.
		Mandatory experiment 6.2	
		Demonstration of the oxidation of methanol using a hot platinum or nichrome catalyst.	
	Activation energy and influence of temperature on the rate of reaction, using reaction profile diagrams.		
	Surface adsorption and intermediate formation theories of catalysis; the effect of catalysts on activation energy.	Demonstration of the oxidation of potassium sodium tartrate by hydrogen peroxide, catalysed by cobalt(**II**) salts.	

Mandatory Experiments

6.1 Monitoring the rate of production of oxygen from hydrogen peroxide, using manganese dioxide as a catalyst.

6.2 Studying the effects on the reaction rate of (i) concentration and (ii) temperature, using sodium thiosulfate solution and hydrochloric acid.

7. ORGANIC CHEMISTRY

Content	Depth of Treatment	Activities	Social and Applied Aspects
7.1 Tetrahedral Carbon (Time needed: 4 class periods)	Saturated organic compounds.	Use of models, as appropriate.	
	Alkanes.		Use as fuels.
	Chloroalkanes: structure and nomenclature up to C-4.		
	Physical properties [physical state, solubility (qualitative only) in water and in non-polar solvents].		Use as solvents.
	Alcohols: structure and nomenclature up to C-4 (primary and secondary alcohols only). Physical properties [physical state, solubility (qualitative only) in water and in non-polar solvents].	Comparison of structure with water. Solubility of (a) methanol and (b) butan-1-ol in (i) cyclohexane and (ii) water.	Ethanol as a solvent. Fermentation as a source of ethanol; use of fermentation in the brewing and distilling industries. Methanol as a denaturing agent.
7.2 Planar Carbon (Time needed: 11 class periods)	Unsaturated organic compounds.	Use of models, as appropriate.	
	Alkenes: non-polar double bond. Structure and nomenclature up to C-4.		Use in making plastics.
	Carbonyl compounds (aldehydes only): polar double bond. Structure and nomenclature up to C-4.	Solubility of ethanal in (i) cyclohexane and (ii) water.	Benzaldehyde in almond kernels (structure of benzaldehyde not required).
	Physical properties [physical state, solubility (qualitative only) in water and in non-polar solvents].		

7. ORGANIC CHEMISTRY (CONTINUED)

Content	Depth of Treatment	Activities	Social and Applied Aspects
7.2 Planar Carbon (continued)	Ketones: structure and nomenclature up to C-4.		
	Physical properties [physical state, solubility (qualitative only) in water and in non-polar solvents].	Solubility of propanone in (i) cyclohexane and (ii) water.	Propanone as a solvent (e.g. in nail varnish remover).
	Carboxylic acids: polar double bond. Structure and nomenclature up to C-4.	Solubility of ethanoic acid in (i) cyclohexane and (ii) water.	Methanoic acid in nettles and ants; ethanoic acid in vinegar. Use of ethanoic acid in the manufacture of cellulose acetate (structure of cellulose acetate not required). Use of propanoic acid and benzoic acid and their salts as food preservatives (structure of benzoic acid not required).
	Physical properties [physical state, solubility (qualitative only) in water and in non-polar solvents].	Mandatory experiment 7.1	
	Esters: structural formulas and nomenclature up to C-4.	Solubility of ethyl ethanoate in (i) cyclohexane and (ii) water.	Fats as natural esters. Ethyl ethanoate as a solvent. Aromas of esters.
	Physical properties [physical state, solubility (qualitative only) in water and in non-polar solvents].		
	Simple explanation of the use of the circle to represent the identical bonds in benzene, intermediate between double and single. Sigma and pi bonding in benzene.		
	Aromatic compounds.	Solubility of methylbenzene in (i) cyclohexane and (ii) water.	Use of methylbenzene as an industrial solvent.

7. ORGANIC CHEMISTRY (CONTINUED)

Content	Depth of Treatment	Activities	Social and Applied Aspects
7.2 Planar Carbon (continued)	An indication of the range and scope of aromatic chemistry (structures not required).	Inspect structural formulas of a range of consumer products to show the presence of benzene rings.	Aromatic compounds form the basis of dyestuffs, detergents, herbicides and many pharmaceutical compounds (one example in each case; structures not required). Aromatic acid-base indicators: phenolphthalein, methyl orange (structures not required). Carcinogenic nature of some aromatic compounds, e.g. benzene. Not all aromatic compounds are carcinogenic, e.g. aspirin (structure of aspirin not required).
7.3 Organic Chemical Reaction Types (Time needed: 21 class periods)	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 be able to write balanced equations for the reactions, using structural formulas, unless otherwise indicated.		
	(a) Addition reactions		
	Alkenes – reactions with hydrogen, chlorine, bromine, water and hydrogen chloride.		Industrial sources. Industrial importance of (i) products of the addition reactions of ethene with chlorine, bromine, water and hydrogen chloride (ii) hydrogenation of vegetable oils.

7. ORGANIC CHEMISTRY (CONTINUED)

Content	Depth of Treatment	Activities	Social and Applied Aspects
7.3 Organic Chemical Reaction Types (continued)	Mechanisms of ionic addition (addition of HCl, Br_2, Cl_2, only to ethene). Evidence for this mechanism: reaction of ethene with bromine water containing sodium chloride results in the formation of 2-bromoethanol, 1-bromo-2-chloroethane and 1,2-dibromoethane.		
	Polymerisation reaction (of ethene and propene only – reaction mechanism not required).		Alkenes as raw materials in the industrial manufacture of plastics.
	Unreactivity of benzene with regard to addition reactions, relative to ethene.		An indication of the range and scope of the petrochemical industry (two examples of synthetic products of this industry; structures not required, unless specified elsewhere in the syllabus).
	(b) Substitution reactions Halogenation of alkanes. Mechanism of free radical substitution (monochlorination of methane and ethane only). Evidence for this mechanism: (i) use of ultraviolet light even for a very short period causes a chain reaction (ii) formation of trace quantities of ethane and butane in the monochlorination of methane and ethane, respectively (iii) these reactions are speeded up by the addition of a known source of free radicals, such as tetraethyllead.		

7. ORGANIC CHEMISTRY (CONTINUED)

Content	Depth of Treatment	Activities	Social and Applied Aspects
7.3 Organic Chemical Reaction Types (continued)	Esterification.		
	Base hydrolysis of esters.	Mandatory experiment 7.2 (structures of reactants and products required).	Soap manufacture (structures of reactants and products required).
	(c) Elimination reactions		
	Dehydration of alcohols.	Mandatory experiment 7.3 (equations and structures of products not required unless specified elsewhere in the syllabus).	
	(d) Redox reactions		
	Alcohols:		
	Oxidation using $KMnO_4$ or $Na_2Cr_2O_7$ to (i) aldehydes and (ii) acids (half equations only required).	Mandatory experiment 7.4 Calculation of percentage yield (the balanced equation will be given).	Ethanal formation in the metabolism of ethanol in the human body.
	Oxidation of aldehydes to acids (half equations only required).	Mandatory experiment 7.5 Calculation of percentage yield (the balanced equation will be given).	
	Ketones are not easily oxidised.		
	Reduction of carbonyl compounds using H_2/Ni catalyst.		
	Combustion — a reaction common to most organic compounds. Combustion of alcohols.		Alcohols as motor fuels.
	Non-flammability of fully halogenated alkanes.		Flame retardants, fire extinguishers.

7. ORGANIC CHEMISTRY (CONTINUED)

Content	Depth of Treatment	Activities	Social and Applied Aspects
7.3 Organic Chemical Reaction Types (continued)	**(e) Reactions as acids** Reactions of alcohols with sodium. Acidic nature of the carboxylic acid group. Reactions of carboxylic acids with magnesium, with sodium hydroxide and with sodium carbonate.	and synthetic route required).	
	(f) Organic synthesis: principles and examples Chemical synthesis involves (i) bond breaking and (ii) bond forming.		
			Working out reaction schemes of up to three conversions, recalling familiar reactions.
	Example of organic synthesis: PVC from ethene (structures		
7.4 Organic Natural Products (Time needed: 4 class periods)	Extraction techniques, e.g. solvent extraction, steam distillation.	Mandatory experiment 7.6	An indication of the range and scope of organic natural product chemistry (two examples of useful organic natural products; structures not required).
7.5 Chromatography and Instrumentation in Organic Chemistry (Time needed: 3 class periods)	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.	Mandatory experiment 7.7	Use of thin-layer chromatography (TLC) in the separation of dyes taken from fibres in forensic work. GC and HPLC as more advanced separation techniques.

7. ORGANIC CHEMISTRY (CONTINUED)

Content	Depth of Treatment	Activities	Social and Applied Aspects
7.5 Chromatography and Instrumentation in Organic Chemistry (continued)	Instrumental methods of separation or analysis, or both:		Examples of uses:
	Mass spectrometry (cf.1.2, page 38).		Analysis of (i) gases from a waste dump and (ii) 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) as a ‘fingerprinting’ technique involving absorption of infra-red radiation (reference to molecular vibrations not required).		Identification of organic compounds, e.g. plastics and drugs.
	Ultraviolet absorption spectrometry as a quantitative technique involving the absorption of ultraviolet light.		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.)		

Mandatory Experiments

7.1 Recrystallisation of benzoic acid and determination of its melting point.
7.2 Preparation of soap.
7.3 Preparation and properties of ethene [combustion, tests for unsaturation using acidified potassium manganate(VII) solution and bromine water].
7.4 Preparation and properties of ethanal [properties limited to reactions with (i) acidified potassium manganate(VII) solution, (ii) Fehling’s reagent and (iii) ammoniacal silver nitrate].
7.5 Preparation and properties of ethanoic acid (properties limited to reactions with sodium carbonate, magnesium and ethanol).
7.6 Extraction of clove oil from cloves (or similar alternative) by steam distillation.
7.7 Separation of a mixture of indicators using paper chromatography or thin-layer chromatography or column chromatography.

8. CHEMICAL EQUILIBRIUM

Content	Depth of Treatment	Activities	Social and Applied Aspects
8.1 Chemical Equilibrium (Time needed: 8 class periods)	Reversible reactions – dynamic equilibrium. At equilibrium, the rate of the forward reaction equals the rate of the reverse reaction.		
	Equilibrium law and constant (K_c only).	Calculations involving equilibrium constants (K_c).	
8.2 Le Chatelier's Principle (Time needed: 5 class periods)	Le Chatelier's principle. Effect (if any) on equilibrium position of concentration, pressure, temperature and catalyst.	Mandatory experiment 8.1	Industrial application of Le Chatelier's principle in the catalytic oxidation of sulfur dioxide to sulfur trioxide and in the Haber process.

Mandatory Experiments

8.1 Simple experiments to illustrate Le Chatelier's principle:

(i) $CoCl_4^{2-} + 6H_2O \rightleftharpoons Co(H_2O)_6^{2+} + 4Cl^-$ (to demonstrate the effects of both temperature changes and concentration changes on an equilibrium mixture).

(ii) $Cr_2O_7^{2-} + H_2O \rightleftharpoons 2CrO_4^{2-} + 2H^+$
(iii) $Fe^{3+} + CNS^- \rightleftharpoons Fe(CNS)^{2+}$
(to demonstrate the effects of concentration changes on an equilibrium mixture).

9. ENVIRONMENTAL CHEMISTRY: WATER

Content	Depth of Treatment	Activities	Social and Applied Aspects
It is strongly recommended that students visit a water treatment plant — industrial or municipal.			
9.1 pH Scale (Time needed: 6 class periods)	Self-ionisation of water; K_w; pH scale. Use of universal indicator paper or solution. Limitations of the pH scale — usefulness confined to dilute aqueous solutions.	Calculation of pH of dilute aqueous solutions of strong acids and bases (calculation of pH of mixtures of strong acids and bases not required).	
	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.	
	Theory of acid-base indicators. Choice of indicator. Titration curves.		
9.2 Hardness in Water (Time needed: 3 class periods)	Hardness in water.		
	Causes of temporary and permanent hardness.	Tests on scale deposits in a kettle.	Removal of hardness by boiling and ion exchange.
	Deionisation. Relative purity of deionised and distilled water.		

9. ENVIRONMENTAL CHEMISTRY: WATER (CONTINUED)

Content	Depth of Treatment	Activities	Social and Applied Aspects
9.3 Water Treatment (Time needed: 5 class periods)	Water treatment – sedimentation, flocculation, filtration, chlorination, fluoridation and pH adjustment.		
	Sewage treatment (primary, e.g. settlement, screening; secondary, e.g. bacterial breakdown; tertiary, i.e. reduction of level of phosphates and nitrates). Cost of tertiary treatment.		
	The role of nutrients in the eutrophication of water. Pollution caused by uncontrolled use of nitrate fertilisers.		
	Pollution by heavy metal ions in water – especially Pb^{2+}, Hg^{2+} and Cd^{2+}		Removal by precipitation. Polluting potential of heavy metals from batteries in the absence of recycling.
			Awareness that there are EU limits for various chemical species in water (two examples, e.g. nitrates, phosphates, specific metal ions).

9. ENVIRONMENTAL CHEMISTRY: WATER (CONTINUED)

Content	Depth of Treatment	Activities	Social and Applied Aspects
9.4 Water Analysis (Time needed: 11 class periods)	Instrumental methods of analysis:		Examples of uses:
	pH meter		Analysis of river and lake water.
	AAS [cf. flame tests (mandatory experiment 1.1), absorption spectra (page 39)].		Analysis of heavy metals in water, e.g. lead, cadmium.
	Colorimetry	Mandatory experiment 9.1	Analysis of (i) lead in water and (ii) fertilisers.
	Brief reference to principles of each method.		
	Tests for anions (cf. mandatory experiment 2.1).	Mandatory experiment 9.2	
		Mandatory experiment 9.3	
	Biochemical oxygen demand (BOD).	Mandatory experiment 9.4	Organic chemical pollutants, e.g. sewage, industrial waste, silage, milk.

Mandatory Experiments

9.1 Colorimetric experiment to estimate free chlorine in swimming-pool water or bleach (using a colorimeter or a comparator).

9.2 Determination of total suspended and total dissolved solids (expressed as p.p.m.) by filtration and evaporation respectively. Determination of pH.

9.3 Estimation of total hardness using ethylenediaminetetraacetic acid (edta). (Balanced ionic equation required.)

9.4 Estimation of dissolved oxygen by redox titration.

Options: Higher level students to choose between Option 1 and Option 2 in their entirety.

OPTION 1A: ADDITIONAL INDUSTRIAL CHEMISTRY

Content	Depth of Treatment	Activities	Social and Applied Aspects
It is strongly recommended that students visit a particular local chemical plant. This visit should be a structured one.			
1A.1 General Principles (Time needed: 3 class periods)	Batch, continuous and semi-continuous industrial chemical processes. Characteristics of effective and successful industrial chemical processes such as (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).	See above.	Awareness 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.

OPTION 1A: ADDITIONAL INDUSTRIAL CHEMISTRY (CONTINUED)

Content	Depth of Treatment	Activities	Social and Applied Aspects
1A.2 Case Study (Time needed: 5 class periods)	A case study based on the Irish chemical industry. ONE of the three following processes should be studied, using the principles outlined in 1A.1 as far as they are relevant to the process:		Awareness 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).
	(a) Ammonia manufacture from natural gas, water vapour and air, and its conversion to urea. Equations required for (i) hydrogen production (ii) removal of carbon dioxide (iii) ammonia formation (iv) urea synthesis.		Use of urea as a fertiliser.
	(b) Nitric acid manufacture from ammonia, and its use to make fertilisers. 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. 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.

OPTION 1B: ATMOSPHERIC CHEMISTRY

Content	Depth of Treatment	Activities	Social and Applied Aspects
1B.1 Oxygen (Time needed: 1 class period)	Manufacture of oxygen using liquefaction and fractional distillation of air.		Uses of oxygen and of liquid nitrogen (two examples in each case).
1B.2 Nitrogen (Time needed: 2 class periods)	Structure and inertness.		Any two uses, e.g. keeping foods fresh, flushing out dangerous vapours from oil tankers.
	Atmospheric abundance.		
	Natural fixation of nitrogen; nitrogen and oxygen in an electric discharge. Nitrogen cycle.		
1B.3 Carbon Dioxide (Time needed: 4 class periods)	Combustion of carbon to give carbon monoxide and carbon dioxide.		
	Carbon monoxide as a neutral oxide.		Carbon monoxide as a poison. Carbon monoxide in cigarette smoke and vehicle exhaust fumes.
	Carbon dioxide as an acidic oxide.	Demonstration of the effect of carbon dioxide on universal indicator solution.	
	Carbon dioxide in water — free and combined as carbonate and hydrogencarbonate.		
	Fermentation in ethanol production as a source of carbon dioxide.		Carbon dioxide in carbonated drinks.
	The carbon cycle.		The greenhouse effect and the influence of human activity on it. Greenhouse gases and their relative effects [especially carbon dioxide and water vapour; also methane, chlorofluorocarbons (CFCs)]. Reduction of atmospheric carbon dioxide levels by dissolving in the ocean. Possible implications of the increased greenhouse effect.

OPTION 1B: ATMOSPHERIC CHEMISTRY (CONTINUED)

Content	Depth of Treatment	Activities	Social and Applied Aspects
1B.4 Atmospheric Pollution (Time needed: 2 class periods)	Oxides of nitrogen and sulfur: sources of pollution (natural, domestic, industrial, internal combustion engine).		
	Dissolving of nitrogen dioxide and sulfur dioxide to form acids.	Demonstration of the effect of sulfur dioxide on universal indicator solution.	Acid rain and its effects on the environment. Scrubbing of waste gases using limestone.
1B.5 The Ozone Layer (Time needed: 4 class periods)	Chloroalkanes: preparation from alkanes, e.g. chlorination of methane.		Chlorofluorocarbons and the ozone layer. Formation of ozone in the stratosphere (equation required). Beneficial effect of the ozone layer. Photodissociation of ozone (equation required). CFCs and HCFCs. Uses of CFCs. Residence times of CFCs. Breakdown of CFCs in the stratosphere. Removal of ozone by Cl atoms (equations required), O atoms and NO molecules. Role of methane in absorbing Cl atoms. CFCs are believed to be the main cause of damage to the ozone layer. Effects of damage to the ozone layer. Replacements for CFCs.

OPTION 2A: MATERIALS

Content	Depth of Treatment	Activities	Social and Applied Aspects
2A.1 Crystals (Time needed: 3 class periods)	Ionic, molecular, metallic and covalent macromolecular crystals – physical properties related to the crystal binding forces. Crystal structure is determined by scattering of X-rays by the crystal (non-mathematical treatment only).	Use of models.	Contributions of (i) Braggs: development of the X-ray technique for determining crystal structure; (ii) Dorothy Hodgkin: determination of the crystal structure of complex organic molecules, e.g. vitamin B_{12}, penicillin (structures not required). The discovery of buckminsterfullerene (structure not required).
2A.2 Addition Polymers (Time needed: 5 class periods)	Addition polymers. Monomers.		
	Polymerisation of alkenes: poly(ethene) (low-density and high-density), poly(chloroethene), poly(phenylethene), poly(tetrafluoroethene), poly(propene).	Demonstration of physical properties (density, flexibility, hardness) of poly(ethene), poly(chloroethene) and poly(phenylethene).	The industrial and domestic importance and advantages of these polymers in plastics and fibres (two examples of uses of each polymer).
	Structural differences between low-density and high-density poly(ethene).		Brief history of the discovery of low-density poly(ethene) and of high-density poly(ethene). Brief history of the discovery of poly(tetrafluoroethene). Recycling of plastics, exemplified by the recycling of polystyrene (stages: sorting, shredding, washing, drying and re-extrusion).
2A.3 Metals (Time needed: 1 class period)	Comparison between metals and non-metals (hardness, lustre, malleability, ductility, heat conductivity and electrical conductivity).		
	Alloys.		Carbon in steel and hardness.

OPTION 2B: ADDITIONAL ELECTROCHEMISTRY AND THE EXTRACTION OF METALS

Content	Depth of Treatment	Activities	Social and Applied Aspects
2B.1 The Electrochemical Series (Time needed: 1 class period)	Different combinations of metals produce different voltages in a simple cell. The electrochemical series (reactions of metals with acids, water and oxygen not required).		Contributions of Galvani, Volta, Davy and Faraday.
2B.2 Electrolysis of Molten Salts (Time needed: 1 class period)	Electrolysis of molten lead bromide, using inert electrodes. (Half equations only required.)		
2B.3 Corrosion (Time needed: 2 class periods)	Corrosion of metals. Relative corrodability of metals.		Corrosion prevention (application of a protective layer on a metal: galvanising and surface coating). Protective layers on Al, Cr. Sacrificial anodes.
2B.4 Strongly Electropositive Metals (Na and Al) (Time needed: 4 class periods)	Extraction by electrochemical methods.		Uses (two examples in each case).
	Sodium in Downs cell.		Chlorine is an important by-product.
	Aluminium from bauxite: bauxite → pure alumina – electrolysis to aluminium.		Environmental aspects of aluminium production. Economics of cheap electricity in the extraction of Al.
	Anodising.		Porous nature of the oxide layer formed by anodising allows dyeing. Recycling of aluminium.

OPTION 2B: ADDITIONAL ELECTROCHEMISTRY AND THE EXTRACTION OF METALS

Content	Depth of Treatment	Activities	Social and Applied Aspects
2B.5 d-Block Metals (Time needed: 4 class periods)	Transition elements: general chemical properties (colour, variable valency, use as catalysts).		
	Manufacture of iron (blast furnace – chemical aspects) and steel. Steels as alloys of iron.		Uses of iron and steel (two examples in each case).
	Electric arc process for steel manufacture (outline of main stages).		Environmental aspects of iron and steel production.

APPENDIX 2

Only the systematic names for organic compounds will be used on examination papers, except where the traditional name continues to enjoy widespread use, particularly in industrial and everyday life. In these cases, the traditional name will also be given in parentheses immediately after the systematic name. Knowledge of these traditional names is not examinable. A representative list of such compounds follows:

Systematic Name	**Traditional Name**
ethanal	acetaldehyde
ethanoic acid	acetic acid
propanone	acetone
ethyne	acetylene
ethyl ethanoate	ethyl acetate
ethanol	ethyl alcohol
ethene	ethylene
methanal	formaldehyde
methanoic acid	formic acid
2,2,4-trimethylpentane	iso-octane
methanol	methyl alcohol
chloromethane	methyl chloride
poly(ethene)	polyethylene
poly(phenylethene)	polystyrene
poly(chloroethene)	polyvinyl chloride
methylbenzene	toluene

The systematic names for H_4edta and methyl *tert*-butyl ether are not required.

The systematic names of inorganic compounds are not required, except for compounds of transition metals (cf. section 2.6).

Mathematical Requirements for Ordinary and Higher levels

Black text is for Higher level only.

1. Use of calculators

Students will be expected to have an electronic calculator conforming to the examination regulations for the duration of the course and when answering the examination paper. It is recommended that students have available the following keys:

Ordinary level: +, –, x, ÷, $^1/_x$, $\log_{10}x$, 10^x, EE or EXP, memory.

Higher level: as above, and x^2, $\sqrt{x}$, x^y.

In carrying out calculations, students should be advised to show clearly all expressions to be evaluated using a calculator. The number of significant figures given in the answer to a numerical problem should match the number of significant figures given in the question.

2. Mathematical requirements

The chemistry syllabus does not require Higher level mathematics. There is no requirement for the use of calculus techniques.

Arithmetic

Students should be able to

- understand the concept of significant figures
- recognise and use significant figures as appropriate
- recognise and use expressions in decimal and standard form (scientific) notation
- recognise and use prefixes indicating multiplication by 10^{-3}, 10^3
- find weighted means
- use an electronic calculator for addition, subtraction, multiplication and division, for reciprocals, squares, square roots, logarithms and their inverses
- make approximate evaluations of numerical expressions and use such approximations to check calculator calculations.

Algebra

Students should be able to

- change the subject of an equation
- solve simple algebraic equations
- substitute for physical quantities in physical equations using consistent units
- formulate simple algebraic equations as mathematical models of physical situations
- comprehend and use the symbols $>$, $<$, $\propto$, $=$, x, Δx.

Graphs

Students should be able to

- translate information between numerical, algebraic, verbal and graphic forms
- select appropriate variables and scales for graph plotting
- determine the slope of a linear graph and allocate appropriate physical units to it
- choose by inspection a straight line that will serve as the best straight line through a set of data represented graphically
- choose by inspection a curve that will serve as the best curve through a set of data presented graphically
- determine the slope of a curve at a point and allocate appropriate physical units to it.

National
Council for
Curriculum
and Assessment

An Chomhairle
Náisiúnta
Curaclaim agus
Measúnachta

NCCA

Procedures for drawing up National Syllabuses

The NCCA's Course Committees for the Leaving Certificate (Established) have the following membership:

- *Association of Secondary Teachers, Ireland*
- *Teachers' Union of Ireland*
- *Joint Managerial Body*
- *Association of Community and Comprehensive Schools*
- *Subject Association*
- *Irish Vocational Education Association*
- *National Council for Educational Awards*
- *Conference of Heads of Irish Universities*
- *Department of Education and Science (Inspectorate).*

On the basis of a brief provided by Council, the NCCA's Course Committees prepare the syllabuses.

Recommendations of Course Committees are submitted to the Council of the NCCA for approval. The NCCA, having considered such recommendations, advises the Minister for Education and Science accordingly.

Further information may be obtained by contacting the NCCA at 24 Merrion Square, Dublin 2.

AN ROINN OIDEACHAIS AGUS EOLAÍOCHTA | DEPARTMENT OF EDUCATION AND SCIENCE

National Council for Curriculum and Assessment | An Chomhairle Náisiúnta Curaclaim agus Measúnachta

NCCA

Published by The Stationery Office
To be purchased directly from:
Government Publications Sales Office,
Sun Alliance House,
Molesworth Street, Dublin 2.
Or by mail order from:
Government Publications, Postal Trade Section,
4-5 Harcourt Road, Dublin 2.
Tel: 01-647 6834/5 Fax: 01-475 2760
Or through any bookseller.

Designed by: Langley Freeman Design Group Limited