A Level

Chemistry

Session: 1974
Type: Syllabus
Code: 866

CHEMISTRY* (866)

(May not be taken with Physical Science.)

INTRODUCTION

In studying Chemistry, it needs to be emphasized that man's interest in the subject is essentially a practical one; to use or convert materials for his own purpose and to discover the most efficient methods of doing so. This function of the subject is then complementary to the logic of scientific method; i.e. observation (establishing facts or laws of experience); theory; prediction; experiment; new facts.

As understanding of the subject grows, it becomes possible to renew study of problems that were formerly not amenable. This is especially relevant in modern times since the advent of more advanced techniques means that more and more phenomena can be studied experimentally. It is of vital interest, therefore, that, at Advanced Level, candidates should be taken as close as reasonably possible to the boundaries of a scientific subject. This is not merely to aid potential graduates but to try to give some relevant understanding of a science to a greater number of people, especially in an age when the pace of research means that new ideas can have important social consequences within a life-time or even a decade.

The understanding of Chemistry must depend on knowing a sufficient but minimal number of facts and their relation to the fundamental principles derived from them, with due emphasis on modern concepts. The present syllabus is an attempt to realize this idea, with the underlying theme that Chemistry is a study of the ways in which energy is associated with mass, chemical structure and chemical reaction. This should help to establish the subject as a quantitative science.

At Ordinary Level, a student should have a good grounding of elementary facts and principles, and it is intended that the Advanced Level syllabus should build on this foundation by introducing such facts or ideas as will develop the student's elementary knowledge towards fuller understanding of modern Chemistry. The Advanced Level syllabus is, therefore, firmly based on Atomic Theory. Since, also, it is the purpose of scientific theory to try to relate and make coherent apparently diverse phenomena, it is intended that the topics of physical chemistry should be fully illustrated by particular examples so as to

* Formerly known as Syllabus T.

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emphasize both the characteristic features of the chemistry of the elements and their compounds and the importance of the principles involved.

In Organic Chemistry, in particular, the use of molecular models is to be encouraged. However, candidates should be taught to realize that such models, in common with other methods of (pictorial) representation, have limitations and are usually not intended to illustrate more than a few aspects of the whole.

The scope of the practical examination is indicated in the Practical Chemistry syllabus printed at the end of the theory syllabus but, as a further emphasis of the practical aspect of the subject, it is intended that, in topics where candidates cannot be expected to obtain their own data, that of original papers may be quoted for candidates to use as the question may demand.

The syllabus as set out applies to both Advanced and Special Level papers for the G.C.E. and it should also be taken to include the syllabus for the subject at Ordinary Level (see 'Subject Syllabus S'). Although there are no topics that are specifically included for the Special paper only, there are a few topics in the syllabus for which indication is given in the notes that particular aspects are considered as being a deeper treatment for this paper and it is expected in this paper that greater evidence of a real grasp of the subject will be shown by the candidate. In general, the mathematics involved in the Advanced Level syllabus is not intended to be much more than that of Ordinary Level Mathematics but, for the Special paper, the deeper treatment should include all necessary mathematics.

ARRANGEMENT OF PAPERS

At Advanced Level there will be two $2\frac{1}{2}$-hour theory papers (Paper 1 and Paper 2) and a $3\frac{1}{4}$-hour Practical Test. The Practical Test will carry one quarter of the total marks for the subject.

Paper 1 will consist of two parts, the questions in each part being based on the whole syllabus. Part I (45 marks) will contain several short questions to be answered on the question paper and Part II (54 marks) will contain longer questions. Candidates will be required to answer all the questions in Part I and six questions in Part II.

Paper 2 will contain ten questions arranged in three sections. Section A will consist of four questions based mainly on the Physical Chemistry sections of the syllabus and two of these questions will be non-mathematical. Sections B and C will each consist of three questions based mainly on the Inorganic and Organic sections of the syllabus respectively. Candidates will be required to answer five questions, including one question from each of the Sections A, B and C.

The questions in the Practical Test will include:

(i) a volumetric analysis problem, based on one set of titrations;

(ii) a simple problem (see Practical syllabus, p 42); this problem may be combined with (i);

(iii) an observational problem, in which the candidate will be asked to investigate by specified experiments an unknown substance or mixture. Systematic analysis will not be required.

Semi-micro methods will be accepted where appropriate. An apparatus list of items which the examiners will assume to be available is printed on p. 43.

The Special Paper will be a $2\frac{1}{2}$-hour paper containing harder questions arranged in three sections. Section A will contain three questions on Physical Chemistry, Section B will contain three questions on Inorganic Chemistry and Section C will contain three questions on Organic Chemistry. Candidates will be required to answer five questions including one question in each of Sections A, B and C.

The Stock system of using Roman numerals to indicate the oxidation states of elements (particularly metals) of variable valency is used where appropriate. Exceptions to this rule will include well-established trivial names such as ammonia and names such as trilead tetroxide (Pb_3O_4) and disulphur dichloride (S_2Cl_2). The names ethanol and methyl cyanide are used exclusively in question papers without quoting the alternative names ethyl alcohol and aceto-nitrile.*

* Consideration is being given to the general adoption of systematic names for both inorganic and organic compounds.

DETAILS OF SYLLABUS

I. ATOMS AND MOLECULES

1. The concept of atoms having fixed properties in explaining the laws of chemical combination.

1·1. Relative atomic and isotopic masses (atomic and isotopic weights), and a simple, non-mathematical treatment of their derivation by mass-spectrometry.

> Questions will not be set on the experimental determination of chemical equivalents and relative atomic masses by classical methods.
>
> $^{12}C = 12$ should be taken as standard and the reasons for the disuse of $H = 1$ and $O = 16$ as standards should be appreciated.

1·2. The determination of relative molecular masses (molecular weights).

> A qualitative explanation of the fact that relative molecular masses as determined do not always correspond to formula masses is required. Calculations involving such anomalies are, however, regarded as being a deeper treatment.

(a) For gases and/or volatile liquids, by methods involving gas densities.

    (i) Direct weighing.

    (ii) Victor Meyer.

(b) For solutes.

    (i) Depression of freezing point.

> Candidates will be required to know only the details of one particular technique for each of the three methods quoted in Sections 1·2 (a) and (b): knowledge of a method for the elevation of boiling point is regarded as being a deeper treatment.

    (ii) Osmotic pressure.

> Only the principles of the method are required, but not the details of the accurate determination of osmotic pressure.

1·3. The calculation of empirical and molecular formulae, using composition by mass.

2. Atomic structure.

2·1. Electrons, protons and neutrons as the fundamental particles of major importance in chemistry; their charges and relative masses.

2·2. The nucleus of the atom.

(a) Isotopes and mass number.

(b) Stable and unstable isotopes; radioactivity.

    (i) The detection of α- and β-particles, γ-rays.

    (ii) The nature of α- and β-particles.

> Evidence from experiments with photographic emulsions and cloud-chambers and from the differences in penetrating ability should be mentioned but a treatment of the detailed physical evidence establishing the nature of α- and β-particles and γ-rays is not intended.

    (iii) Half-life, treated qualitatively, as a measure of the relative stability of the nucleus.

> See also the note to Section 9(a).

    (iv) The group displacement law as illustrated by the natural decay of ^{235}U.

> See also Section 15(a).

2·3. The electronic structure of the atom.

(a) The concept of electronic energy levels, treated qualitatively and illustrated by characteristic line spectra of elements.

> The introduction of principal quantum numbers, n, (illustrated by using the Lyman series, $1/\lambda = R(1/1^2 - 1/n^2)$, for hydrogen) is regarded as being a deeper treatment except that the relation between the convergence limit of the Lyman series and the ionization energy of hydrogen should be appreciated.

(b) Atomic orbitals.

    (i) The number and relative energies of the s, p and d orbitals for the principal quantum numbers 1, 2 and 3.

    (ii) The shape and symmetry of s and p orbitals.

    (iii) Hybridized orbitals as alternative orbitals, especially for tetrahedral carbon.

> The qualitative model of repulsion between electron pairs should be introduced to describe the shapes of simple molecules with not more than four electron pairs around a central atom. A simple, non-mathematical treatment of tetrahedral cabon is required.
>
> Consideration of sp^2 and sp hybridization for the carbon atom is regarded as being a deeper treatment.

3. The Periodic Table.

See also Sections 4 and 14.

(a) Atomic number as the basis of classification of the elements in the Periodic Table.

Questions will not be set on the historical development of the Periodic Table.

(b) Extranuclear structure as the basis of periodicity.

(i) The filling of orbitals according to their energy and the pairing of electrons.

(ii) The periodicity of electronic structure leading to the periodicity of chemical properties.

4. Chemical bonding.

An appreciation of the dependence of the properties of solids, liquids, and gases on formula mass and also on the types of chemical bonding involved is expected. See also Sections 3 and 14.

(a) Electrovalent bonds between ions.

(b) Covalent bonds; the pairing of electrons and the overlapping of orbitals.

See Section 2·3 (b).

(c) Co-ordinate and hydrogen bonds.

The relation of these two types of bond to covalency and the influence of hydrogen bonding on physical properties should be appreciated.

(d) Metallic and Van der Waals bonds.

A simple treatment only of the importance of these types of bond is required.

II. STATES OF MATTER: STRUCTURE AND PROPERTIES

5. Gases, liquids, solids.

5·1. The gas laws, kinetic theory.

The use of $pv = \frac{1}{3}Nm\overline{c^2}$ is regarded as a deeper treatment: the derivation of the equation is not required.

(a) Boyle's law; $pv = nRT$; Dalton's law; the Avogadro constant; the mole.

See also the note to Section 8·3 (a).

(b) Graham's law, illustrated experimentally.

Syringe methods are acceptable.

(c) Deviations from ideality; their qualitative explanation.

Questions will not be set on Van der Waals' equation.

5·2. Liquids.

No study of the liquid phase is required beyond appreciation of the fact that in a liquid individual molecules have an environment similar to that in a solid, but have freedom of motion.

5·3. Solids.

(a) Lattice structure and spacing.

Generally, only the qualitative idea that the particles are situated at fixed points in a regular pattern is expected but, for the three examples quoted below, a knowledge of the geometry (but not dimensions) of the actual lattice is required. It should, however, be appreciated that the individual particles may be atoms, molecules or ions. The facts that random translation is totally inhibited but that vibration and sometimes rotation about a lattice point is possible should be appreciated.

(i) NaCl, Cu as simple examples of cubic lattices.
See Section 4.

(ii) Graphite as a simple example of a layer lattice.
See Sections 4 and 18 (c).

(b) Lattice energy; its comparison with latent heat of fusion.

Only a qualitative appreciation that energy is required to break up the structure of a lattice is expected. This should be related to the fact that the solubility of solids usually increases with temperature; see also Section 7·3.

Reference should be made to the qualitative differences in the force of attraction between the particles in different types of lattice.

6. Phase equilibria for single component systems.

The phase rule is not required.

6·1. Vapour pressure diagrams, illustrated by water.

(a) As graphical plots of experimental determinations.

(b) As curves describing the conditions of equilibrium between phases; the qualitative relationship between boiling point, latent heat of evaporation and intermolecular forces.

(c) As regions representing single phases.

6·2. Allotropy, as in sulphur, phosphorus, carbon.

> The occurrence of allotropy and polymorphism arising from differences in lattice structure and the effect of these differences on physical and chemical properties should be appreciated.

7. Phase equilibria for multi-component systems.

7·1. Solubility of gases in liquids; Henry's law; deviations therefrom treated qualitatively.

> Methods of measurement of solubility are not required.

7·2. Mixtures of two liquids.

(a) Miscible liquids: Raoult's law applied to the vapour pressures of miscible liquids; boiling point/composition curves; azeotropic mixtures; fractional distillation.

(b) Immiscible liquids: vapour pressures of immiscible liquids; steam distillation.

7·3. Solubility of solids in liquids.

> The qualitative influence on solubility of the relationship between heat of solution, lattice energy of the solid, hydration or other solvent/solute interaction.

7·4. Simple eutectic diagrams, illustrated by Sn/Pb or Zn/Cd, KCl/H_2O, o-nitrophenol/p-toluidine.

7·5. Distribution of a solute between two solvents.

(a) Partition coefficient: ether extraction.

> It should be appreciated that the partition law only applies when the solute is in the same molecular state in the two solutions. The quantitative effect of association of the solute is regarded as being a deeper treatment.

(b) Chromatography: a qualitative treatment only but with an indication of its use as an analytic tool.

7·6. Colloidal solutions.

(a) The preparation and properties of colloids, both hydrophobic (illustrated by S or As_2S_3) and hydrophilic (illustrated by starch or gelatin).

> No treatment of gold number is required.

(i) Electrophoresis as evidence that colloidal particles are charged.

> The importance of large surface area and adsorption should also be appreciated.

(ii) Stability and precipitation of hydrophobic colloids; Hardy-Schulze law.

8. Electrical properties of solutions.

8·1. Conductivity of electrolytes; equivalent or molar conductivity; equivalent or molar conductivity at infinite dilution.

> Details of the measurement of conductivity are regarded as being a deeper treatment.

(a) Strong electrolytes; equivalent or molar conductivity and the qualitative effect of ionic atmosphere; independent migration of ions.

> No treatment of transport numbers is required.

(b) Weak electrolytes: degree of dissociation.

> Problems and extended calculations involving manipulation of standard formulae will not be set at Advanced Level but simple calculations involving direct substitution into a standard formula may be set. See also Section 1·2.

8·2. Applications of ionic theory.

(a) Solubility product and the common ion effect.

(b) Ostwald's dilution law; ionic product of water.

(c) pH.

(i) pH indicators: choice of indicators.

(ii) Buffer solutions.

> Problems and extended calculations involving manipulation of standard formulae will not be set at Advanced Level but simple calculations involving direct substitution into a standard formula may be set. See also Sections 1·2 and 10 (a).
> Ionic equations should be used, where suitable; see Sections 12, 13 and 14.

8·3. Electrode processes.

> See Section 13, note (i).

(a) Electrolysis; Faraday's laws of electrolysis.

> The relationship between the Faraday and the Avogadro constants and the charge on the electron, $F = Le$, should be given though details of Millikan's experiment are not required.

(b) Electrode potentials.

> See also section 3 (b). The I.U.P.A.C. convention will be used.

(i) Standard electrode and redox potentials.

> Only the principles of their measurement are required.

(ii) The electrochemical and redox series.

(iii) Electric cell potentials as the combination of two standard electrode potentials, illustrated by the Daniell cell.

III. REACTION KINETICS, CHEMICAL EQUILIBRIA AND THERMOCHEMISTRY

9. Chemical kinetics.

(a) Simple rate equations and the law of Mass Action; definition of order of reaction; velocity constants.

> Rate = $k[A]^n [B]^m$. It should be appreciated that the quoted rate equation only applies to single stage reactions and that many reactions proceed by successive simple reactions.
>
> The integrating of first- and second-order rate equations is regarded as being a deeper treatment but use of the integrated forms is expected.

(b) The qualitative effect of temperature on velocity constants; concept of an energy barrier.

(c) Reversible reactions; dynamic equilibrium.

> See Section 10 (b).

(d) Catalysis.

> It should be appreciated that the presence of the catalyst allows a different mechanism to operate, i.e. a different (usually lower) energy barrier is involved.

10. Chemical equilibria.

> Emphasis should be placed on the distinction between the composition of an equilibrium mixture and the rate at which equilibrium is attained.

(a) Equilibrium constants, in terms of partial pressures, and concentrations.

> The following examples are useful: (i) the hydrogen iodide equilibrium. (ii) the dissociation of dinitrogen tetroxide, (iii) the hydrolysis of simple esters, (iv) the hydrolysis of salts, (v) the contact process for the manufacture of sulphuric acid, (vi) the synthesis of ammonia.
> Reference should also be made to solubility product, Ostwald's dilution law, the ionic product of water (see Section 8·2) in terms of equilibria and equilibrium constants.

(b) Le Chatelier's principle: the qualitative effect of temperature on equilibrium constants.

> It should be emphasized that a change in the value of an equilibrium constant with temperature demands a corresponding change in the composition of the equilibrium mixture.

11. Thermochemistry and Chemical Energetics.

(a) Heats of formation, combustion, solution, neutralization, atomization and reaction; Hess' law.

> Calculations based on the difference between the heats of reaction at constant volume (ΔU) and constant pressure (ΔH) for gases are regarded as being a deeper treatment. The acquisitive convention should be used, e.g. ΔH is negative for an exothermic reaction.

(b) Ionization, latent heats, lattice energy, energy barriers.

> Candidates will be expected to appreciate that all chemical reactions involve energy transfer and to appreciate, therefore, the importance of energy considerations, e.g. the wide application of Hess' law. The above items, which all appear elsewhere in the syllabus, are quoted here for ease of reference. Bond dissociation energy is regarded as being a deeper treatment.

IV. INORGANIC CHEMISTRY

12. Detailed study of the following non-metals and their compounds: hydrogen, nitrogen, oxygen, sulphur, chlorine.

> Particular reference should be made to oxidation states, electronic structure and general chemical properties of the elements, their hydrides and oxides. Knowledge of the preparation of the elements (for nitrogen, NH_3 and N_2H_4 only), the major oxides NO, NO_2, SO_2 and SO_3, and the major oxo-acids HNO_3 and H_2SO_4, will be expected. Characteristic properties, including outline preparation of the sodium or potassium salt, of other important oxo-acids, i.e. HNO_2, H_2SO_3, $H_2S_2O_3$, HClO, $HClO_3$ and $HClO_4$, are also included.

13. Detailed study of the following metals and their familiar compounds, illustrating where appropriate the characteristic features of the chemistry of transition elements: aluminium; iron; copper; zinc; lead; manganese or chromium.

> The particular study of these metals should include: (i) the principles of the extraction of the metal. e.g. by electrolysis (Al), by the 'Thermite' process (Mn), by reduction with carbon (Fe), by the roasting of sulphide ores (Cu, Zn, Pb) [see Section 8·3]; (ii) the oxides and oxidation states of the metals; (iii) complex formation, with one example. where appropriate. of both the anionic and cationic complexes of the metals, e.g. $Cu(NH_3)_4^{2+}$, $Cu(H_2O)_4^{2+}$, $CuCl_4^{2-}$, $Zn(NH_3)_4^{2+}$, ZnO_2^{2-}, $PbCl_4^{2-}$, AlO_2^-, AlH_4^-, AlF_6^{3-}. $Fe(CN)_6^{4-}$, $Fe(CN)_6^{3-}$. The study of the hexacyanoferrates and permanganates should be particularly related to their uses in analysis.

14. A simple, comparative study of the variation of physical and chemical properties of the elements within a period and a group, illustrated by reference to

(i) the period: Na, Mg, Al, Si, P, S, Cl, Ar;

(ii) Groups II, V and VII (see Periodic Table as printed on p. 44).

> The study should include reference to: ion formation and the relative ease of ionization; the reaction, where appropriate, of the element with water, sodium hydroxide, hydrochloric acid and the oxidizing acids; the volatility of, and the action of water on, the oxides, chlorides and hydrides. A simple explanation of these differences in terms of electronic structure, atomic radius and type of bonding is included.

15. Nuclear chemistry.

(a) The characteristics of nuclear reactions, illustrated by a typical example of the first stage only of the fission of ^{235}U.

> An appreciation of the possibility of a chain reaction is also expected. Nuclear equations should be balanced with respect to mass number and atomic number.

(b) The production and uses of radio-isotopes such as ^{14}C or ^{32}P.

> The reasons for the use of high-energy particles in bombarding nuclei should be mentioned but no treatment of the machines producing these particles is required.

V. ORGANIC CHEMISTRY

16. (a) Homologous series: isomerism.

> Optical isomerism, e.g. in lactic acid, and geometrical isomerism are regarded as being a deeper treatment.

17. (a) Practical details for carrying out in the laboratory the following reactions, including purification of the products:

(i) dehydration of an alcohol, e.g. ethylene and di-ethyl ether from ethanol;

(ii) addition to olefine, e.g. 1,2-dibromoethane;

(iii) replacement of —OH by —halogen, e.g. bromoethane;

(iv) oxidation of a primary alcohol to aldehyde and acid, e.g. acetaldehyde and acetic acid;

> The purification of acetaldehyde is not required.

(v) esterification, e.g. ethyl acetate;

(vi) preparation of an aromatic acid, e.g. benzoic acid from toluene;

(vii) nitration, e.g. nitrobenzene;

(viii) reduction of nitro-compound, e.g. aniline.

> Choice of examples to illustrate (i) to (viii) above need not be restricted to those quoted.

(b) A study of different types of reaction as illustrated by the following classes of compound:

(i) hydrocarbons, e.g. ethane, toluene;

> The ring structure for benzene may be assumed but the fact that the carbon-carbon bonds in this molecule are all equal in length and in strength, and are intermediate between C—C and C=C, should be mentioned.

(ii) olefines, C=C, e.g. ethylene, and acetylenes, C≡C, e.g. acetylene;

(iii) halogen derivatives of hydrocarbons, C—Hal, e.g. bromoethane, chlorobenzene, 1,2-dibromoethane;

(iv) hydroxy compounds, C—OH, e.g. ethanol, phenol;

(v) aldehydes and ketones, CHO and C=O, e.g. acetaldehyde, benzaldehyde, acetone;

(vi) carboxyl compounds, COOH, e.g. acetic acid, benzoic acid, oxalic acid;

(vii) esters, COOR, e.g. ethyl acetate;

(viii) ethers, C—O—C, e.g. di-ethyl ether;

(ix) nitro-compounds, C—NO$_2$, e.g. nitrobenzene;

(x) amines and amides, e.g. aniline, acetamide.

> Where appropriate, organic compounds should be used as examples in other sections of the syllabus but in this section the study of the properties of a particular compound should be related both to the presence of the functional group involved and to the general aliphatic or aromatic nature of the compound. However, disubstitution and the orientating influence of substituents in aromatic systems and the reactions of molecules containing more than one functional group are generally regarded as being a deeper treatment. The reactions of diazonium salts are also regarded as being a deeper treatment.
> Study of the condensation and polymerization reactions of benzaldehyde may be restricted to the aldol condensation with acetaldehyde and the benzoin reaction.

18. (a) The principles of addition and condensation polymerization.

> Candidates will be expected to illustrate their answers by reference to not more than two well-known materials, e.g. polyethylene, polymethylmethacrylate (Perspex), nylon, polyvinyl chloride and a polyester (Terylene). Brief reference should also be made to the naturally occurring polymers rubber, polysaccharides (illustrated by cellulose) and proteins in terms of (i) their molecular structures (ii) the biological importance of cellulose and proteins. Technical details are not required.

(b) The effect of chain length and cross-linking on physical properties.

> Specific examples of cross-linked polymers should only be included in a deeper treatment.

(c) Bond length and bond strength.

> The relationship between bond length and bond strength should be further illustrated by reference to diamond and graphite.

PRACTICAL SYLLABUS

19. Questions on the techniques and principles involved in the practical syllabus may be set in the theory papers.

20. A knowledge of the following volumetric determinations will be required: acids and alkalis, using suitable indicators; iron(II) and iron(III) by potassium permanganate; oxalic acid (and oxalates) and hydrogen peroxide by potassium permanganate. Simple titrations involving potassium dichromate, iodine and sodium thiosulphate may also be set, but if problems are set involving any other reactions sufficient working details will be given. In calculations, the normality and molarity methods will be equally acceptable and the questions will be worded appropriately.

21. Candidates will be required, having been given full instructions, to carry out an experiment that may involve the measurement of some quantity, e.g. the volume of a gas liberated during reaction, the rate of a reaction. Such experiments will depend on the simple manipulation of usual laboratory apparatus.

22. Although systematic analysis and a knowledge of traditional methods of separation will not be required, it will be assumed that candidates will be familiar with the simple reactions of the

following ions: NH_4^+, Mg^{2+}, Al^{3+}, Ca^{2+}, Cr^{3+}, Mn^{2+}, Fe^{2+} Fe^{3+}, Ni^{2+}, Cu^{2+}, Zn^{2+}, Ag^+, Ba^{2+}, Pb^{2+}; CO_3^{2-}, NO_3^-, NO_2^-, PO_4^{3-}, SO_4^{2-}, SO_3^{2-}, $S_2O_3^{2-}$, ClO^-, Cl^-, Br^-, I^-, CrO_4^{2-}, CH_3COO^-, $(COO)_2^{2-}$.

> Candidates will not need to refer to analysis tables but the use of analysis books will be allowed in the Practical examination, particularly with reference to tests for confirming the named ions.
> Exercises requiring a knowledge of simple organic reactions as outlined in Section 17 may be set.

APPARATUS LIST

The list given below has been drawn up in order to give guidance to schools and to examiners concerning the apparatus that is expected to be generally available for examination purposes. The list is not intended to be exhaustive: in particular, items (such as bunsen burners, tripods, glass-tubing) that are commonly regarded as standard equipment in a chemical laboratory are not included. Unless otherwise stated, the rate of allocation is 'per candidate',

Two burettes, 50 cm³
Two pipettes, 25 cm³
One pipette, 10 cm³
Dropping pipette
'Safety' flask for pipetting or, preferably, one pipette filler
Conical flasks: 3 × 250 cm³; 1 × 500 cm³
Volumetric flask, 250 cm³
Measuring cylinders, 100 cm³ and 250 cm³
100 cm³ gas measuring tube, or syringe
Large vessel for 'levelling' for measuring gas volumes
Wash-bottle
Two filter funnels
Separating funnel, stoppered, 200 cm³
Filter flask, 250 cm³
Porcelain crucible, with lid, 00 size
Evaporating basin, at least 30 cm³
Beakers, squat form, with lip: 100 cm³; 250 cm³; 600 cm³
   (1 per 3 candidates)
Thermometers: −10 °C to +110 °C at 1°;
   −5 or 10 °C to +105 or 110 °C at ½° (1 per 2 or 3 candidates)

Vacuum flask (either $\frac{1}{2}$ pt or 1 pt), 'polythene' beaker or flask or other suitable alternative.

Clocks (or wall-clock) to measure to an accuracy of about 1 s.

Balance, single-pan, direct reading, 1 mg (1 per 8-12 candidates).

THE PERIODIC TABLE

1	2													3	4	5	6	7	8
1 H																		1 H	2 He
3 Li	4 Be													5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg													13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn			31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd			49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57 — 71	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg			81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89 — 103																	

57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Mv	102 No	103 Lw