

A Level

Chemistry

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INTRODUCTION TO CHEMISTRY

SYLLABUS

The two following principles should be borne in mind:

(i) that the study of chemistry should be based on experimental work;

(ii) that a clear understanding of chemical and physical principles, founded on first-hand knowledge, is of paramount importance.

GENERAL AND INORGANIC CHEMISTRY. One of the fundamental principles of the subject to which importance is attached is the gradation in properties of the elements and their compounds. For instance, the study of hydrides, oxides, halides, and atomic volumes may be closely linked with the Periodic Table. The importance of electrode potentials in connexion with the behaviour of elements and the electrolysis of solutions may with advantage be stressed. Every effort should be made to provide the student with a mental picture of the molecular processes involved in the mechanisms of fusion of solids, evaporation of liquids, diffusion, gaseous reactions, and chemical equilibria. Mathematical treatment of these processes will not be expected; they should be explained in terms of molecular motion and energy, and represented pictorially.

In the work concerning molecular theory it is considered important to emphasize the logical deductions from the gas laws, including Gay-Lussac's law, leading to the idea of the existence of discrete molecules in gases, to Avogadro's principle, and hence to the determination of molecular weights by the fundamental method of relative density. A clear understanding of Cannizzaro's method of determining atomic weights is also desirable.

The application of Faraday's laws and Ohm's law to the electrolysis of solutes leads in a logical way to the ionic theory of dilute solutions of electrolytes, and evidence from boiling-point elevation and freezing-point lowering in such solutions should be shown to be consistent with the theory.

ORGANIC CHEMISTRY. Importance is attached to a thorough understanding of the arrangements of the atoms forming molecules of organic compounds (best illustrated by the use of simple models) and an appreciation of the typical reactions of characteristic groups. For instance, it should be stressed that reactions of some groups, such as the carboxyl group, are common to all compounds containing them, whereas others, such as the carbonyl and hydroxyl groups, have properties which are dependent upon the nature and proximity of other groups in the molecule. This treatment, linking together many related compounds, reduces the burden on the memory, and emphasizes the logical nature of organic chemistry.

The methods of passing from one group of compounds to another can also be emphasized; for example, the methods of inter-conversion of alkyl halides, alcohols, aldehydes, fatty acids, amides, and amines.

This type of approach to organic chemistry is considered to be more important than a detailed knowledge of laboratory preparation of a large number of compounds. Laboratory work should consist of experiments, illustrating typical reactions of the compounds studied, and the techniques of preparation and purification of a few typical substances.

Important economic aspects of organic chemistry should not be overlooked. Outstanding examples are: cracking of oils, polymerization of olefines, syntheses from acetylene and carbon monoxide.

PRACTICAL WORK. Qualitative analysis should be closely linked with the teaching of inorganic chemistry and it is desirable that the fundamental principles involved (for instance the application of solubility products to the separation of groups of metals) should be understood and appreciated.

Whenever questions on formal analysis are set in the practical test, candidates may use standard analysis tables. Any book of qualitative analysis tables may be used provided it does not include other information which might be of use to the candidate during the examination. Semi-micro methods of analysis are

accepted, provided that they follow the usual lines of group analysis. Spot tests will not be accepted, except as final confirmatory tests. All tests should be based on the properties of the elements which have been studied in the theoretical work.

CHEMISTRY

The syllabus for the G.C.E. (Advanced Level) and the H.S.C. (Principal Subject) is printed in ordinary type. **It must be taken to include the syllabus for the subject Chemistry in Subject Syllabus S.** The additional matter printed in italics applies to Special Papers only; but these papers may also include harder questions on the subject-matter printed in ordinary type.

At Advanced Level (H.S.C. Principal Subject) papers will be set as follows:

(a) Paper I and Paper II, each of $2\frac{1}{2}$ hr., based on any part of the syllabus printed in ordinary type. In each, candidates will be required to answer five out of eight questions.

(b) A 3 hr. Practical Examination based on sections 45 and 46 (see pp. 19 and 20). Candidates will be required to answer both of the questions set.

The Special Paper (G.C.E. only) will be a $2\frac{1}{2}$ hr. written paper containing harder questions. Candidates will be required to answer five out of nine questions.

DETAILED CHEMISTRY SYLLABUS

1. The laws of chemical combination.
2. The atomic theory. The periodicity of atomic structure. Simple qualitative treatment of the electronic theory of valency; electrovalency and covalency. The relationship between position in the Periodic Table and the type of valency exerted. The physical properties (volatility, solubility, conductivity) essentially associated with electrovalent and covalent compounds, as exemplified by typical compounds such as sodium chloride, methane, carbon tetrachloride, phosphorus trichloride, ammonium chloride.
3. The periodic classification of the elements treated in relation to atomic structure and valency and illustrated principally by a simple general study of the elements of Periods I and II (hydrogen to argon), and the following groups: inert gases, alkali metals,

alkaline earths, nitrogen group, halogens. The importance of the maximum covalency of four in Period I.

[Candidates should know the positions in the Periodic Table of all the elements selected for special study in this syllabus, and should be able to relate their properties, and those of their compounds, to these positions.]

4. A simple non-mathematical treatment of the kinetic behaviour of the molecules in gases, in the evaporation of liquids, and in the melting of solids.

5. Equivalents of elements and compounds and general methods for their determination. Normal solutions. Calculations involving the use of solutions used in practical volumetric analysis.

6. The effects of temperature and pressure on gases. Deviations from simple gas laws *and their explanations*. Liquefaction of air.

[Van der Waals' equation is excluded. Detailed knowledge of the plant for the liquefaction is not required.]

7. Dalton's law of partial pressures.

[Proof not required.]

8. Graham's law of diffusion of gases.

9. Gay Lussac's law. Avogadro's principle.

10. Molecular weight determination by Regnault's, Hofmann's, and Victor Meyer's methods.

[Practical details of these methods are included.]

11. Gram molecular volume. Molar solutions.

12. Atomic weight determinations by Cannizzaro's, Dulong and Petit's, and Mitscherlich's methods.

13. The experimental methods for finding the volume composition and formulae of steam, hydrogen chloride, ammonia, sulphur dioxide, carbon monoxide, carbon dioxide.

14. Equilibria between solids, liquids, and vapours. *Vapour pressure curves* and solubility curves. Salt hydrates, deliquescence and efflorescence.

[The phase rule is not included. Determination of vapour pressure by a simple barometer only is required. See also § 38.]

15. *Partition of a solute between two immiscible solvents.*

16. Osmotic pressure, *vapour pressure*, freezing-point and boiling-point measurements and their application to molecular-weight determinations, with practical details in the case of freezing-point *and boiling-point measurements*.

[One method for measuring osmotic pressure is required.]

17. Association and dissociation as revealed by molecular weight measurements. Van't Hoff's factor.

18. A general study of chemical reactions in homogeneous gaseous and liquid systems, leading to the effects of temperature, pressure, concentration, and the presence of a catalyst on the velocity of chemical reactions and the position of equilibrium.

[Gaseous reactions should be explained in terms of collisions between the reacting molecules. Order of reaction and the mathematical treatment of reaction velocities are not included.]

19. Chemical equilibrium and reversible reactions. Important examples are: the hydrogen iodide equilibrium, dissociation of dinitrogen tetroxide (N_2O_4), hydrolysis of simple esters, the contact process for the manufacture of sulphuric acid, the synthesis of ammonia. Le Chatelier's principle. *The law of mass action.*

20. Electrolysis. Faraday's laws. Ohm's law applied to solutions. *Conductivity of solutions, including specific and equivalent conductivity, and a method for determining the specific conductivity of a solution.* The development of the ionic theory from the above.

[The determination of ionic mobilities and transport numbers is not included.]

21. A qualitative treatment of the hydrolysis of salts. The meaning of pH. *A simple treatment based on the law of mass action of the electrolytic dissociation of weak acids, including Ostwald's dilution law. Titration curves for the neutralization of acids and bases. Buffer solutions.*

[The determination of pH by use of indicators only.]

22. Solubility products treated qualitatively and applied to the sulphides, solubility in acids of insoluble salts of weak acids, the ammonia-soda process, the common ion effect. *Simple calculations involving solubility products.*

23. Thermo-chemistry: heats of formation, combustion, neutralization, and reaction, and their importance.

24. Oxidation and reduction, *including the electronic explanation.*

25. *The preparation and properties of colloids.*

26. *Simple experimental treatment of adsorption.*

27. Candidates will be expected to be familiar with the chief occurrence, methods of preparation, and properties of the elements mentioned below, except where it is stated that preparations will not be required. Special emphasis should be given throughout to:

(a) The general methods of preparation and the properties of the chlorides and oxides of the metallic elements, and the hydrides, chlorides, and oxides of the non-metallic elements, considered in relation to the Periodic Table.

(b) Properties leading to other methods of classification, e.g. the electrochemical series.

[Although details of technical operations will not be required, candidates will be expected to know the chief sources of the elements and the chemistry of important processes for their extraction.]

28. The following metals and their important compounds should receive thorough treatment on the lines indicated above: sodium, calcium, magnesium, aluminium, zinc, mercury, copper, tin, lead, iron. The compounds studied to be the metallic oxides, hydroxides, sulphides, chlorides, sulphates (with examples of double salts), nitrates, carbonates and orthophosphates which are in common use, with the addition of sodium sulphite, sodium hypochlorite, sodium nitrite, sodium bisulphate, sodium bicarbonate, bleaching powder, calcium bicarbonate, potassium iodide, *potassium ferrocyanide, potassium ferricyanide, potassium permanganate and potassium dichromate.* Simple reactions of potassium ferrocyanide, potassium ferricyanide, potassium permanganate, potassium dichromate.

29. The chemistry of potassium, barium, silver, nickel, cadmium, arsenic, antimony, bismuth, chromium (including the chromates) and manganese should be studied only sufficiently to bring out their relationship in the periodic classification, and to show their economic and industrial importance.

[Particularly important in this connexion are the properties of their oxides, hydrides, sulphides and chlorides. In this section preparations will not be required.]

30. The importance of the common alloys, brass, duralumin, solder, type-metal, steel.

31. Hydrogen, water, hardness of water and its removal, hydrogen peroxide.

32. The halogens (excluding fluorine), and their compounds with hydrogen. Hypochlorous acid, hypochlorites, bleaching powder. Chlorates and iodates. A study of the atmosphere, including the inert gases. Oxygen. The classification of oxides. Ozone. Sulphur. Hydrogen sulphide, and sulphides. Sulphur dioxide, sulphur trioxide; sulphurous acid, sulphuric acid, and

their salts. Sodium thiosulphate. Nitrogen, nitrous oxide, nitric oxide, nitrogen dioxide. Ammonia and the ammonium salts. The nitrogen cycle. Nitric acid, nitrous acid, and their salts. Phosphorus. Phosphoric anhydride. Ortho-phosphoric acid and its salts. Phosphorus chlorides. Phosphine compared and contrasted with ammonia.

33. Carbon, carbon monoxide and carbon dioxide; carbonic acid and carbonates: carbon in nature; *sodium cyanide*; calcium carbide, calcium cyanamide. *Silicon, silica, silicon carbide. Glass and water glass.*

34. Allotropy of elements. Physical differences of the allotropes of carbon, phosphorus, and sulphur; chemical differences of those of phosphorus. *Enantiotropy and monotropy, the determination of transition temperatures.*

35. Questions may be set on the outlines of the commercial production and the economic importance of the following: sodium carbonate by the ammonia-soda process; sodium hydroxide; chlorine; hydrochloric acid; hydrogen; ammonia; bleaching powder; nitric acid; sulphuric acid; producer gas from coke; water gas; coal gas. The economic importance of the hydrogenation of coal, and of the cracking of oils should be outlined.

[Reference should be made to the development and to the economic importance of these chemical processes.]

36. The detection of carbon, nitrogen, sulphur, and the halogens in organic compounds.

37. The determination of the empirical and molecular formulae, and reactions which establish the structural formulae of ethyl alcohol, ether, ethylene, acetaldehyde and acetic acid.

38. Purification by crystallization, distillation, steam distillation, and fractional distillation.

[Fractional distillation and steam distillation to be treated from a practical viewpoint only, *except for scholarship candidates.*]

39. Homologous series.

[The important relationship of the maximum covalency of four of the carbon atoms and the stability of organic compounds should be stressed.]

40. Structural isomerism (as essentially a property of covalent compounds). *Stereo-isomerism (cis-trans and optical).*

41. Chemical properties as functions of characteristic groups, illustrated by the commoner groups: $-\text{OH}$, $-\text{COOH}$, $=\text{CO}$, $-\text{NH}_2$, the ethylenic bond.

[It is important that candidates should relate the properties of an organic compound to the types and position in the molecule of its constituent radicals.]

42. An outline of the methods of preparation, properties, reactions and uses of the following: methane, ethane, ethylene, acetylene, alkyl halides, ethylene dibromide, chloroform, methyl alcohol, ethyl alcohol, ether, formaldehyde, acetaldehyde, acetone, formic acid (not preparation), acetic acid, acetyl chloride, acetic anhydride, acetamide, the esters of simple carboxylic acids, oxalic acid, the simple primary, *secondary and tertiary* amines, alkyl cyanides and *isocyanides*, *chloroacetic acid and glycine, urea (treated as a simple amide).*

[Particular stress should be laid on the principles underlying each method of preparation. The preparation of isocyanide is not required.]

43. Occurrence and importance of fats and oils, and their uses for food and soap.

44. Benzene; its sources, sulphonation, nitration and halogenation. The preparation of phenol from benzene sulphonic acid, the properties of phenol and the reaction of its $-\text{OH}$ group compared and contrasted with those of the $-\text{OH}$ group of alcohols. The preparation of aniline from nitrobenzene. The reactions of the $-\text{NH}_2$ group in aniline should be compared with those of primary aliphatic amines. *Diazotization of aniline and simple reactions of diazonium salts.* The reactions of chlorobenzene compared with those of an alkyl chloride. Toluene, *benzaldehyde, benzoic acid.*

[The evidence for the structure of benzene will not be required; the Kekulé formula may be assumed. The chemistry of mononuclear substituted derivatives of aromatic compounds need only be considered. *Structure of diazonium salts is not required.*]

PRACTICAL EXAMINATION

45. A knowledge of the following volumetric processes will be required: The determination of acids and alkalis, using suitable indicators; ferrous and ferric iron, oxalic acid and oxalates, by permanganate; halides in neutral solution by silver nitrate. Simple titrations involving iodine and sodium thiosulphate may also be set. If problems are set involving any other reactions sufficient working details will be given.