GENERAL CERTIFICATE OF EDUCATION
SCHOOL CERTIFICATE
HIGHER SCHOOL CERTIFICATE

EXAMINATION SYLLABUSES FOR

1984

CHEMISTRY

UNIVERSITY OF CAMBRIDGE
LOCAL EXAMINATIONS SYNDICATE
INTERNATIONAL EXAMINATIONS

June 1982
Aims and Objectives

Aims
The aims of the syllabus are to:
1. encourage candidates to investigate the phenomena associated with chemistry, to master some of the relevant techniques involved and to understand the distinctive concepts and relationships used to explain chemistry;
2. present some of the models, theories and classification systems developed to explain and rationalise the phenomena observed;
3. illustrate the role of the chemist in seeking ways of converting natural raw materials into useful or desirable products;
4. show how the activities of chemists have social, industrial and economic consequences for the community.

It is hoped that the Ordinary level Chemistry course will promote the qualities summarised below.

Basic qualities
1. Knowledge of chemical facts and terminology.
2. Knowledge of physical and chemical principles.
3. Confidence in using scientific equipment properly and safely.
4. The ability to perform experiments.
5. The ability to observe and record.
6. The ability to formulate and perform relevant calculations.
7. The ability to organise ideas and facts and to present them clearly.

Higher qualities
1. The ability to devise good experiments and draw conclusions from them.
2. The ability to understand and interpret scientific information presented in verbal, mathematical, diagrammatic or graphical form and to translate such information from one to another.
3. The ability to formulate and test hypotheses.
4. The ability to interpret phenomena in terms of models, laws and principles.
5. The ability to solve problems both practical and theoretical which are unfamiliar or presented in a novel manner.
6. A critical approach to information and ideas.

It is also hoped that the course will cultivate the following attitudes:
1. objectivity and impartiality;
2. safety consciousness;
3. an awareness of science as a construct of the human mind and of the philosophical dependence of science on scientific method—observation (establishing facts or laws of experience); hypothesis and theory; testing hypotheses and predictions from theory; investigation by experiment; new facts.

The scope of practical examination is indicated in the Practical Chemistry syllabus printed at the end of the theory syllabus.

MATHEMATICAL NEEDS
It is assumed that candidates will be competent in the techniques described below. The list is intended as a guide but, in essence, no very significant change relative to previous policy is implied.
In the examination, questions will be set requiring factual knowledge of the syllabus, a sound understanding of the principles involved and the ability to apply these principles to problem situations in the laboratory and in everyday life whether domestic or industrial. In questions relating to topics not specifically mentioned in the syllabus, sufficient information will be given within such a question to enable the candidates to answer the question. (It should be appreciated, however, that the absence of a reference to a particular term, both well established and in common use at this level, does not necessarily preclude the use of such a term in a question paper.)

Candidates will be expected to be able to describe chemical reactions in terms of the colour, physical state (e.g. gaseous, liquid, solid or in aqueous solution) and other important conditions (e.g. room temperature or the use of heat). State symbols will be used where appropriate. They will also be expected to interpret experimental data, including quantitative results expressed graphically or otherwise.

Candidates will be expected to be aware of the hazards associated with chemicals, e.g. the corrosive nature of concentrated alkalis and acids, the poisonous nature of many substances and the combustibility of certain gases and volatile, especially organic, liquids. Questions will not be set on safety measures except insofar as they may affect the techniques in carrying out particular processes, e.g. the dilution of concentrated acids.

The form of the Periodic Table as given on page 16 together with other data will be printed on a foldout sheet at the front of both Papers 1, 2 and 6. In the practical papers the Periodic Table will be given instead of quoting individual relative atomic masses.

GENERAL PRINCIPLES

1. THE PARTICULATE NATURE OF MATTER

A simple kinetic—molecular picture as illustrated by the diffusion and dilution experiments. Dependence of rate of diffusion on molecular mass, treated quantitatively.

The concept of Brownian motion is not required.

2. EXPERIMENTAL TECHNIQUES

2.1 (a) Criteria of purity—melting and boiling point determination. Paper chromatography, including the idea that the technique is not limited to coloured substances. Knowledge of particular locating agents is not required.

(b) Methods of purification—use of suitable solvent, filtration, crystallisation, sublimation, distillation (including use of the fractional distillation of crude oil, liquid air, (ii) fermented

2.2 Preparative methods—examples to include solids, liquids and gases as specified in sections 8 and 10.

Standard methods of collecting gases based on density, solubility and chemical properties.

3. CLASSIFICATION OF MATTER ON THE BASIS OF ABILITY TO CONDUCT ELECTRICITY

Experiments leading to the classification of substances according to their ability to conduct electricity when solid, liquid or gaseous and, where appropriate, in aqueous solution.

4. ATOMS, ELEMENTS AND COMPOUNDS

4.1 Atomic structure and the Periodic Table

The relative charges and approximate relative masses of protons, neutrons and electrons. Atomic number and mass number. Atomic number and mass number. Atomic number and mass number.
7. CHEMICAL REACTIONS

7.1 Kinetics of reaction

Energy changes during chemical reactions to illustrate:
(i) the production and absorption of heat energy,
(ii) the production and absorption of light energy (e.g., flames, photosynthesis—simply and the hydrogen/chlorine reaction),
(iii) the production (from simple cells) and absorption (in electrolysis) of electrical energy. (This should be linked with the electrochemical series, section 10.1).

Candidates should appreciate that the formation of a bond between isolated atoms involves the release of energy (exothermic) while breaking of bonds requires an input of energy (endothermic).

Questions involving calculations will not be set.

7.2 Speed of reaction

The speed of a reaction at a given instant regarded as the slope of a graph showing the variation of extent of reaction with time.

Elementary treatment of the effects on speed of reaction of (a) temperature, (b) concentration, (c) surface area, (d) presence of catalyst (including reference to enzymes), (e) light, (f) type of bond.

These effects should be investigated experimentally making use of convenient examples such as (i) sodium thiosulphate with dilute acids, (ii) magnesium or granulated zinc with dilute acids, (iii) calcium carbonate (marble) chips with hydrochloric acid, (iv) decomposition of hydrogen peroxide catalysed by manganese(IV) oxide, (v) the oxyhydrolysis of starch.

A simple reference should be made to reversible reactions. A treatment of Le Chatelier’s principle is not required.

7.3 Redox reactions

Redox reactions in terms of oxygen/hydrogen gain/loss leading to the concept of electron transfer and changes of oxidation state. Use of oxidation states limited to inorganic compounds and ions mentioned elsewhere in the syllabus, S(O)2 being excluded.

Equations for reactions involving KMnO₄ and K₂Cr₂O₇ are not expected.

8. ACIDS, BASES AND SALTS

8.1 The meaning of the terms acid, base and alkali in terms of the ions they contain or produce in aqueous solution. The properties of acids in aqueous solution contrasted with the properties of hydrogen chloride dissolved in methylene blue.

The effect of acids on indicators, metals and carbonates. The pH scale as a practical measure of relative acidity and alkalinity (definition not required) hence the idea of strong and weak acids.

Refer to (i) the occurrence of and importance of energy sources, e.g., fossil fuels and nuclear fuels, (ii) the use of batteries as convenient, portable energy sources. The use of silver salts in photography, limited to the idea of reduction to silver.

Refer to pressure cookers and the danger of explosive combustion in flour mills (fine powder) and in mines (combustible gases and coal dust).

Refer to cooking methods and the control of acidity in soil.

The relative solubilities of the oxides and hydroxides of metals (see section 10.1). Preparation of insoluble hydroxides by precipitation. Amphoteric hydroxides.

8.3 Salts as ionic compounds. The formation of salts by the action of acids on metals, oxides, hydroxides and carbonates. Normal and acid salts, basicity of acids. The relative solubilities of the salts of metals, (see section 10.1). Laboratory methods of preparing salts (see section 10.1): (a) soluble salts by action of acid on (i) a metal, (ii) an oxide, insoluble hydroxide or insoluble carbonate, (iii) a soluble hydroxide or carbonate, (b) insoluble salts by precipitation, (c) direct combination.

Methods of obtaining good crystals. Water of crystallisation and the loss of water when hydrated salts are heated. The idea of deliquescence, hygroscopy and efflorescence (formal definitions not required), illustrated by calcium chloride, concentrated sulphuric acid and sodium carbonate.

Questions on tests for the actions, cations and gases quoted in the Practical syllabus may be set in the Theory papers.

DESCRIPTIVE CHEMISTRY

9. THE PERIODIC TABLE: TRENDS IN GROUPS AND PERIODS

9.1 The relationships between group number, oxidation states and metallic/non-metallic character. This should be illustrated by reference to the period sodium to argon (the elements and their oxides, where appropriate) in terms of characteristic properties and reactions specified elsewhere in the syllabus.

9.2 Group properties illustrated by (a) lithium, sodium, and potassium—their physical properties, the reaction of the metal with water, the solubility of the hydroxide in water to give an alkaline solution. (b) chlorine, bromine and iodine—their physical properties, reaction of the element with other halide ions, sulphides and iron(II) compounds, reaction of halide ions with aqueous silver nitrate, the formation of gasous, acidic hydrides. These two groups also illustrate the extremes of the variation across a period, with special reference to the two short periods.

9.3 Transition metals as a collection of elements having high densities, high melting points and coloured compounds (in contrast to group 1). These elements and their compounds often acting as catalysts. The properties of iron and its compounds detailed under section 10.1 as being typical of a transition metal.
10. CHARACTERISATION OF ELEMENTS AS METALS AND NON-METALS

10.1 Metals: the reactivity (electrochemical) series.

The placing of aluminium, calcium, copper, iron, lead, magnesium, potassium, sodium and zinc in order of reactivity in terms of the reactions, if any, of (a) these elements with (i) air (considered as diluted oxygen), (ii) water or steam, (iii) dilute, 'non-oxidising' acids with special reference to hydrochloric acid and sulphuric acid, (iv) the aqueous ions of the other listed metals, (b) the oxides of these elements with (i) carbon, (ii) carbon monoxide, (iii) hydrogen.

Knowledge of the higher oxides of sodium and potassium and of metallic nitrates is not expected.

The electrochemical series related to the tendency of a metal to form its positive ion. The action of aqueous sodium hydroxide on aqueous solutions containing the ions Al<sup>3+</sup>, Ca<sup>2+</sup>, Cu<sup>2+</sup>, Fe<sup>3+</sup>, Fe<sup>2+</sup>, Pb<sup>2+</sup>, Zn<sup>2+</sup> (see also section 10.2(b)). Action of heat on the hydroxides, carbonates and nitrates of the listed metals related to the reactivity series.

10.2 Non-metals

Contrasted with metals in relation to the tendency to form negative ions and to form both ionic and covalent compounds.

(a) Hydrogen

Released as a reduction product by the action of reactive metals on water, steam and dilute acids. The formation of water by the burning of hydrogen. Its reducing properties with the oxides of less reactive metals. (See section 10.1(b)).

(b) Oxygen

Released in the decomposition of hydrogen peroxide and as a product of photosynthesis.

The burning of elements in air and in oxygen. The formation of rust requiring both oxygen and water. The percentage by volume of oxygen in the air by any one method giving 1% accuracy (e.g., a syringe method using hot copper). The composition of the air. The variability of the composition of the air with special reference to water and carbon dioxide due to industrial and natural processes.

(c) Nitrogen

The essential conditions of the Haber reaction. The displacement of ammonia from its salts. The reactions of ammonia (i) as a reducing agent with oxygen and with copper(II) oxide, (ii) as a base with hydrogen chloride and aqueous acids, (iii) as a base and/or complexing reagent with aqueous solutions containing Al<sup>3+</sup>, Ca<sup>2+</sup>, Cu<sup>2+</sup>, Fe<sup>2+</sup>, Fe<sup>3+</sup>, Pb<sup>2+</sup>, Zn<sup>2+</sup> (formulae of Outlines of the manufacture of sodium (from NaCl), aluminium (from Al<sub>2</sub>O<sub>3</sub>), iron (from haematite) and zinc (from ZnS) in terms of the choice of reducing method.

Simple treatment of the changes in the properties of steel by the controlled use of additives. Important uses of aluminium, zinc, iron and copper.

Use of hydrogen

The separation of oxygen and nitrogen from liquid air by fractional distillation. Refer to common pollutants of the air and their adverse effect on buildings and health.

Methods of rust prevention.

The important uses of ammonia, ammonium salts, nitric acid and nitrates. The importance of nitrogenous fertilisers.

(f) Carbon

The role of carbon in the manufacture of iron. Carbon monoxide—a product of incomplete combustion, a product of reaction between steam and carbon, its reducing properties. A simple explanation of its toxicity and risks associated with its formation.

Carbon dioxide—a product of respiration and of the action of heat and dilute acids on carbonates. Its reactions with alkalis to form carbonates and hydrogen carbonates. The action of heat on, and the relative
CHEMISTRY (O)

11. ORGANIC CHEMISTRY

11.1 The importance of chain formation by carbon.

The structure and names of the unbranched alkanes, alkenes, primary alcohols and acids containing up to five carbon atoms per molecule. The structures, not names, of the alkenes and alkanes (not cis—trans) containing four and five carbon atoms per molecule.

Questions on isomerism of alcohols and acids will not be set.

11.2 Natural gas and petroleum. Distillation of crude oil. The general characteristics of a homologous series. The reactions to be treated should include:

(i) for alkanes—burning and substitution by chlorine and bromine,
(ii) for alkenes—buring and addition with hydrogen, chlorine and bromine and the addition reaction of ethene with steam,
(iii) for alcohols—buring, reaction with sodium, dehydration to give alkenes and oxidation to give acids.
(iv) for acids—reactions with metals, oxides, hydroxides and carbonates and ester formation.

11.3 Macromolecules

To be considered simply as large molecules built up from small units, different macromolecules having different units and/or different linkages.

(a) Synthetic Polymers

The formation of (i) poly(ethylene) by addition polymerisation of monomer units, (ii) nylon (a polyamide) and Terylene (a polyester) by condensation polymerisation. The structure of nylon represented as

![Nylon structure](image)

and the structure of Terylene as

![Terylene structure](image)

Details of manufacture and mechanisms of these polymerisations are not required.

(b) Natural Macromolecules

Proteins as possessing the same linkages as nylon but with different units. Their hydrolysis to aminosids (structures and names not required).

Fats as possessing the same linkages as Refer to their hydrolysis to soap.

Terylene but with different units.

CHEMISTRY (O)

Topic

Solubilities of carbonates and hydrogen carbonates of calcium and sodium. Method of softening water are not required.

Applications

Refer to the occurrence and simple consequence of hydrogen carbonates in water supplies. A simple reference to the advantages and disadvantages of synthetic detergents relative to soap.

PRACTICAL CHEMISTRY

A major aim of the practical examination is to test the extent to which a candidate's knowledge is firmly grounded in experiment.

N.B. Candidates will be allowed to refer to notes books and text books in the practical examination.

Within the limitations imposed by cost, availability of apparatus in school laboratories, restriction to simple techniques, time and (most important) safety, the examination is designed to evaluate the ability of the candidate in the following skills:

(i) ability to make accurate quantitative measurements (in terms of the available apparatus) and use the results in relevant calculations;
(ii) ability to make and interpret accurate observations of a qualitative nature;
(iii) ability to make precise and concise records of all observations and conclusions.

To achieve these aims, candidates may be asked to carry out simple exercises involving:

(a) volumetric analysis; if titrations other than acid/alkali titrations are set, full instructions and other necessary information will be given;

Candies may be asked to carry out simple quantitative experiments such as determining the concentrations of solutions, or finding the mole ratio in which substances react together. Concentrations will be given in moles/dm³ or in g/dm³. Candidates will not be asked to prepare their own standard solutions.

(b) speeds of reaction;

(c) measurement of temperature based on a thermometer with 1°C graduations;

(d) problems of an investigatory nature using one or more of the above or other simple techniques;

(e) tests for oxidising agents in solution using potassium iodide and iron(ll) salts and for reducing agents using potassium manganate(VII), potassium dichromate(VI) and aqueous bromine;

(f) identification of:

hydrogen, carbon dioxide, ammonia, oxygen, sulphur dioxide, hydrogen chlorides, water vapour, nitrogen dioxide, chlorine;

carbonate, nitrate, sulphate, sulphite, chloride, bromide, iodide (wet tests only for the last three ions);

lead, aluminium, calcium, iron(ll), iron(III), copper, zinc and ammonium ions.

Apparatus requirements will be kept simple but candidates will be expected to be familiar with chromatography using ordinary filter paper, and the use of suitable organic compounds in qualitative experiments is not excluded.

Candidates will not be required to carry out weighing for the Practical examination.
<table>
<thead>
<tr>
<th>Group</th>
<th>I</th>
<th>II</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>H</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>13</td>
</tr>
<tr>
<td>5</td>
<td>14</td>
<td>15</td>
</tr>
<tr>
<td>6</td>
<td>16</td>
<td>17</td>
</tr>
<tr>
<td>7</td>
<td>18</td>
<td>19</td>
</tr>
<tr>
<td>8</td>
<td>20</td>
<td>21</td>
</tr>
<tr>
<td>9</td>
<td>22</td>
<td>23</td>
</tr>
<tr>
<td>10</td>
<td>24</td>
<td>25</td>
</tr>
<tr>
<td>11</td>
<td>26</td>
<td>27</td>
</tr>
<tr>
<td>12</td>
<td>28</td>
<td>29</td>
</tr>
<tr>
<td>13</td>
<td>30</td>
<td>31</td>
</tr>
<tr>
<td>14</td>
<td>32</td>
<td>33</td>
</tr>
<tr>
<td>15</td>
<td>34</td>
<td>35</td>
</tr>
<tr>
<td>16</td>
<td>36</td>
<td>37</td>
</tr>
<tr>
<td>17</td>
<td>38</td>
<td>39</td>
</tr>
<tr>
<td>18</td>
<td>40</td>
<td>41</td>
</tr>
<tr>
<td>19</td>
<td>42</td>
<td>43</td>
</tr>
<tr>
<td>20</td>
<td>44</td>
<td>45</td>
</tr>
<tr>
<td>21</td>
<td>46</td>
<td>47</td>
</tr>
<tr>
<td>22</td>
<td>48</td>
<td>49</td>
</tr>
<tr>
<td>23</td>
<td>50</td>
<td>51</td>
</tr>
<tr>
<td>24</td>
<td>52</td>
<td>53</td>
</tr>
<tr>
<td>25</td>
<td>54</td>
<td>55</td>
</tr>
<tr>
<td>26</td>
<td>56</td>
<td>57</td>
</tr>
<tr>
<td>27</td>
<td>58</td>
<td>59</td>
</tr>
<tr>
<td>28</td>
<td>60</td>
<td>61</td>
</tr>
<tr>
<td>29</td>
<td>62</td>
<td>63</td>
</tr>
<tr>
<td>30</td>
<td>64</td>
<td>65</td>
</tr>
<tr>
<td>31</td>
<td>66</td>
<td>67</td>
</tr>
<tr>
<td>32</td>
<td>68</td>
<td>69</td>
</tr>
<tr>
<td>33</td>
<td>70</td>
<td>71</td>
</tr>
<tr>
<td>34</td>
<td>72</td>
<td>73</td>
</tr>
<tr>
<td>35</td>
<td>74</td>
<td>75</td>
</tr>
<tr>
<td>36</td>
<td>76</td>
<td>77</td>
</tr>
<tr>
<td>37</td>
<td>78</td>
<td>79</td>
</tr>
<tr>
<td>38</td>
<td>80</td>
<td>81</td>
</tr>
<tr>
<td>39</td>
<td>82</td>
<td>83</td>
</tr>
<tr>
<td>40</td>
<td>84</td>
<td>85</td>
</tr>
<tr>
<td>41</td>
<td>86</td>
<td>87</td>
</tr>
<tr>
<td>42</td>
<td>88</td>
<td>89</td>
</tr>
</tbody>
</table>

In each box:
- a = relative atomic mass
- X = atomic symbol
- b = atomic number