

O Level

Chemistry

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UNIVERSITY OF CAMBRIDGE
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SCIENCE SUBJECTS

1966 and 1967

GENERAL CERTIFICATE OF
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(ORDINARY LEVEL)

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CHEMISTRY

Syllabus, Alternative N

(May not be taken with General Science or Physics-with-Chemistry)

There will be two papers:

Paper 1 will be a 2½-hour Theory paper containing nine questions. Question 1 will consist of several independent short-answer questions and will carry 32 marks; the remaining questions will be normal-type questions. Candidates will be required to answer Question 1 and any four other questions (68 marks).

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

DETAILED SYLLABUS

(For the significance of the italics see under Physics-with-Chemistry, p. 21)

1. The air and its chief gaseous constituents including oxygen, nitrogen, water vapour, carbon dioxide, and a brief mention of argon and neon; proportion of oxygen in air (e.g. by burning phosphorus or by using alkaline pyrogallol). Preparation of oxygen; *its commercial preparation from liquid air*. Properties and uses of oxygen; the burning of carbon, sulphur, phosphorus, sodium, magnesium and iron; acidic and basic oxides.

A detailed knowledge of the rare gases is not expected. *Details of apparatus for the liquefaction of air are not required.*

2. Water as an oxide of hydrogen. Action of the metals sodium, calcium, magnesium and iron on water. The rusting of iron. The *composition of water by weight*. *Commercial production of hydrogen from steam*. The action of steam and magnesium. The reaction between steam and heated iron *as a reversible action*. Preparation of hydrogen from dilute acids. Properties and uses of hydrogen.

Rusting should be regarded as slow oxidation.

Oxidation in terms of addition of oxygen or removal of hydrogen; reduction as removal of oxygen or addition of hydrogen.

An alternative syllabus, *Alternative T*, based on a new approach to the subject is available. For details see pp. 37-51.

3. Water as a solvent for gases and solids. Evaporation, distillation, sublimation, crystallization, filtration, precipitation, and the use of these processes in preparing pure substances. The uses of other solvents for fats, oils, *paints*, *lacquers* and for cleaning. Saturated and unsaturated solutions; the determination of solubilities of solids. *Solubility curves and simple deductions from them*. Atmospheric gases dissolved in water; their biological significance. Hard and soft water; temporary and permanent hardness; the methods of softening hard water. Hydration, efflorescence and deliquescence as illustrated by sodium carbonate, magnesium sulphate, copper sulphate, ferrous sulphate, and calcium chloride.

It is expected that a simple example of fractional distillation will be included.

No chemistry of fats, oils, etc., is expected. The emphasis is on solvents other than water.

Candidates will be expected to know the hardening effects of calcium and *magnesium* salts. The examiners will take account of the fact that, in some areas, hard water does not occur naturally.

4. Chalk (limestone and marble), quicklime, slaked lime, mortar. Preparation and properties of carbon dioxide, carbonic acid, carbonates and bicarbonates; properties and uses of washing soda and baking soda (sodium bicarbonate); the ways in which carbon dioxide is constantly added to air (combustion, respiration, fermentation and decay, by-product of industrial processes) and removed by plants; carbon cycle; mineral waters; simple fire extinguishers.

A simple knowledge of the manufacture of quicklime will be expected.

5. Combustion of carbon and carbon-containing substances in (a) plentiful, (b) limited supplies of air. The candle flame. The Bunsen burner and its flame. *Combustion of a candle as typical of hydrocarbons*. Coal; coal-gas, coke, coal-tar, and ammonia as products of the destructive distillation of coal: coal fires and coke fires. *Coal-gas, water-gas and producer-gas (from coke) as fuels; outline of their manufacture*.

The energy changes in combustion should be discussed. The storing of the sun's energy as a result of photosynthesis and its release in respiration and combustion should be discussed.

A detailed description of the gas-works is not required, but candidates should be familiar with the following stages: distillation, removal of tar and ammonia, *and the removal of hydrogen sulphide*.

6. Elements, compounds and mixtures; chemical change and physical

change. Law of conservation of mass and the constancy of chemical composition (definite proportions); *the law of multiple proportions*; simple treatment of Dalton's Atomic Theory. Atoms, molecules, formulae (simple calculations involving formulae and chemical composition), chemical equations and their use in so far as they assist in giving a mental picture of a chemical action. Simple calculations from equations of reacting weights of substances and volumes of gases. Equivalent weights and the methods of their determination. Valency. Atomic weights. *Dulong and Petit's law; determination of atomic weights of metals*.

The equivalent weights of simple acids and alkalis, and the use of standard (including normal) solutions of acids and alkalis.

Candidates will be expected to have determined equivalents by the following methods:

(a) by replacement of hydrogen;

(b) by the addition or removal of oxygen;

(c) for copper, by the displacement with zinc.

Simple temperature and pressure corrections are included for the subject Chemistry.

Methods of determination of atomic weights are not required for Physics-with-Chemistry.

7. *The study of gases. The laws of Boyle, Charles, Gay-Lussac and Avogadro; volume relations exemplified by hydrogen chloride, steam and sulphur dioxide (or carbon dioxide). Atomicity of hydrogen. The relation between the vapour density of a gas and its molecular weight. Simple calculations based on these laws.*

8. Characteristics of acids, bases and salts. General methods of preparing acids illustrated by hydrochloric acid from common salt, nitric acid from sodium or potassium nitrate, sulphuric acid from sulphur dioxide (contact process); general properties of acids; acids in everyday use (e.g. acetic, citric and tartaric acids); baking powders. *Preparation of bases; the oxides of common metals. Caustic soda; ammonia*. Neutralization. Salts.

Candidates are only expected to know that citric, tartaric, and acetic acids are common acids in everyday use. They are not expected to deal with the chemistry of these acids.

9. An elementary study of electrolysis. *Faraday's laws*. Electrolytes and non-electrolytes; the electrolysis of water (dilute sulphuric acid); the liberation by electrolysis with platinum electrodes of copper from copper sulphate solution with the subsequent electrolysis of the dilute

sulphuric acid); *the use of electrolysis in the purification of copper*; copper-plating; *production of caustic soda from brine by any one electrolytic process.*

This portion of the syllabus has much in common with the corresponding part of the Physics syllabus.

10. In addition to those previously mentioned the study of the following non-metallic elements and their compounds is required:

(a) Carbon: properties and uses of graphite and charcoal. Carbon monoxide; its preparation and properties. *The sources and uses of hydrocarbons exemplified by methane, petrol and paraffin wax.*

The preparation of carbon monoxide should include both the reduction of carbon dioxide and one dehydration method.

A laboratory preparation of methane is not required. A knowledge of the chemical structure of petrol and paraffin wax is not required.

(b) Nitrogen: 'atmospheric nitrogen'; *preparation of pure nitrogen by any one method.* The laboratory preparation and properties of ammonia and its synthesis from nitrogen and hydrogen; ammonium salts, their importance and use; *the oxidation of ammonia in the soil compared with the catalytic oxidation of ammonia to nitric oxide and nitric acid.* The reactions of nitric acid (a) as an acid, (b) as an oxidizing agent. *The preparation and properties of nitrous oxide, nitric oxide and nitrogen dioxide.* Nitrates and the action of heat on them.

The circulation of nitrogen in nature should be discussed.

The action of heat on ammonium nitrate will not be required for Physics-with-Chemistry.

(c) Sulphur: its extraction and uses. *Hydrogen sulphide: preparation and properties; its part in atmospheric pollution. Sulphides.* Sulphur dioxide: its preparation and properties; sulphurous acid as a bleaching agent and preservative. Sulphuric acid: its commercial preparation by the contact process *or lead-chamber process*: its properties when concentrated and as a dilute acid.

The preparation of sulphur dioxide should include its formation from sulphur and natural sulphides in addition to a laboratory preparation. Details of commercial plant, either the contact process or the lead-chamber process, are not required.

(d) Common salt. Preparation and properties of hydrogen chloride and hydrochloric acid. Chlorine: *its production by the electrolysis of brine* and by the oxidation of hydrochloric acid. Its properties (excluding the formation of chlorates); *the preparation and uses of bleaching powder and sodium hypochlorite.*

11. The metallic elements. The physical and chemical differences between metallic and non-metallic elements. The extraction of iron by the blast-furnace process. The action of water (or steam) on sodium, calcium, magnesium, iron. The action of dilute mineral acids on magnesium, aluminium, zinc, iron, lead, copper. *The action of sodium hydroxide on aluminium and zinc.* The chief uses of zinc, iron, lead and copper. The preparation of quicklime (heating calcium carbonate), *magnesium oxide (heating nitrate and carbonate), aluminium oxide (heating hydroxide), zinc oxide (heating nitrate and carbonate), ferric oxide (heating hydroxide and ferrous sulphate), lead monoxide (heating nitrate and carbonate), cupric oxide (heating nitrate and carbonate).* The action of dilute mineral acids on these oxides, and the action of alkalis on the oxides of aluminium and zinc. *The preparation of red lead by heating lead monoxide in oxygen. The action of dilute hydrochloric and nitric acids on red lead.* The preparation of *sodium hydroxide (by electrolysis of brine and from sodium carbonate), slaked lime (from calcium oxide), ferric hydroxide (by precipitation) and cupric hydroxide (by precipitation).* The action of dilute mineral acids on these hydroxides. Uses of sodium hydroxide and slaked lime. *The manufacture of sodium carbonate by the Solvay process.* Alloys: steel, brass, *type-metal, duralumin* and soft solder. The simpler reasons for the use of these alloys in preference to the metals from which they are made.

Details of commercial plant for the blast furnace process are not required.

Details of commercial plant for the manufacture of sodium hydroxide are not required.

Candidates will be expected to know the chemistry of the Solvay process, but not the technical details of the commercial plant.

12. The preparation of salts as illustrated:

(a) by neutralization (sodium and ammonium salts of common mineral acids);

(b) by the action of an acid on the appropriate metal (zinc and ferrous sulphates), or oxide (cupric sulphate and lead nitrate) or carbonate (calcium chloride or nitrate);

(c) by precipitation involving the double decomposition (copper carbonate, lead chloride, lead sulphate);

(d) by direct union, e.g. *ferric chloride.*

13. The study of the following topics: types of chemical change; reversible reactions; catalysts as substances which alter the speeds of reactions; allotropy as exemplified by carbon and sulphur; basicity of acids, acid salts and normal salts; variable valency illustrated by ferrous and ferric salts; oxidation and reduction extended to a change in valency; methods of detecting oxidizing and reducing agents.

Some consideration should be given to the importance of surface-area catalysts, e.g. contact process.

PRACTICAL CHEMISTRY

(Not for candidates offering Physics-with-Chemistry)

In the PRACTICAL EXAMINATION candidates may be asked to observe the effects of heat and of reagents on substances supplied to them. Simple exercises in visual observation and experiments may include the recognition of the gases hydrogen, oxygen, carbon dioxide, chlorine, hydrogen chloride, hydrogen sulphide, sulphur dioxide, ammonia, nitrogen dioxide, water vapour; of the acid radicals nitrate, chloride, carbonate, sulphate, sulphite, sulphide; and of the metallic radicals lead, copper, iron, zinc, and calcium. Knowledge of a formal scheme of analysis is not required.

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 bicarbonate); (b) the equivalent 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 normalities or from reacting weights. Candidates will not be expected, in the examination, to prepare their own standard solutions.

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. 5.)

CHEMISTRY

Syllabus Alternative I

(May not be taken with General Science or Physics-with-Chemistry)

It is intended that this syllabus should be interpreted in the spirit of the Syllabus in Chemistry for Grammar Schools published for the S.M.A. and A.W.S.T. by John Murray, 1961.

There will be two papers:

Paper 1 will be a 2½-hour Theory paper containing nine questions. Question 1 will consist of several independent short-answer questions and will carry 32 marks; the remaining questions will be normal-type questions. Candidates will be required to answer Question 1 and any four other questions (68 marks).

Paper 2 will be a 2-hour Practical Test and will carry 30 marks. An Alternative-to-Practical paper will be available as from 1967 (see p. 31).

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 melting points and 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, sublimation, drying, etc. Physical change.

In studying section 1 the following substances could be used: water, alcohol, methylated spirit, benzene, paraffin, oil, salt, sand, chalk, sulphur, iron filings, copper, copper sulphate, naphthalene, paraffin wax. 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, copper, iron, lead, tin are included. It is expected that sodium will be burnt in air, but not in oxygen.

Air is necessary for burning, a portion of it is used up, a new substance is formed and there is a gain in weight. Air has mass and possibly the air used up is responsible for the gain in weight. 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 dioxide 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, copper, lead).

Acidic and basic oxides examined by litmus, also by their reactions with water, acids and alkalis. The amphoteric nature of zinc oxide.

Other methods of obtaining oxygen, e.g. by heat on mercuric oxide, lead dioxide, red lead 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 liquid 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.

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 (steam) on water, 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 preparing and burning of dry hydrogen in air.

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

The reduction of copper oxide and of lead oxides by hydrogen or coal gas.

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 acidulated water 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 sodium, potassium, calcium, magnesium, zinc, copper, lead and ammonium.

The soluble hydroxides give alkaline solution. Ammonium hydroxide for salt formation.

The action of dilute hydrochloric acid and dilute sulphuric acid on the following metals and their compounds. (i) Metals: magnesium, zinc, iron, lead, copper; (ii) metallic oxides: magnesium, zinc, lead (monoxide only), copper; (iii) hydroxides: sodium, potassium,

calcium, magnesium, zinc, copper and ammonium; (iv) metallic carbonates: sodium, potassium, 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 (i) gives opportunity for further reference to the activity series.

The preparation of insoluble salts by precipitation, e.g. silver chloride, barium sulphate, calcium sulphate, lead salts 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 sulphate, washing soda; (ii) the carbonates of calcium, magnesium, zinc, copper, lead, sodium; (iii) a few salts that show no decomposition: sodium chloride and potassium chloride.

For both copper sulphate and washing soda the action should be confined to loss of water of crystallization.

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

Water of crystallization, deliquescence, efflorescence, drying agents, hygroscopic substances.

5. Sodium and calcium carbonates. Washing soda and baking soda and how to distinguish them.

Chalk (limestone and marble), quicklime and slaked lime, lime water. Uses of lime.

The uses of lime expected include (i) agricultural for soil treatment; (ii) manufacture of cement, calcium carbide and glass (no practical details are required).

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.

Carbonic acid, carbonates and bicarbonates. At least one test for a carbonate or bicarbonate.

Hardness of water and methods of softening. Simple introduction to soap. The formation of 'fur'.

Methods of softening should include (i) the use of soap; the point being made that a lather cannot be obtained until the water is softened; (ii) boiling; (iii) the use of slaked lime; (iv) the use of sodium carbonate; (v) the zeolite or permutite process. A distinction between temporary and permanent hardness is expected, but no other methods of softening are required.

Soap should be introduced as the soluble sodium salts of a few organic acids.

The manufacture of sodium bicarbonate and sodium carbonate by the solution of carbon dioxide in sodium hydroxide solution.

Technical details are not required, but the essential chemistry is wanted.

6. Further Investigation of Non-metallic Elements.

(a) CARBON. Charcoal, graphite, diamond. The combustion of various charcoals and of graphite in oxygen. All forms burn to give carbon dioxide.

The combustion of organic matter in limited and in plentiful supplies of air.

This should be illustrated by coal, wood, candle, petrol, diesel oil.

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 coal gas, car exhaust fumes, fumes from badly ventilated fires, and in mines after explosions.

The poisonous nature of carbon monoxide should be emphasized.

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*.

Thermal decomposition of organic substances.

This should be illustrated by coal.

Origins of coal. Thermal decomposition to give coal gas, ammonia, tar, coke.

Approximate composition of crude coal gas and how the addition of water gas increases considerably its carbon monoxide content. The advantage of adding natural gas (methane) in increasing calorific value.

Water gas and producer gas.

Technical details are not required but candidates should know that the formation of water gas absorbs heat energy (endothermic).

(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 zinc, magnesium and iron; (iv) has very little reaction with carbonates.

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

The oxidizing agents expected include lead dioxide, red oxide of lead, manganese dioxide, potassium permanganate.

The properties and uses of chlorine.

The chemical properties expected are its reactions with (i) hydrogen and hydrocarbons; (ii) metals (Na, Mg, Zn, Fe, Cu); (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.

The electrolysis of brine at ordinary temperatures leading to the manufacture of sodium hydroxide.

The electrolysis should be used to illustrate (i) the use of by-products; (ii) the conservation of matter $2\text{NaCl} + 2\text{H}_2\text{O} \rightarrow 2\text{NaOH} + \text{H}_2 + \text{Cl}_2$.

Synthesis of sodium chloride and hydrogen chloride by burning the elements in chlorine.

The chlorides of sodium, potassium, calcium, zinc, ferric, copper, lead and silver.

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 bisulphites (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.

The chemicals reduced should include KMnO_4 , $\text{K}_2\text{Cr}_2\text{O}_7$, HNO_3 , H_2SO_4 , H_2O_2 , Cl_2 , Br_2 , moist SO_2 , and the effect of air on its solution. (Equations for KMnO_4 and $\text{K}_2\text{Cr}_2\text{O}_7$ are not expected.)

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

Atmospheric pollution.

At least one test for a sulphide. Sulphur dioxide. Its preparation from a sulphite. Its properties as an acid anhydride and as a reducing agent. Uses.

The chemicals reduced should include KMnO_4 , $\text{K}_2\text{Cr}_2\text{O}_7$, HNO_3 , H_2SO_4 , H_2O_2 , Cl_2 , Br_2 and the effect of air on its solution. (Equations for KMnO_4 and $\text{K}_2\text{Cr}_2\text{O}_7$ are not expected.)

The uses of sulphur dioxide expected include (i) the manufacture of sulphuric acid and of bisulphites 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, oxidizing and 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 oxidation of H_2S when cold and of C and S when hot; (iii) 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 and one test for a sulphite.

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

(d) NITROGEN and its compounds.

The laboratory preparation of nitrogen is not expected.

The laboratory preparation of ammonia.

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 amm. 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 simple properties and uses.

This should be restricted to sulphate, chloride, nitrate, carbonate.

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 laboratory preparation of nitric 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. Its action on magnesium to give hydrogen, and on copper.

The acid system is HNO_3 plus water.

The oxidation of H_2S , SO_2 , HCl and ferrous salts is required.

A simple comparison of nitric oxide and nitrogen dioxide.

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

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

At least 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.

The nitrogen cycle.

Fertilizers generally, there is a real necessity for nitrogen, phosphorus and potassium and a smaller need for calcium, magnesium,

iron and sulphur. Adequate supplies of carbon, hydrogen and oxygen are always present, provided water is available.

Fertilizers should include ammonium sulphate, potassium nitrate and superphosphates.

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

The reactions of the above metals with air, water (steam) and acids.

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 coal gas.

The precipitation of the hydroxides of the metals including ferrous and ferric, and the amphoteric nature of zinc, aluminium and lead hydroxides.

The effect of heat on the metallic hydroxides and its application in identifying the original metallic radical.

The effect of heat on washing soda, baking soda, common salt, chalk, limestone, the carbonates of lead, zinc and copper, and the nitrates.

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

Flame tests for Na^+ , K^+ , Ca^{2+} , Cu^{2+} .

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, copper, lead and the alloys, steels, brass, solder, type-metals, duralumin. The simple reasons for the use of these alloys in preference to the metals from which they are made.

8. 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.

The nature of matter, evidence leading to particle theories, experiments to test these, diffusion and Brownian movement.

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

Definition of atom and molecule.

The atom to emerge as the smallest particle having the properties of the element.

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, determined empirically by physical methods, showing isotopes.

The values of atomic weights 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. The relationship between atomic weights and combining weights should be stressed.

Atomic weight scale. Combining weights. 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.

It should be made clear that the relative masses of atoms can only be found chemically from the combining weights if the combining number of the element is known.

Combining numbers, later called valencies in this syllabus, are found by way of the relative atomic masses (given by physical or chemical methods) and the combining weight (equivalent).

The combining weights are to be accepted values as they have been determined by accurate experiments.

Experimental confirmation of the law of conservation of matter and the law of constant composition can be used to illustrate the concept of combining weights.

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

The idea of multiple valencies. The idea of the gram-atom and gram-formula.

Whatever the size and mass of the atom one gram-atom of all elements will contain the same number of atoms.

Chemical equations.

9. The Study of Gases. The laws of Boyle and Charles, Gay-Lussac and Avogadro.

It is not intended that questions should be asked requiring the experimental proof of Boyle's and Charles' laws but that questions requiring the application of these laws may be set.

Volume relationships exemplified by hydrogen chloride, steam, sulphur dioxide, carbon dioxide, carbon monoxide and ammonia.

Practical details of the demonstration of the volume relationships are not required.

Atomicity of hydrogen.

The atomicity of chlorine and of oxygen should also be described, the latter from the volume composition of steam: the atomicity of other gases to be given.

The relation between the vapour density of a gas and its molecular weight.

This will lead to the formulae of hydrogen chloride, steam, carbon dioxide, sulphur dioxide, the latter two by using the atomic weights of carbon and sulphur. Other gaseous formulae should be given.

The gram-molecular volume as 22.4 litres when the conditions are 0° C. and 760 mm. pressure.

10. Quantitative Work on Chemical Equations. (a) Standard solutions of HCl, HNO₃, H₂SO₄, acetic acid (formula and equation given), NaOH, KOH, Na₂CO₃, NaHCO₃, KHCO₃ and the relevant titration work and simple calculations.

The concentration of solutions to be quoted in grams per litre and either normalities or molarities. Question will be framed so that either normalities or molarities may be used.

Chemical equations and the quantitative information obtainable from an equation, including the volumes of gases evolved.

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 H₂O₂. Catalysts expected include (i) MnO₂ on H₂O₂; (ii) Pt or V₂O₅ in contact process; (iii) Fe (Fe₂O₃) 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).

Heat is evolved in many reactions but it is absorbed in water gas formation. Light is also evolved in some reactions; it is absorbed in photosynthesis and in photography and affects the reaction between hydrogen and chlorine.

Calorific value of fuels and foods.

The oxidation of food occurs slowly at body temperatures and fuels oxidize rapidly at high temperatures.

It is not intended that lists of values should be taught but that there should be (i) an understanding of comparative values; (ii) an appreciation of ignition temperatures.

11. 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 molar 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 gram-atom of an element, and the realization that some atoms require twice as much electricity to liberate them as 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.

Evidence from conductance of metals should be mentioned.

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 gram-atom.

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 acidulated water with platinum and copper electrodes; (ii) the electrolysis of cold brine with carbon electrodes, excluding formation of sodium hypochlorite; (iii) the electrolysis of copper sulphate solution with copper and platinum electrodes; (iv) the isolation of lead from fused lead bromide. In all cases technical details are not required.

12. Organic Chemistry. The structure of simple organic compounds from the study of paraffins, olefines, 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), hydrogen chloride, concentrated sulphuric acid and hydrogen; (iii) for alcohols: burning, their reaction with sodium, with phosphorus trichloride or phosphorus pentachloride, 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, their reaction with phosphorus trichloride or phosphorus pentachloride.

13. 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.

This transfer gives rise to 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.

Compounds formed by this bonding are non-conductors.

(c) Crystals formed from atoms, molecules and ions.

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

A simple model of an atom as consisting of a 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.

Nuclear changes, unlike normal chemical reactions, involve changes in the structure of the nucleus, i.e. in the number of protons and neutrons therein. The liberation of considerable quantities of energy may be involved in nuclear changes.

14. The Chemical Industry. Raw materials and their sources.

The air, the sea, mineral (including sulphide) ores, coal, petroleum should be quoted as sources.

The scope of the industry—heavy chemicals, fine chemicals, medicinals, fertilizers, glass, ceramics, plastics, etc.

Only a simple review is intended.

The study of the following manufacturing processes: (i) iron and steel; blast furnace and manufacture of steel by the converter process, using oxygen (or by the open-hearth process); (ii) the Haber process and its importance to agriculture; (iii) the contact process for sulphuric acid; (iv) the electrolysis of brine at ordinary temperatures to give sodium hydroxide.

PRACTICAL CHEMISTRY

In the PRACTICAL EXAMINATION candidates may be asked to observe the effect of heat and of reagents on substances supplied to them. Simple exercises in visual observation and experiments 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 acid radicals: nitrate, chloride, carbonate, sulphate, sulphite, sulphide; and (c) the metallic radicals: lead, copper ion, zinc and calcium. Knowledge of a formal scheme of analysis is not required.

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 bicarbonate); (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 weights 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.

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 pp. 5 and 37.)