

O Level

Chemistry

Session: 1974
Type: Syllabus
Code: 542

CHEMISTRY (542)

[May not be taken with Physical Science]

Concentrations of solutions are no longer quoted in 'normalities' in question papers but both 'molarity' and 'normality' methods of calculation are acceptable where appropriate in candidates' answers.

There will be two papers:

*Paper 1** will be a 2½-hour Theory paper containing eight questions. Question 1 will consist of several independent short-answer questions and will carry 40 marks; the remaining questions will be normal-type questions. Candidates will be required to answer Question 1 and any four other questions (60 marks).

Paper 2 will be a 2-hour Practical Test and will carry 30 marks. An Alternative-to-Practical paper will also be available (1½ hours) (30 marks.)

DETAILED SYLLABUS

1. The states of matter and their interconversion. Laboratory techniques, including the collection and handling of gases. The use of the bunsen and balance. Simple determinations of boiling points. Distillation, fractional distillation and crystallization as methods of purification. The use of physical constants as a means of identifying substances and of testing their purity. The use of the separating funnel. Solution, filtration, washing, evaporation, drying, etc.

Physical change.

In studying section 1 the following substances could be used: water, ethanol, benzene, paraffin, salt, sand, chalk, sulphur, iron filings, copper, copper(II) sulphate, naphthalene. The determination of solubilities of solids and the construction of solubility curves are not required. The conception that crystals cannot be obtained until a solution is saturated is expected.

2. The air and oxygen and the nature of burning. The heating and/or burning of elements in the air.

Carbon, sulphur, phosphorus, magnesium, zinc, iron, lead, copper, are included. It is expected that sodium will be burnt in air, but not in oxygen.

* Consideration is being given to the introduction of multiple choice tests, possibly in the 1975 examination: at least two years notice will be given about the year of introduction when this has been decided.

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Air is necessary for burning, a portion of it is used up, a new substance is formed and there is a gain in mass. Air has mass and possibly the air used up is responsible for the gain in mass. A first introduction to the conservation of mass and to a chemical change (a substance with a fresh set of properties is formed).

The portion of air used up is approximately one-fifth of the whole.

Any suitable method will be accepted.

Nitrogen to be given as the other constituent.

The composition of air should be given as being approximately one-fifth oxygen and four-fifths nitrogen, with only small quantities of other constituents.

Laboratory preparation of oxygen from hydrogen peroxide by the use of manganese(IV) oxide or by any suitable method. Uses of oxygen.

Hydrogen peroxide is to be considered as a substance containing a high percentage of oxygen, some of which can readily be released by simple methods.

The uses of oxygen expected include (i) assistance in respiration; (ii) various oxy flames and metal cutting; (iii) tonnage oxygen in steel production.

The burning of elements in oxygen (carbon, sulphur, phosphorus, calcium, magnesium, iron) and a first introduction to the activity series for metals (sodium, calcium, magnesium, iron, lead, copper).

Acidic and basic oxides examined by litmus, also by their reactions with water, acids and alkalis.

Other methods of obtaining oxygen, e.g. by heat on mercury(II) oxide, potassium or sodium nitrate, and potassium or sodium chlorate.

It should be stressed that nearly all the chemicals in this further preparation of oxygen are potentially dangerous.

The commercial preparation of oxygen from air.

Details of the apparatus used for the liquefaction of air are not required but candidates should know that liquefaction is achieved by cooling and increase of pressure.

The composition of the air.

The percentage of water vapour varies and is never really high, and the percentage of carbon dioxide is small. Argon, neon and helium should be mentioned.

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3. Water. The burning of organic substances in air yields water and carbon dioxide with the release of energy. Energy release is typical of many chemical reactions.

Water, as a product of burning, may be an oxide of hydrogen; experiments to investigate this possibility. The action of the metals potassium, sodium, calcium, magnesium and iron on water (steam), and a further reference to the metal activity series.

The action of steam on magnesium is required, and the slow liberation of hydrogen from hot water is expected.

The uses of hydrogen.

The uses expected include (i) fuels and flames; (ii) the Haber process; (iii) the hardening of oils.

Synthesis of water by the burning of dry hydrogen in air.

The details of determining the gravimetric composition of water are not required.

The reduction of copper(II) oxide by hydrogen.

Oxidation to be given as the addition of oxygen or the removal of hydrogen, and reduction as the removal of oxygen or the addition of hydrogen.

The electrolysis of water (containing a little sulphuric acid) using platinum electrodes.

Conditions for the rusting of iron and methods of prevention.

Rusting, in this section, requires only reference to oxygen and water. It should be regarded as slow oxidation.

4. Acids, bases and salts. Characteristics of acids, bases and salts. Common acids and bases, indicators.

Acids should be illustrated by reference to hydrochloric, nitric, sulphuric, acetic, tartaric, citric, carbonic and sulphurous acids.

Bases should be illustrated by reference to the oxides and/or hydroxides of potassium, sodium, calcium, magnesium, zinc, lead, copper and ammonium. The reaction between calcium oxide and water is included.

The soluble hydroxides give alkaline solution.

The action of dilute hydrochloric acid and dilute sulphuric acid on the following (i) metals: magnesium, zinc, iron, copper; (ii) metallic oxides: magnesium, zinc, lead (lead(II) oxide only), copper; (iii) hydroxides: potassium, sodium, calcium, magnesium, zinc, copper and

ammonium; (iv) metallic carbonates: potassium, sodium, calcium, magnesium, zinc, copper.

Other acids including dilute nitric are not necessarily excluded, but oxidizing conditions are to be avoided. The action of nitric acid on metals is not expected as a method of salt formation. Section 4 gives opportunity for further reference to the activity series.

The preparation of insoluble salts by precipitation, e.g. silver chloride, barium sulphate, lead(II) chloride and lead(II) sulphate and many carbonates.

Sulphides are to be treated as insoluble salts (See § 6(c).)

Methods of naming salts and the techniques for obtaining good crystals.

The action of heat on different types of salt: (i) hydrates; copper(II) sulphate, sodium carbonate; (ii) the carbonates of sodium, calcium, magnesium, zinc, lead, copper; (iii) a few salts that show no decomposition: potassium chloride and sodium chloride.

For both copper(II) sulphate and sodium carbonate the action should be confined to loss of water of crystallization.

The stability of carbonates on heating should be linked to the activity series.

5. Further investigation of non-metallic elements.

(a) CARBON. Charcoal, graphite, diamond. The combustion of various charcoals and of graphite in oxygen.

Carbon monoxide, formation by reduction of carbon dioxide. Carbon monoxide burns to carbon dioxide, and when hot it is a good reducing agent.

The presence of carbon monoxide in car exhaust fumes, fumes from badly ventilated fires, and in mines after explosions. The poisonous nature of carbon monoxide.

The carbon and oxygen cycles in nature. Similarities and differences between respiration in plants and animals and burning generally.

Respiration involves slow oxidation at relatively low temperatures.

Photosynthesis *simply*. Formation of carbonates and hydrogen carbonates by the solution of carbon dioxide in sodium hydroxide and calcium hydroxide solutions.

Reference should be made to the dissolving of calcium carbonate in rocks (chalk, limestone and marble) and to the formation of 'fur' and boiler scale. No further treatment of hard water is expected.

Carbon dioxide, preparation, properties and uses.

The uses of carbon dioxide expected include (i) aerated drinks or mineral waters; (ii) fire extinguishers (no practical details are required); (iii) refrigeration.

One test for a carbonate or hydrogen carbonate.

(b) CHLORINE. Common salt. Hydrogen chloride, its preparation and properties; the properties of its solution in water and in toluene, including electrical conductance.

The acid system is hydrogen chloride plus water but not hydrogen chloride plus toluene.

The properties of hydrogen chloride in dry toluene should mention that the solution (i) is a non-conductor; (ii) gives a white precipitate on passing ammonia; (iii) has no reaction with magnesium, zinc and iron; (iv) has very little reaction with carbonates.

Chlorine, its formation by oxidation and electrolysis of hydrochloric acid and sodium chloride solution.

The oxidizing agents expected include manganese(IV) oxide and potassium permanganate.

The properties and uses of chlorine.

The chemical properties expected are its reactions with (i) hydrogen and hydrocarbons; (ii) metals (Na, Mg, Fe); (iii) non-metals (phosphorus and sulphur but no direct action with carbon); (iv) reducing agents such as hydrogen sulphide, sulphites, ammonia; (v) water and dilute alkali solution; (vi) bromides and iodides; (vii) dyes, i.e. bleaching. The manufacture of bleaching powder is not expected. The study of bromine and iodine is not expected but reference to the 'halogen' family is expected.

The uses expected include (i) manufacture of hydrochloric acid; (ii) water 'purification'; (iii) bleaching; (iv) manufacture of many organic compounds, e.g. chloroform, D.D.T., trichloroethylene, plastics.

Two tests for a chloride, one for the dry solid and one in dilute solution.

(c) SULPHUR. Occurrence and uses. Crystallization from melt and from solution.

The uses expected include (i) the manufacture of sulphuric acid and hydrogen sulphites (see sulphur dioxide); (ii) as a fungicide in horticulture; (iii) vulcanizing of rubber.

Hydrogen sulphide, combustible, a reducing agent and a precipitant for many metallic sulphides: its formation from iron(II) sulphide.

The chemicals reduced should include HNO_3 , H_2O_2 , Cl_2 , Br_2 , moist SO_2 , and the effect of air on its solution.

The precipitation of PbS , CuS , ZnS should be quoted.

Sulphur dioxide. Its formation from a sulphite. Its properties as an acid anhydride and as a reducing agent. Uses.

The chemicals reduced should include HNO_3 , H_2O_2 , Cl_2 , Br_2 and the effect of air on its solution.

The uses of sulphur dioxide expected include (i) the manufacture of sulphuric acid and of hydrogen sulphites for the paper industry; (ii) bleaching and food preserving.

The conversion of sulphur dioxide to sulphur trioxide.

The manufacture of sulphuric acid by the contact process.

The properties of sulphuric acid both pure and diluted, its dehydrating properties.

The properties expected include (i) its behaviour, when dilute, as an acid in every respect, the acid system being H_2SO_4 plus water; (ii) in concentrated form; the dehydration of sugar, $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ and flesh. The action of the concentrated acid on metals is not expected.

Its use as a non-volatile acid liberating more volatile acids from chlorides and nitrates.

One test for a sulphate, a sulphite and a sulphide.

Atmospheric pollution.

(d) NITROGEN and its compounds.

The laboratory preparation of nitrogen is not expected.

The reducing properties of ammonia and its great solubility. The basic properties of its solution.

Uses of ammonia and its synthesis from nitrogen and hydrogen.

The uses expected include (i) manufacture of nitric acid; (ii) preparation of ammonium salts, mainly ammonium sulphate as a fertilizer; (iii) refrigeration; (iv) cleaning purposes.

For the Haber process, technical details are not required beyond the use of pressure, temperature and a catalyst, and a simple outline of the preparation of the nitrogen and the hydrogen.

Ammonium salts, their solubility and reaction with alkalis: uses.

The action of heat on ammonium salts may be restricted to the sulphate and chloride.

The oxidation of ammonia by hot copper or lead oxides to give nitrogen and water, and its oxidation by air in the presence of a catalyst to nitric oxide.

This reveals ammonia as being a nitrogen hydride.

The difficulty of oxidizing nitrogen directly.

The distillation of nitric acid from potassium nitrate or sodium nitrate and concentrated sulphuric acid and an outline of its manufacture from ammonia. The properties of nitric acid, dilute as an acid and more concentrated as an oxidizing agent. Action of concentrated and dilute acid on copper.

The acid system is HNO_3 plus water.

The oxidation of H_2S , SO_2 , and iron(II) salts is required.

A simple comparison of nitric oxide and nitrogen dioxide.

The comparison should be limited to colour, solubility, acidity and action with oxygen.

Nitrates: the preparation of potassium, sodium, and lead(II) nitrates and the uses of potassium and ammonium nitrates in explosives and of ammonium nitrate as a fertilizer (nitro-chalk).

One test for a nitrate.

Brown ring test (with no equation) or copper and conc. sulphuric acid.

The importance of nitrogen compounds to life, and the necessity for the 'fixation' of atmospheric nitrogen.

6. The Chemistry of some of the Metals and of some of their Compounds; potassium, sodium, calcium, magnesium, zinc, iron, lead, copper.

The reactions of the above metals with air, water (steam) and acids, limited as specified in Sections 2, 3 and 4.

It is expected that this work will be based firmly on the metal activity series. Potassium is an excellent metal to head the activity series. Its reaction on water can be safely shown using very small pieces. The violence of this reaction justifies its high position in the series. It is *not* intended that any other experiments should be shown with potassium. Its great activity can be quoted.

Reduction of the oxides of the metals by carbon, hydrogen and carbon monoxide: manufacture of iron in the blast furnace.

The precipitation of the hydroxides of the metals (including iron(II) and iron(III)) and the amphoteric nature of zinc, aluminium and lead(II) hydroxides.

The effect of heat on the metallic hydroxides, carbonates and nitrates.

It is expected that this work will be based firmly on the metal activity series.

The liberation of metals at the cathode by electrolysis. The general physical and chemical properties of metals and the chief uses of magnesium, aluminium, zinc, iron, lead, copper and the alloys, steels, brass, solder, duralumin. The simple reasons for the use of these alloys in preference to the metals from which they are made.

Atmospheric pollution.

The general properties of non-metals and their differences from metals.

7. Theoretical Chemistry. Elements, compounds, mixtures, chemical and physical change.

This overlaps section 1.

The law of conservation of mass and the law of constant composition.

Experiments illustrating diffusion and Brownian movement, as evidence supporting particle theories.

Some idea of the size of the particles should be conveyed.

Atoms and molecules.

Formal definitions are not expected.

Symbols for atoms. Interpretation of the above two laws in terms of atoms. Dalton's conception of atoms and modifications made necessary by later discoveries, e.g. isotopes, radioactivity. The nature and limitations of a scientific law.

Relative masses of atoms, isotopes. Relative atomic mass (atomic weight) scale.

The values of relative atomic masses should be assumed. Although the principles and experimental details of their determination are not required, it is desirable to call attention to the fact that both chemical and physical evidence has produced the present set of values.

Percentage composition of simple compounds leading to the ratio of the numbers of atoms present. The deduction of simple formulae and of valencies or combining numbers. The idea of multiple valencies.

The traditional experimental determinations of equivalents and numerous calculations concerning them are not intended.

The laws of Boyle and Charles. The molar (g-molecular) volume of gases (via gas densities) as being 22.4 l at s.t.p. Avogadro's Principle. The ideas of the mole (the g-atom, g-molecule and g-formula) and atomicities of gases.

Whatever the mass of the atom or molecule, one mole (one g-atom or one g-molecule) will always contain the same number of atoms or molecules. The experimental proof of Boyle's and Charles' laws is not required but questions requiring the application of these laws may be set. Evidence for the atomicity of hydrogen (and of oxygen and chlorine) should be mentioned, e.g. the volume composition of steam and hydrogen chloride, but practical details of the demonstration of volume relationships are *not* required. The atomicity of other gases to be given.

8. Quantitative Work on Chemical Equations. Standard solutions, acid/alkali titrations and simple calculations.

Questions on the use of standard solutions in reactions of other types may be set to test understanding of volumetric work but, in such questions, equations or other necessary information will be given.

Chemical equations and the quantitative information obtainable from an equation. Calculations involving reacting masses and reacting volumes of gases.

It should be established that an equation does not guarantee that a reaction will take place, nor does it give information concerning the conditions of the reaction.

(b) Elementary treatment of the factors which can change the rate of a chemical reaction: (i) temperature; (ii) concentration; (iii) the presence of a catalyst.

Comparative results only are expected from such reactions as (i) zinc or magnesium on dilute acids; (ii) the decomposition of H_2O_2 . Catalysts expected include (i) MnO_2 on H_2O_2 ; (ii) Pt or V_2O_5 in contact process; (iii) Fe (Fe_2O_3) in the Haber process; (iv) Ni in many hydrogenation reactions.

Energy changes during chemical reactions.

Experiments to illustrate the production and absorption of heat, electricity and light during chemical reactions (qualitative treatment only).

Examples of absorption of light may be limited to the H_2/Cl_2 reaction and the effect of light on silver halides. The production of electricity may be limited to the example of the reaction $Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu$ in the Daniell cell.

9. Electrolysis. The conduction of electric current by substances.

This should be illustrated by salts, acids, bases, sugar.

Electrolytes and non-electrolytes, simple ionic theory.

The three classes of substances: (a) those conducting when molten or in solution; (b) those that do not conduct; (c) substances not themselves conductors but which form conducting systems on contact with water.

This should be illustrated by ammonia, acetic acid, hydrogen chloride, nitric acid, sulphuric acid.

Hydrogen chloride in toluene as a non-conducting system.

Qualitative comparison of conductances of 1M solutions of strong and weak acids and bases.

This should be illustrated by H_2SO_4 , HCl , HNO_3 , acetic acid, $NaOH$, KOH , NH_4OH .

Relation between current, time and mass (or volume) of substance liberated at an electrode. Quantity of electricity needed to liberate one mole or g-atom of an element, and the realization that some atoms require more electricity to liberate them than do others.

This should be linked with combining numbers or valencies. Simple calculations may be best.

The electron as an 'atom' of electricity. Electric current as a flow of electrons; anode, cathode, ion, anion, cation.

Origins of the charges: atoms of metals lose electrons to give positive cations, atoms of non-metals gain electrons giving negative anions.

Ions as charged particles formed from atoms or groups of atoms, by loss or gain of electrons.

Electro-valency as the number of electrons gained or lost and its link with the quantity of electricity needed to liberate one mole.

The electromotive series and its relation to the metal activity series.

Plating, purification of copper, liberation of gases, isolation of elements, e.g. aluminium (with no technical details), sodium.

It is intended that the following points should be appreciated: (i) the p.d. and current used; (ii) the need for the substance to be in the liquid state, or in solution, if ions are to migrate; (iii) both solute and solvent can take part in an electrolytic process.

The study of a few specific systems in electrolysis.

It is intended that the following solutions (or systems) should receive special attention: (i) the electrolysis of water containing a little sulphuric acid with platinum and copper electrodes; (ii) the electrolysis of cold aqueous sodium chloride with carbon electrodes, excluding formation of sodium hypochlorite; (iii) the electrolysis of copper(II) sulphate solution with copper and platinum electrodes; (iv) the isolation of lead from fused lead(II) bromide. In all cases technical details are not required.

10. Organic Chemistry. The structure of simple organic compounds from the study of paraffins, olefines, primary alcohols and acids, leading to a knowledge of the general physical and chemical characteristics of homologous series.

In this section the properties expected include a knowledge of the gradual change in m.p., b.p., density and solubility in water as the molecular weight increases but exact values of these properties are not expected. The chemical properties to be treated should include (i) for paraffins: burning and substitution with chlorine; (ii) for olefines: burning, addition reactions with chlorine (or bromine) and hydrogen; (iii) for alcohols: burning, their reaction with sodium and with concentrated sulphuric acid to give olefines, ester formation and oxidation in two stages to give acids; (iv) for acids: salt and ester formation.

11. Structure of atoms, ions, and molecules. (a) Electron transfer. Usually from metallic to non-metallic elements with the formation of ions. Satisfactory as an explanation for bonding in simple electrolytes.

Soluble and insoluble products. Precipitation. Ionic equations.

(b) Electron sharing. This is the usual method of bonding between non-metallic elements. Sharing of electrons to form a covalent bond. Molecules.

Differences in volatility and conductance between ionic and covalent compounds.

It should be stressed that ionic compounds have high melting and boiling points, whereas covalent compounds of fairly low molecular weight are volatile. Questions asking for an explanation of this difference in volatility will not be set.

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(c) Examples of crystals formed from atoms, molecules and ions, e.g. diamond, copper, sulphur, naphthalene, sodium chloride and magnesium oxide.

Detailed knowledge of the geometrical form of crystal lattices is not expected.

A simple model of an atom as consisting of a very small nucleus built up of protons and neutrons with a balancing number of extra-nuclear electrons, illustrations of this model to be given for elements of atomic number between 1 and 20 (i.e. up to calcium). Isotopes.

Distribution of the electrons in the sub-orbits is not expected. If questions are set on the atomic structure of particular elements, atomic numbers and mass numbers will be given.

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In the PRACTICAL EXAMINATION candidates may be asked to carry out simple exercises (a) in volumetric analysis, (b) in observation and deduction, (c) of a quantitative or investigatory nature.

Volumetric analysis: the use of standard solutions of acids and alkalis and the indicators methyl orange (or screened methyl orange) and phenolphthalein in determining (a) the concentration of solutions of acids and alkalis (including sodium carbonate and hydrogen carbonate); (b) the reacting weights of acids and alkalis by direct titration; (c) simple exercises to test a knowledge of the principles of volumetric analysis. Back titrations will not be required and calculations may be worked either from reacting masses or from normalities* or molarities. In all volumetric tests the relevant equations will be given together with the necessary experimental details. Candidates will not be expected, in the examination, to prepare their own standard solutions.

Simple exercises in visual observation and deduction may include the recognition of (a) the gases: hydrogen, oxygen, carbon dioxide, chlorine, hydrogen chloride, hydrogen sulphide, sulphur dioxide, ammonia, nitrogen dioxide, water vapour; (b) the anions: nitrate, chloride, carbonate, sulphate, sulphite, sulphide; and (c) the cations:

* See the note on p. 49 concerning the quoting of concentrations in question papers.

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lead, copper, iron, zinc, calcium and ammonium. Knowledge of a formal scheme of analysis is not required.

In exercises of a quantitative or investigatory nature (e.g. heats of reaction, effect of temperature or concentration on rates of reaction, and in volumetric exercises involving solutions other than acids and bases), candidates will be given full instructions. Apparatus requirements will be kept simple. Such exercises may, on occasion, be combined with or replace the volumetric exercise. Weighing will not be required in the examination.

ALTERNATIVE-TO-PRACTICAL CHEMISTRY. The practical Chemistry paper will be alternative to a 1½-hour written paper to be known as the Alternative-to-Practical paper. This paper is designed to test a knowledge of the practical work cognate to the theoretical syllabus; candidates taking it are required to submit satisfactory evidence that they have undergone a proper course of laboratory work. (See p. 4.)