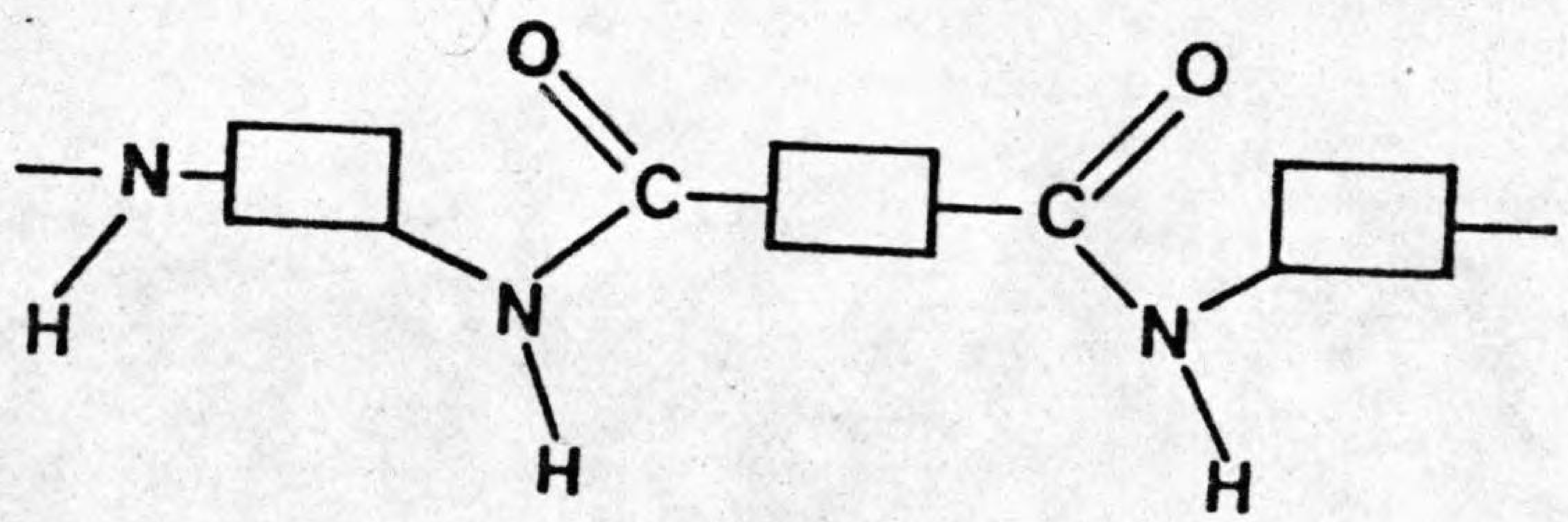
and students could draw block diagrams, in which the detailed structures of the linkages, but not those of the units, are shown, e.g. for nylon:



They could depolymerize polystyrene and perhaps repolymerize it (Nuffield III 7.1a and 7.5c), depolymerize perspex to methyl methacrylate and perhaps reverse this change also. Nuffield A 21.7; B 15.7. A sample of nylon could be made. Nuffield A 21.8; B 15.7.

Naturally occurring macromolecules–carbohydrates and proteins. Starch and glucose could be used to introduce the carbohydrates and the breakdown of naturally occurring large molecules, e.g. Nuffield A 21.1, 21.2; B 15.2. Because of their importance in life processes and natural fibres, proteins should be mentioned briefly.

4.5 The heavy chemicals industry–Ammonia, nitric acid, sulphuric acid. Electrolytic manufacture of sodium hydroxide and chlorine. Soap and detergents. Emphasis should be on raw materials, the demand for products and the principles involved. An experimental approach could be made to both soaps and detergents. Nuffield A 21.6; B 15.4.

4.6 Fertilizers

Nitrogenous and phosphatic fertilizers and sources of potassium should be mentioned.

General information

The following publications may be found helpful. Only the *Revised* Nuffield Chemistry publications are listed and reference to the original publications will also be of value.

ASSOCIATION FOR SCIENCE EDUCATION, College Lane, Hatfield, Herts AL10 9AA.
The School Science Review (Journal of ASE).

THE NUFFIELD FOUNDATION SCIENCE TEACHING PROJECT
Revised Nuffield Chemistry. (Longman Group Ltd.).

1. Teachers' Guide I
2. Experiment Sheets I
3. Study Sheets
4. Teachers' Guide II
5. Experiment Sheets II
6. Handbook for Pupils
7. Chemists in the World
8. Teachers' Guide III
9. 10 Option Pamphlets* for pupils

*There is no Option Pamphlet for Option 11. This option is described in outline only in Teachers' Guide III.

ROYAL SOCIETY OF CHEMISTRY, Burlington House, Piccadilly, London W1.
Monographs for Teachers.
Education in Chemistry (bi-monthly).

ADVANCED LEVEL

Chemistry 080

Introduction

This syllabus is the direct successor of the syllabus A081 introduced by the University of London in 1985, and has been constructed to take into account changes in the curriculum and assessment since that date.

The syllabus is free standing but it is expected that most candidates will have followed a course involving chemistry at ordinary level or equivalent. The syllabus content section is headed by a list of concepts with which it is expected that candidates will be familiar at the start of the course.

In order to assist teachers and pupils the syllabus has been redefined in terms of the skills which candidates will be expected to demonstrate and these skills should emphasise the continuity from more elementary courses. In particular, candidates will be expected to solve problems within a chemical context and to show their awareness of the place of chemistry in society. Sections indicating how this might be done have been incorporated throughout the syllabus, but teachers should also use examples of their own in showing how Applications of Chemistry and their implications – technological, industrial, economic, environmental and social – are important.

In order to accommodate this change of emphasis the required examinable syllabus has been curtailed significantly in favour of the skills defined in the Assessment Objectives.

Aims

The syllabus aims to:

1. stimulate and sustain students' interest in, and enjoyment of, chemistry;
2. enable students to gain a knowledge and understanding of chemistry appropriate to this level and to appreciate the interlinking patterns which are a distinguishing feature of the subject;
3. show the interrelationship between the development of the subject and its Applications: social, economic, environmental and technological;
4. 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;
5. foster imaginative and critical thinking as well as the acquisition of knowledge, together with an appreciation of the intellectual discipline which the subject provides;
6. develop students' ability to acquire knowledge by means of practical investigation;
7. develop students' abilities to form hypotheses and to design experiments to test them;
8. provide an appropriate course for those who will end their study of the subject at this stage as well as laying a secure foundation for those who will continue their studies in this or related subjects.

Objectives

The examination is designed to test the attainment of candidates according to a specification based on Abilities and Activities.

Abilities

The abilities of the candidates to be tested are grouped into four categories (see below) and are related to the Syllabus Content in terms of the skills that candidates may be asked to demonstrate in the examination.

	Ability	*Corresponding aim*	*Corresponding skills*
(1)	Knowledge – the ability to recall and communicate information. As well as specific facts, this may include recall of terminology, techniques, theories, and so on.	2, 3, 4	recall
(2)	Comprehension – the ability to interpret familiar information. This is a routine level of understanding. The solution of problems and calculations in a manner with which the candidates are familiar would fall into this category.	2, 3, 4	demonstrate understanding, perform calculations, identify, justify, recognise
(3)	Application – the ability of candidates to use and communicate their knowledge and understanding in situations which, to some extent, are unfamiliar or to deal with familiar situations by unfamiliar methods	1, 3, 4, 5, 6	apply select predict interpret deduce
(4)	Analysis/evaluation/synthesis – the ability to: analyse a complex communication or situation into its various parts and to see the relationship between them: compose a communication, bringing together several areas of knowledge and understanding, and forming a statement complete in itself.	1, 2, 3, 5, 6	Plan investigations, demonstrate awareness

Activities

Candidates will also be tested on their skills in the main activities in which they can be expected to have engaged during their study of chemistry:

(A) studying specific substances by non-practical methods;
(B) using practical techniques to investigate the behaviour of materials;

(C) looking for and using patterns in the behaviour of substances;
(D) solving problems using mathematical techniques;
(E) solving problems using concepts (without the aid of mathematics);
(F) studying the Applications of Chemistry in selected fields, together with their social and economic aspects.

The Examination

The examination will consist of three theory papers and a practical test. A special paper will also be set.

It is intended that Applications of Chemistry will pervade the teaching of the course and this will be reflected in the examination, particularly in papers 1 and 2.

Candidates will be expected to have access to an electronic calculator in all parts of the examination. Further details are given on page 7. Four figure mathematical tables may be issued to candidates requesting them.

Candidates will be provided with a Periodic Table for use in all papers, including the multiple choice paper. The Periodic Table will include the names and symbols of all the elements together with their atomic numbers and relative atomic masses corrected, in most cases, to the nearest whole number. A limited range of other data as required will also be included.

Candidates will be allowed no books or notes in the written theory papers: in the practical examination they will be permitted to use any books or notes they wish.

Specification

The marks awarded for each component of the examination will be combined to give a total examination mark of 400.

		marks
Paper 1		120
Paper 2		120
Paper 3		80
Practical test		80
	TOTAL	400 marks

The target weightings, expressed as percentages of the overall examination marks, for the various components are:

<table>
<tr><th>Ability \ Paper</th><th>1 and 3</th><th>2</th><th>Practical test</th></tr>
<tr><td>1</td><td>15</td><td rowspan="2">10</td><td rowspan="4">20</td></tr>
<tr><td>2</td><td>10</td></tr>
<tr><td>3</td><td>20</td><td>10</td></tr>
<tr><td>4</td><td>5</td><td>10</td></tr>
</table>

The theory papers 1 – 3 will be constructed in such a way that, taken as a whole, they provide broadly balanced coverage of topics 1 – 22 of the syllabus content.

Paper 1 (2 hours)

Paper 1 will consist of about 7 compulsory structured questions leading to a total of 120 marks. Applications will be included where appropriate and opportunity will be provided for differentiation by outcome in parts of some questions.

Paper 2 (2¼ hours)

Paper 2 will consist of 4 compulsory questions.

Question 1 will be a data response or comprehension question. Candidates will be provided with stimulus material which may be in the form of a passage of written text, tables of data or experimental results, or graphical or diagrammatic information, through which an assessment relating primarily to abilities 3 and 4 will be made.

Question 2 will be a problem solving exercise which may, but will not necessarily, relate to experimental design. Choice will be given within this question.

Question 3 will require candidates to respond freely to one of four titles. Opportunity will be provided for candidates to demonstrate their knowledge of Applications of Chemistry and a variety of approaches will be acceptable: the objective will be to allow candidates to show what they know and to demonstrate their skill in communication.

Question 4 will also be a free response question in which some choice may be given. The objective of this question will be to ensure that all major sections of the syllabus, in terms of both content and skills, are covered and to allow candidates to demonstrate positive achievement. The style of this question will be similar to that of questions in paper 3 of the 1985-1989 examinations.

The four questions on this paper will carry equal marks.

Paper 3 (1 hour)

Paper 3 will be a multiple choice objective test of 40 compulsory questions. Three types of question will be used: simple multiple choice, classification sets and multiple completion questions. There will be no separate section confined to laboratory situation sets though groups of questions linked to a common stem will be included with other multiple choice or multiple completion questions.

Multiple completion questions will include three responses numbered 1, 2 and 3 and candidates will be required to answer according to the following key which will be reprinted on each appropriate double page spread of the question paper.

A 1, 2 and 3 only correct
B 1 and 2 only correct
C 2 and 3 only correct
D 1 only correct
E 3 only correct

Applications will receive less emphasis in this paper than in papers 1 and 2 as the multiple choice format is less appropriate than that of the other papers for testing these aspects.

Each question will carry two marks leading to a total of 80 marks. No marks will be deducted for incorrect answers.

Special Paper (3 hours)

A special paper will also be set which may include questions on any aspect of the course. Candidates will be required to attempt 4 questions out of 8. Some questions will be of a sufficiently general nature as to allow, but not require, the use of material relating to Applications not included in the main syllabus.

Paper 4 (3 hours)

This will be a practical test for those candidates whose work has not been assessed by the teacher. The test will consist of two compulsory questions. Candidates may use any notebooks or text books they wish in the practical test.

The practical test will seek to test the ability of candidates to:

1. manipulate apparatus and chemicals in quantitative and qualitative exercises,
2. observe the results of experimental work, both quantitative and qualitative, and to record these observations accurately,
3. interpret their observations and arrive at valid inferences and conclusions, including those reached through the calculation of results in quantitative exercises,
4. devise and plan experiments of a simple kind.

The practical test will carry a total of 80 marks.

NOMENCLATURE AND MATHEMATICAL REQUIREMENTS

In the naming of compounds, reference should be made to the joint statement on chemical nomenclature issued by the GCE Boards in 1984, reproduced below.

A JOINT STATEMENT BY THE GCE BOARDS, 1984

"Chemical nomenclature in GCE examination papers

Following the publication in 1972 by the Association for Science Education of "Chemical Nomenclature, Symbols and Terminology", the GCE Boards and the ASE discussed the possibility and desirability of the use of one system of chemical nomenclature for all syllabuses and examinations, and the extent to which the recommendations contained in the ASE document might constitute the acceptable system. As a result of these discussions, the GCE Boards agreed a joint statement in 1973 which each Board would use as the basis for its practice in setting examination papers. A Second Edition of the ASE document (containing the joint statement) was published in 1979. With regard to the Third Edition of the ASE document, the Boards wish to reaffirm the principles governing the use of nomenclature in their examination papers and which recognise the widespread use of systematic nomenclature and the advantages of uniform practice in schools. At the same time it is recognised that traditional names are at present part of the language of chemistry and may well continue to be used for some time to come. Although systematic names are increasingly employed in learned journals and textbooks, the traditional names are still used in many publications and by chemists in their work. Further, various common materials in everyday use, or commonly met in a non-scientific context, are widely known by non-systematic names (e.g. pvc, acetylene, ozone) and it is considered desirable that candidates should be aware of such names. It has to be noted that IUPAC Rules (rules of the Commissions of the International Union of Pure and Applied Chemistry) permit the use of more than one name in a number of cases.

"The following general principles will be followed in setting examination papers.

(a) ASE recommended names will be used for all compounds. In the case of carbon compounds and their derivatives, recommended names will be used, except that common names may be used additionally for certain well-known compounds. In a few cases, common names may be given preference; these occur mainly in compounds containing one or two carbon atoms, in mono-substituted benzene derivatives, and in natural products.

(b) A Kekule structure or a hexagon/circle symbol may be used for benzene.

(c) In cases where doubt may remain, the intention will be made clear in the examination paper. For instance, the formula may be given or alternative names may be stated. In some cases it may be convenient to set out in the paper a short list of alternative names or formulae for substances referred to in the question papers.

"Any examination questions set on nomenclature will be determined by the syllabus of each board, and this statement does not in any way extend examinable material. In answers to examination questions candidates may use any name, symbol or abbreviation which is generally accepted for a compound or group, unless the question is specifically on some aspect of nomenclature that falls within the syllabus."

Questions will be set in accordance with the recommendations contained in *SI Units, Signs, Symbols and Abbreviations*, Association for Science Education, 1981, except that the unit of pressure may be the atmosphere (atm). Centres are also recommended to consult *Chemical Nomenclature, Symbols and Terminology*, ASE, Third Edition, 1985.

MATHEMATICAL REQUIREMENTS

Candidates will be expected to calculate numerical results using any of the functions listed below and to plot and interpret graphs, including the determination of the gradient of a curve at a given point.

Candidates will be expected to have an electronic calculator conforming to the University's Regulation, 22.4 when answering all papers including the multiple-choice paper, Paper 3. It is recommended that calculators have the following keys: $+$, $-$, $\times$, $\div$, π, x^2, $\sqrt{x}$, $1/x$, x^y; $\lg x$ and $\ln x$ and their inverses, memory.

In calculations candidates are advised to show all the steps in their working giving their answer to appropriate number of significant figures.

Syllabus Content

The examination will be based on the skill statements set out below in relation to each of the main headings of the syllabus. It is intended that most areas of the syllabus will be illustrated by references to Applications of Chemistry. Examples of these are given in the awareness statements which occur throughout the syllabus and many of the general principles relating to them are set out in topic 2 of the content.

The syllabus content is defined in terms of statements relating to recall, abilities and awareness.

The recall statements define that material which candidates will be expected to be able to reproduce from memory during the examination. This body of specific factual knowledge has been kept to a minimum to allow candidates time to develop their own interests and to develop practical and problem solving skills.

The ability statements, introduced by the words "Candidates should be able to ......", define those areas in which candidates will be required to demonstrate their abilities relating to Comprehension and Application. Questions requiring these abilities may relate to material of which the candidate is not expected to have specific knowledge; in such cases all necessary factual material will be included in the question.

The awareness statements define material of which candidates should have some experience but not specific factual knowledge. These aspects of the syllabus are ones likely to be chosen by examiners in conjunction with comprehension or data response questions in which interpretation skills together with analysis, evaluation and synthesis are being tested. It is not intended that substantial teaching time should be devoted to all these topics but that they will provide guidance to teachers as to important Applications of Chemistry as well as setting out vehicles for the testing of problem solving and comprehension skills. It is hoped that candidates will experience material relating to many of these statements as part of their general reading, rather than formally.

1. *Basic Knowledge*

   Candidates should be aware:

   (a) of the nature of chemical change in terms of rearrangements of atoms

   (b) that chemical change is the means by which new substances are formed and that the products of chemical reactions are important in our society

(c) that economic factors often influence industrial processes in terms of energy considerations, cost and availability of raw materials, and capital cost of plant

(d) that many chemical properties of elements and their compounds can be rationalized in terms of their position in the Periodic Table

(e) that chemistry is a quantitative science and that by making suitable measurements it is possible to arrive at the chemical equation for a reaction

2. *Applications of Chemistry*

Candidates should be able to recall

(a) that the accessibility of raw materials, the cost of processing them and the market price of the product are important factors in determining the feasibility of an industrial chemical process

(b) that the reaction to produce the desired product is one facet only of a series of processes including purification/separation of raw materials, transfer of materials, separation and purification of products and disposal of waste material

(c) that the choice of a particular industrial process depends on technological, economic and environmental issues as well as chemical considerations

3. *Atomic Structure*

3.1 Candidates should be able to recall

(a) that the atomic nucleus is made up of protons and neutrons

(b) that relative atomic and molecular masses are measured on a scale in which $^{12}C = 12.000$

(c) simple charge cloud representations of s and p atomic orbitals and of σ and π molecular orbitals in relation to simple organic molecules

(d) the definitions of first and successive ionization energies

3.2 Candidates should be able to

(a) demonstrate understanding of the relationships between numbers of protons and neutrons with atomic number, atomic mass number, relative atomic mass and the existence of isotopes which may be described in terms of symbols e.g. $^{12}_{6}C$

(b) perform calculations to determine the relative molecular mass of a compound from relative atomic masses

(c) predict the electronic configurations of isolated atoms up to krypton using 1s, 2p etc notation or electrons in boxes notation using the building-up principle

(d) interpret mass spectrometer data to make simple deductions relating either to isotopes or to organic molecules

(e) interpret successive ionization energies in terms of electronic configuration

(f) interpret periodic trends in first ionization energy in terms of electronic configuration

3.3 Candidates should be aware

(a) of the general principles and uses of the mass spectrometer

(b) that electrons are characterized by their energies, that they are not localized in fixed orbits, and that the electron structure determines the chemical properties of an element

(c) that the atomic spectrum of hydrogen provides experimental evidence for energy levels, that the energy difference between levels can be found from the frequency of the radiation emmitted and that the first ionization energy can be found spectroscopically

(d) that measurement of the frequency of absorbed or emitted radiation provides an important analytical tool

(e) of $\alpha-$, $\beta-$ and $\gamma-$ radiation and principles connected with the use of radioisotopes in medicine and industry

4. *Quantitative Chemistry*

Candidates should be able to:

(a) deduce masses of particles in terms of moles, and *vice-versa*, given suitable data

(b) deduce volumes of gases in terms of moles of gas, at s.t.p. or at room temperature and atmospheric pressure

(c) describe an experiment to collect appropriate data for the determination of the formula of a simple compound

(d) describe an experiment to determine the relative numbers of reacting particles in a chemical reaction

(e) deduce the empirical formula of a compound from reacting masses

(f) deduce simple equations from reacting masses of pure substances and from the volumes of gases at the same temperature and pressure and *vice-versa*

(g) carry out calculations relating to substances in solution, concentration being expressed in g dm^{-3} or mol dm^{-3}

5. *Bonding and Structure*

5.1 Candidates should be able to recall

(a) the nature of the forces between electrons and nuclei leading to different types of bond: ionic, covalent, dative, hydrogen and metallic

(b) the relative strengths of the various types of bond

(c) the arrangement of ions in sodium chloride

(d) that alkali metals have body-centred cube structures as compared with many other metals which have close-packed structures

(e) structures and bonding of diamond and graphite

5.2 Candidates should be able to

(a) demonstrate an understanding of the relationship between the physical properties of a substance and its bonding and structure: metals, simple molecules, giant structures and polymers

(b) demonstrate an understanding of the properties of benzene and graphite in terms of delocalization of electrons

(c) interpret ionic and covalent bonds using dot and cross diagrams

(d) interpret the shape of a simple molecule or ion in terms of the electron pair repulsion theory

(e) interpret the physical properties of noble gases, hydrides in groups 4, 5, 6 and 7, water and carboxylic acids in terms of intermolecular forces

5.3 Candidates should be aware

(a) that ions are frequently hydrated in solution and that dative bonding is important in some hydrated and complex ions
(b) that the size of an atom can be interpreted in terms of covalent, metallic or van der Waal's radii
(c) of the concept of ionic radius for some elements
(d) of the effect of nuclear charge and closed shells of electrons on the value of ionic radius
(e) that covalent radius for an element is a variable quantity depending upon the molecular environment in which the atom is placed
(f) that the physical properties of metals are governed not only by bonding but also atomic flow as controlled by the size of crystals resulting from heat treatment e.g. annealing, quenching and tempering
(g) that the properties and uses of everyday materials are governed by their structure and bonding

6. *Energetics*

6.1 Candidates should be able to recall

(a) that enthalpy changes for reactions are defined under certain standard conditions
(b) the principle of the conservation of energy (Hess's Law)
(c) the distinction between bond enthalpy and mean bond enthalpy for molecules of the type AB_n

6.2 Candidates should be able to

(a) construct simple enthalpy level diagrams and make deductions from them given suitable data
(b) perform calculations to determine or predict enthalpy changes for reactions in solution or for combustion of organic compounds using mean bond enthalpy values or other suitable data

6.3 Candidates should be aware

(a) that the sign of an enthalpy change does not always indicate the direction of spontaneous change.
(b) that the enthalpy change for a reaction varies with temperature.
(c) that energy changes influence the conditions under which certain industrial processes function
(d) that there are economic considerations to be borne in mind concerning the siting and organisation of plant in industrial processes

7. *Phase Equilibria*

7.1 Candidates should be able to recall

(a) the phase diagrams for two volatile liquids in which Raoult's Law is obeyed.
(b) the diagrams representing variation of boiling point and vapour pressure with composition for systems of two volatile liquids at constant pressure or constant temperature

(c) that fractional distillation is used for separating fractions in crude oil and separating components in liquid air.

7.2 Candidates should be able to

(a) demonstrate understanding of the principles of fractional distillation in terms of plots of boiling point and vapour pressure against composition
(b) perform calculations based on Raoult's Law for two component systems, given suitable data
(c) interpret both positive and negative deviations from Raoult's Law in terms of enthalpies of mixing
(d) predict the formation of an azeotrope given an appropriate plot of vapour pressure against composition for a two component system.

7.3 Candidates should be aware

(a) that deviations from Raoult's Law may be related to hydrogen bonding
(b) that liquids cannot always be completely separated by fractional distillation if their boiling points are similar or they form an azeotrope.

8. *Chemical Equilibria*

8.1 Candidates should be able to recall

(a) that equilibria are dynamic and that the state of equilibrium is defined by the equilibrium constant which is dependent only on temperature
(b) Le Chatelier's Principle
(c) that solid and pure liquid phases may be regarded as having constant concentration
(d) that the presence of a catalyst does not affect the position of equilibrium but does affect the time taken to reach equilibrium
(e) that the manufacture of ammonia and of sulphuric acid involve equilibrium processes

8.2 Candidates should be able to

(a) deduce the effect of changes in concentration, pressure and temperature on the position of equilibrium using Le Chatelier's principle and given suitable data
(b) deduce an expression for K_c from a given equation and calculate numerical values with units, given suitable data
(c) determine the equilibrium concentrations in a reaction from the equilibrium constant and any other necessary data

8.3 Candidates should be aware

(a) that most chemical processes are equilibrium ones
(b) that many commercially important processes involve equilibrium

9. *Acid/Base Equilibria*

9.1 Candidates should be able to recall

(a) the Brønsted-Lowry theory and its use in correlating acid/base behaviour
(b) the definition of pH

(c) two methods of measuring pH experimentally
(d) definitions of K_a, K_w and their units
(e) the simple theory of indicators as weak acids or basis

9.2 Candidates should be able to

(a) identify acid/base conjugate pairs and relate them by means of suitable equations
(b) calculate pH from hydrogen ion concentration and from K_a and *vice versa*
(c) calculate the pH of a buffer solution from suitable data
(d) select a suitable indicator for a given titration using suitable pH/colour change data
(e) interpret the variations of pH during titrations

9.3 Candidates should be aware

(a) that pH is an important factor in determining enzyme activity
(b) that regulation of soil pH is important in agriculture
(c) that many everyday processes, including photographic processes, are dependent on pH and take place in buffered solutions

10. Redox Equilibria

10.1 Candidates should be able to recall

(a) the definition of standard electrode potential and standard redox potential and the conventions for representation of cells
(b) the reason for defining a standard electrode
(c) the use of the standard hydrogen electrode as a reference electrode

10.2 Candidates should be able to

(a) predict the direction of spontaneous change for redox reactions using suitable redox potential data
(b) interpret ionic half equations and use them to deduce the equations of redox reactions
(c) interpret the electrochemical series in terms of electrode potentials

10.3 Candidates should be aware

(a) of the applications of electrode potentials in connection with corrosion problems
(b) that results of predictions regarding the direction of spontaneous change could prove to be erroneous due to kinetic inhibition or departures from standard conditions
(c) of the importance of storage cells

11. *Chemical Kinetics*

Candidates should be able to recall

(a) the factors which affect the rate of a chemical change
(b) the definition of order of reaction, both overall and with respect to a given reagent

(c) the significance of the rate constant in the rate law for a chemical reaction
(d) that rate constant always increases with temperature
(e) that rates of reaction are kinetically controlled and that activation energy is a barrier to chemical reaction
(f) the distribution of energies in an assembly of particles at constant temperature and the changes which occur in this distribution with changes in temperature
(g) a simple kinetic explanation for rate of a chemical change in terms of the energies of particles
(h) that many reactions proceed through a transition state

11.2 Candidates should be able to

(a) select a suitable experimental technique for following a chemical reaction
(b) interpret the results of kinetic measurement in graphical form
(c) interpret the terms activation energy and pre-exponential factor in the Arrhenius equation.
(d) interpret the results of kinetic experiments in terms of rate laws (integrated forms not required)
(e) use the Arrhenius equation to determine the activation energy for a reaction given suitable data
(f) interpret first order reactions in terms of half-life and *vice-versa*

11.3 Candidates should be aware

(a) that many common reactions are complex
(b) of the implications of kinetic factors for the success of industrial and biological processes
(c) that the order of a reaction is experimentally determined and that it is possible to deduce information regarding the mechanism of a chemical reaction from kinetic information

12. *Catalysis*

12.1 Candidates should be able to recall

(a) that a catalyst creates a new reaction pathway with a lower energy barrier, change of Arrhenius factor or both
(b) examples of catalysis including some of industrial importance
(c) that enzymes are biological catalysts

12.2 Candidates should be able to

(a) demonstrate an understanding of homogeneous as opposed to heterogeneous catalysis
(b) identify the existence of a transition state from a reaction profile
(c) interpret suitable data to produce a reaction profile

12.3 Candidates should be aware

(a) that many transition metals and their compounds show catalytic activity

(b) that catalytic activity shown by transition metal cations may sometimes be explained in terms of redox behaviour.

(c) that the use of a catalyst in an industrial process is often a means of saving energy

13. *Groups 1 and 2*

13.1 Candidates should be able to recall

(a) the characteristic physical properties of the elements

(b) the characteristic flame colours shown by compounds of the elements

(c) the reactions of the elements with oxygen, chlorine and water

(d) the reactions of the oxides with water

(e) the trends in solubility of the sulphates and hydroxides of Group 2 elements.

(f) the trends in thermal stability of the nitrates and carbonates of the elements in Groups 1 and 2

13.2 Candidates should be able to

(a) interpret the physical properties of the elements in terms of their structures

(b) interpret the oxidation states of s-block elements in terms of electron configuration

(c) make predictions concerning the physical and chemical properties of the elements and their compounds

(d) recognise patterns of behaviour in relation to other groups

13.3 Candidates should be aware

(a) of the application of characteristic flame colours in the analysis for these elements

(b) of the economic importance and uses of compounds of s-block elements in the chlor-alkali industry, in building materials and in biological systems

(c) of the main sources of compounds of the s-block elements: limestone, deposits of sodium and potassium salts, and the sea

14. *Groups 3 and 4*

14.1 Candidates should be able to recall

(a) that metallic character increases down groups 4.

(b) the trends in hydrolytic behaviour of the chlorides and in the acid-base character of the oxides or hydroxides as illustrated by boron and aluminium in group 3 and by carbon, silicon and lead in Group 4.

(c) that the 2+ oxidation state in Group 4 becomes more stable as the atomic number increases

(d) that Sn(II) is reducing and Pb(IV) is oxidizing

14.2 Candidates should be able to

(a) interpret the chemistry of the elements in terms of their position in the Periodic Table.

14.3 Candidates should be aware

(a) that the purification of bauxite depends on the amphoteric nature of Al_2O_3, that the extraction of aluminium is done electrolytically and that the extraction is economically important yet expensive.

(b) that carbon is a valuable industrial reducing agent

(c) that silicon and germanium are important in the electronics industry.

15. *Groups 5 and 6*

15.1 Candidates should be able to recall

(a) that oxygen and sulphur combine with many other elements directly, forming compounds that are abundant in nature

(b) that hydroxides and sulphides may be formed by the addition of OH^- and H_2S respectively to solutions containing metal ions

(c) the method of formation in industry of ammonia, sulphur dioxide and sulphur trioxide

(d) the stoichiometry of the principal oxo-anions of nitrogen and sulphur: NO_2^-, NO_3^-, SO_3^{2-}, SO_4^{2-}

15.2 Candidates should be able to:

(a) compare the physical and chemical properties of N_2, P_4, O_2 and S_8

(b) interpret the chemical character of these elements in terms of their positions in the Periodic Table and their structures

15.3 Candidates should be aware of

(a) the importance of inorganic nitrogen and phosphorus compounds in agriculture

(b) the economic importance of oxides and sulphides in the production of metals

(c) the sources of sulphur for the production of sulphuric acid

(d) the importance of sulphuric acid in the manufacture of detergents

(e) the environmental impact of some compounds of nitrogen and sulphur.

16. *Group 7*

16.1 Candidates should be able to recall

(a) the physical properties of the elements F, Cl, Br, I

(b) that all HX compounds are water soluble and are acidic in solution

(c) that HF is a weak acid

(d) the reactions and analytical importance of the reactions between Ag^+ and X^-

(e) The reactions of the halide salts with concentrated sulphuric acid

(f) The existence of the various oxidation states of chlorine as exhibited in the oxo-anions

(g) the nature of disproportionation as illustrated by Cl_2 and ClO^-

16.2 Candidates should be able to

(a) suggest and explain differences in the physical or chemical behaviour of compounds when one halogen is substituted for another

(b) discuss the reactions of the elements in terms of their oxidizing ability.

(c) interpret trends in values of ionization energy and atomic radius

16.3 Candidates should be aware that

(a) the use of chlorine as a poison gas and as a disinfectant show that chemistry can be used for destructive as well as beneficial purposes.

(b) halogens are used in the manufacture of pesticides, disinfectants, polymers and refrigerants

(c) chlorine compounds are important in the alkali industry

17. *d-block elements*

17.1 Candidates should be able to recall

(a) that the elements Ti to Cu (inclusive) within the d-block are known as transition elements

(b) that transition elements have characteristic electron structures and properties

(c) that d-block elements are always metals, that the transition elements often form coloured compounds and complex ions, and that they usually show variable oxidation state.

(d) that complex ions consist of a central positively charged metal ion surrounded by ligands which carry a lone pair of electrons

(e) that many complex ions are tetra- or hexa-coordinated giving rise to characteristic shapes.

(f) that the bonding in complex ions may be interpreted either in terms of dative co-ordinate bonding or the attraction between centres of negative charge on the ligand and the positive central metal ion.

(g) that hydroxides are precipitated from solution by the addition of OH^- ions

(h) one method for the formation of each of CuCl and Cu_2O

(i) one method for the interconversion of Fe^{2+} and Fe^{3+}

(j) the common oxidation states of manganese and vanadium and methods for their interconversion

17.2 Candidates should be able to:

(a) deduce the d-electron configuration of an element from its position in the Periodic Table and vice versa

(b) relate the above properties of d-block elements to their electronic structures, either in general or for a specific example, given suitable data

(c) predict suitable agents for bringing about conversions between oxidation states using suitable electrode potential data.

(d) relate processes used for the extraction of transition elements from their ores (limited to reduction with carbon, reduction with other metals, reduction with hydrogen, and electrolytic processes) to their standard electrode potentials, to economic factors and to the level of purity required.

(e) interpret the bonding in a given complex ion using the electrons in boxes notation

(f) propose the shape of a complex ion, given its formula (without distinction between square planar and tetrahedral arrangements)

(g) interpret the existence of isomers, given suitable data

(h) interpret the solubilities of AgCl and AgBr in ammonia, and of $Zn(OH)_2$ in sodium hydroxide or ammonia and to extend this approach to other examples given suitable data

17.3 Candidates should be aware that:

(a) most elements are d-block elements

(b) most simple ions of d-block elements are hydrated in solution

(c) many d-block elements are extremely important in society

(d) many d-block elements have an important biological role

18. Periodicity

18.1 Candidates should be able to recall

(a) the formulae of the oxides, hydrides and chlorides of elements from Li to Ar in the Periodic Table.

(b) the reactions with water of the oxides, hydrides and chlorides of these elements

(c) main methods of preparation of the oxides, hydrides and chlorides of these elements.

18.2 Candidates should be able to

(a) relate the atomic number of an element to its position in the Periodic Table

(b) make predictions relating to the physical or chemical properties of an element given its position in the Periodic Table and vice versa

(c) demonstrate an understanding of the term periodicity with reference to variation in melting point, boiling point, atomic radius and first ionization energy

(d) explain how the changes in melting point and enthalpy of fusion which take place across a period are related to structure

(e) interpret the types of structure and bonding shown by the elements from Li to Ar in terms of their positions in the Periodic Table

(f) explain, in structural terms, why the difference between melting point and boiling point is greater for metals than for non-metals

(g) interpret the methods used for preparation of the oxides, hydrides and chlorides of elements in the first and second periods in terms of their properties

19. *Chemistry of Carbon Compounds*

19.1 Candidates should be able to recall:

(a) the tetravalent nature of carbon and spatial distribution of bonds in aliphatic compounds. (No knowledge of alicyclic compounds will be expected)

(b) the conventions for representation of three dimensional structures of aliphatic and aromatic compounds, and rules for systematic nomenclature. (See IUPAC and ASE etc.)

(c) the structure of benzene and the reasons for its special properties.

19.2 Candidates should be able to:

(a) recognise and predict the existence of structural, geometric, functional group and optical isomerism.
(b) recognise chirality in a structural representation of a compound
(c) interpret the reactivities of hydrocarbons in terms of their structure and bonding, including mention of pi- bonds and delocalization.
(d) recognise functional groups which confer acidic or basic properties on an organic compound.

19.3 Candidates should be aware

(a) of the importance of organic compounds in pharmaceuticals, agricultural products, materials (plastics, fibres, adhesives and composites), and in the production of energy.
(b) of the importance of chirality in biological systems and that this may also be important in pharmaceutical compounds.
(c) of the hazards associated with many organic compounds: flammability, toxicity, non-biodegradability; and of the techniques available for minimizing them

20. *Organic Synthesis*

20.1 Candidates should be able to recall, in terms of reagents and general reaction conditions, the reactions of

(a) alkanes with chlorine and bromine
(b) alkenes with chlorine, bromine and hydrogen halides
(c) methyl benzene with nitration mixture and with potassium manganate(VII)
(d) primary, secondary and tertiary alcohols towards oxidizing agents (dichromate (VI) and manganate (VII)), dehydrating agents (including sulphuric acid), halide formation
(e) primary amines with hydrogen ions (including relative strengths of ammonia, alkyl amines and phenylamine), nitrous acid (including diazo-coupling reactions of phenylamine), acid chlorides
(f) halogenocompounds with hydroxide ions in aqueous and alcoholic solution, cyanide ions, ammonia
(g) nitrobenzene with reducing agents to give phenylamine
(h) carbonyl compounds towards 2,4–dinitrophenylhydrazine, hydrogen cyanide, oxidizing agents including the haloform reaction, sodium borohydride
(i) carboxylic acids with alcohols (together with hydrolysis of the product) lithium aluminium hydride, phosphorus pentachloride
(j) acid chlorides with water, and with ammonia
(k) nitriles towards hydrolysis and reducing agents

20.2 Candidates should be able to

(a) propose viable pathways to the synthesis of simple organic molecules and of polymers using the reactions above
(b) demonstrate familiarity with a range of practical techniques used in organic chemistry and to relate them to the above reactions

(c) propose suitable apparatus, conditions and safety precautions for realizing an organic process, given suitable data

21. *Organic Analysis*

Candidates should be able to:

(a) find empirical and molecular formulae from suitable data
(b) interpret physical and chemical data to arrive at the structural formula of a compound including the use of information relating to derivatives where appropriate
(c) interpret simple low resolution mass spectra and make use of given characteristic data to interpret infra red spectra

22. *Reaction Mechanisms*

22.1 Candidates should be able to recall the following reaction mechanisms:

(a) homolytic substitution (alkanes with chlorine and bromine)
(b) heterolytic electrophilic addition (alkenes with halogen and with hydrogen halides)
(c) heterolytic electrophilic substitution (nitration of methyl benzene)
(d) heterolytic nucleophilic substitution: SN1 and SN2 (halogenoalkanes with nucleophiles)
(e) heterolytic nucleophilic addition (carbonyl compounds with hydrogen cyanide)
(f) homolytic addition (polymerization of alkenes)

22.2 Candidates should be able to

(a) interpret simple allied reactions in terms of the above mechanisms

ADVANCED SUPPLEMENTARY LEVEL

Chemistry 082

This syllabus is available only to candidates entered by schools recognised as examination centres in their own right under Regulation 4.

Introduction

This syllabus has been designed to meet the needs of students requiring a two year course in Chemistry to the depth of Advanced level but less extensive in content. It is particularly intended for those studying related subjects at Advanced level, for those wishing to broaden their scientific training, and for those whose main interests lie in other areas but who wish to maintain their contact with science.
Although industrial and technological aspects are included as a separate section these topics should pervade the teaching of the subject and will be assessed as such whenever possible.
The syllabus is designed either to be free standing or as part of a teaching programme in which candidates are taught alongside those studying for Advanced level. It incorporates the agreed common core in chemistry at Advanced level of the General Certificate of Education published by the GCE Examining Boards of England and Wales 1983, with the exception of those topics listed in Appendix I to the syllabus.