SYLLABUS FOR CHEMISTRY ENTRANCE TEST

1. Experimental Chemistry

(a) Experimental design

- name appropriate apparatus for the measurement of time, temperature, mass and volume, including burettes, pipettes, measuring cylinders and gas syringes
- suggest suitable apparatus, given relevant information, for a variety of simple experiments, including collection of gases and measurement of rates of reaction.

(b) Methods of purification and analysis

- describe methods of separation and purification for the components of mixtures, to include:
  (i) use of a suitable solvent, filtration and crystallisation or evaporation
  (ii) sublimation
  (iii) distillation and fractional distillation
  (iv) use of a separating funnel
  (v) paper chromatography
- suggest suitable separation and purification methods, given information about the substances involved in the following types of mixtures:
  (i) solid-solid
  (ii) solid-liquid
  (iii) liquid-liquid (miscible and immiscible)
- interpret paper chromatograms including comparison with 'known' samples and the use of Rf values
- explain the need to use locating agents in the chromatography of colourless compounds (knowledge of specific locating agents is not required)
- deduce from given melting point and boiling point data the identities of substances and their purity
- explain that the measurement of purity in substances used in everyday life, e.g. foodstuffs and drugs, is important.

(c) Identification of ions and gases

- describe the use of aqueous sodium hydroxide and aqueous ammonia to identify the following aqueous cations: aluminium, ammonium, calcium, copper(II), iron(II), iron(III), lead(II) and zinc (formulae of complex ions are not required)
- describe tests to identify the following anions: carbonate (by the addition of dilute acid and subsequent use of limewater); chloride (by reaction of an aqueous solution with nitric acid and aqueous silver nitrate); iodide (by reaction of an aqueous solution with nitric acid and aqueous silver nitrate); nitrate (by reduction with aluminium in aqueous sodium hydroxide to ammonia and subsequent use of litmus paper) and sulfate (by reaction of an aqueous solution with nitric acid and aqueous barium nitrate)
- describe tests to identify the following gases: ammonia (using damp red litmus paper); carbon dioxide (using limewater); chlorine (using damp litmus paper); hydrogen (using a burning splint); oxygen (using a glowing splint) and sulfur dioxide (using acidified potassium manganate(VII)).

2. The Particulate Nature of Matter

(a) Kinetic particle theory

- describe the solid, liquid and gaseous states of matter and explain their interconversion in terms of the kinetic particle theory and of the energy changes involved
- describe and explain evidence for the movement of particles in liquids and gases (the treatment of Brownian motion is not required)
- explain everyday effects of diffusion in terms of particles, e.g. the spread of perfumes and cooking aromas; tea and coffee grains in water
- state qualitatively the effect of molecular mass on the rate of diffusion and explain the dependence of rate of diffusion on temperature.

(b) Atomic structure

- state the relative charges and approximate relative masses of a proton, a neutron and an electron
- describe, with the aid of diagrams, the structure of an atom as containing protons and neutrons (nucleons) in the nucleus and electrons arranged in shells (energy levels) (knowledge of s, p, d and f classification is not required; a copy of the Periodic Table will be available)
- define proton (atomic) number and nucleon (mass) number
- interpret and use symbols such as $^{12}_{6}C$
- define the term isotopes
- deduce the numbers of protons, neutrons and electrons in atoms and ions given proton and nucleon numbers.

(c) Structure and properties of materials

- describe the differences between elements, compounds and mixtures
- compare the structure of simple molecular substances, e.g. methane; iodine, with those of giant molecular substances, e.g. poly(ethene); sand (silicon dioxide); diamond; graphite in order to deduce their properties
- compare the bonding and structures of diamond and graphite in order to deduce their properties such as electrical conductivity, lubricating or cutting action (candidates will not be required to draw the structures)
- deduce the physical and chemical properties of substances from their structures and bonding and vice versa.

(d) Ionic bonding

- describe the formation of ions by electron loss/gain in order to obtain the electronic configuration of a noble gas
- describe the formation of ionic bonds between metals and non-metals, e.g. $NaCl$; $MgCl_2$
- state that ionic materials contain a giant lattice in which the ions are held by electrostatic attraction, e.g. $NaCl$ (candidates will not be required to draw diagrams of ionic lattices)
- deduce the formulae of other ionic compounds from diagrams of their lattice structures, limited to binary compounds
- relate the physical properties (including electrical property) of ionic compounds to their lattice structure.

(e) Covalent bonding

- describe the formation of a covalent bond by the sharing of a pair of electrons in order to gain the electronic configuration of a noble gas
- describe, using 'dot-and-cross' diagrams, the formation of covalent bonds between non-metallic elements, e.g. H_2; O_2; H_2O; CH_4; CO_2
- deduce the arrangement of electrons in other covalent molecules
- relate the physical properties (including electrical property) of covalent substances to their structure and bonding.

(f) Metallic bonding

- describe metals as a lattice of positive ions in a 'sea of electrons'
- relate the electrical conductivity of metals to the mobility of the electrons in the structure

3. Formulae, Stoichiometry and the Mole Concept

- state the symbols of the elements and formulae of the compounds mentioned in the syllabus
- deduce the formulae of simple compounds from the relative numbers of atoms present and vice versa
- deduce the formulae of ionic compounds from the charges on the ions present and vice versa
- interpret chemical equations with state symbols
- construct chemical equations, with state symbols, including ionic equations
- define relative atomic mass, Ar
- define relative molecular mass, Mr, and calculate relative molecular mass (and relative formula mass) as the sum of relative atomic masses
- calculate the percentage mass of an element in a compound when given appropriate information
- calculate empirical and molecular formulae from relevant data
- calculate stoichiometric reacting masses and volumes of gases (one mole of gas occupies 24 dm^3 at room temperature and pressure); calculations involving the idea of limiting reactants may be set (Knowledge of the gas laws and the calculations of gaseous volumes at different temperatures and pressures are not required.)
- apply the concept of solution concentration (in mol / dm^3 or g / dm^3) to process the results of volumetric experiments and to solve simple problems (Appropriate guidance will be provided where unfamiliar reactions are involved.)
- calculate % yield and % purity.

4. Electrolysis

- describe electrolysis as the conduction of electricity by an ionic compound (an electrolyte), when molten or dissolved in water, leading to the decomposition of the electrolyte
- describe electrolysis as evidence for the existence of ions which are held in a lattice when solid but which are free to move when molten or in solution
- describe, in terms of the mobility of ions present and the electrode products, the electrolysis of molten sodium chloride, using inert electrodes
- predict the likely products of the electrolysis of a molten binary compound
- apply the idea of selective discharge based on

(i) cations: linked to the reactivity series

(ii) anions: halides, hydroxides and sulfates (e.g. aqueous copper(II) sulfate and dilute sodium chloride solution (as essentially the electrolysis of water))

(iii) concentration effects (as in the electrolysis of concentrated and dilute aqueous sodium chloride)

(In all cases above, inert electrodes are used.)

- predict the likely products of the electrolysis of an aqueous electrolyte, given relevant information
- construct ionic equations for the reactions occurring at the electrodes during the electrolysis, given relevant information
- describe the electrolysis of aqueous copper(II) sulfate with copper electrodes as a means of purifying copper (no technical details are required)
- describe the electroplating of metals, e.g. copper plating, and state one use of electroplating
- describe the production of electrical energy from simple cells (i.e. two electrodes in an electrolyte) linked to the reactivity series and redox reactions (in terms of electron transfer).

5. Energy from Chemicals

- describe the meaning of enthalpy change in terms of exothermic (ΔH negative) and endothermic (ΔH positive) reactions
- represent energy changes by energy profile diagrams, including reaction enthalpy changes and activation energies
- describe bond breaking as an endothermic process and bond making as an exothermic process
- explain overall enthalpy changes in terms of the energy changes associated with the breaking and making of covalent bonds
- describe hydrogen, derived from water or hydrocarbons, as a potential fuel, reacting with oxygen to generate electricity directly in a fuel cell (details of the construction and operation of a fuel cell are not required).

6. Chemical Reactions

(a) Speed of reaction

- describe the effect of concentration, pressure, particle size and temperature on the speeds of reactions and explain these effects in terms of collisions between reacting particles
- define the term catalyst and describe the effect of catalysts (including enzymes) on the speeds of reactions
- explain how pathways with lower activation energies account for the increase in speeds of reactions
- state that some compounds act as catalysts in a range of industrial processes and that enzymes are biological catalysts
- suggest a suitable method for investigating the effect of a given variable on the speed of a reaction
- interpret data obtained from experiments concerned with speed of reaction.

(b) Redox

- define oxidation and reduction (redox) in terms of oxygen/hydrogen gain/loss
- define redox in terms of electron transfer and changes in oxidation state
- identify redox reactions in terms of oxygen/hydrogen gain/loss, electron gain/loss and changes in oxidation state

- describe the use of aqueous potassium iodide and acidified potassium manganate(VII) in testing for oxidising and reducing agents from the resulting colour changes.

7. Acids, Bases and Salts

(a) Acids and bases

- describe the meanings of the terms acid and alkali in terms of the ions they produce in aqueous solution and their effects on Universal Indicator
- describe how to test hydrogen ion concentration and hence relative acidity using Universal Indicator and the pH scale
- describe qualitatively the difference between strong and weak acids in terms of the extent of ionization
- describe the characteristic properties of acids as in reactions with metals, bases and carbonates
- state the uses of sulfuric acid in the manufacture of detergents and fertilisers; and as a battery acid
- describe the reaction between hydrogen ions and hydroxide ions to produce water, $H^+ + OH^- \rightarrow H_2O$, as neutralization
- describe the importance of controlling the pH in soils and how excess acidity can be treated using calcium hydroxide
- describe the characteristic properties of bases in reactions with acids and with ammonium salts
- classify oxides as acidic, basic, amphoteric or neutral based on metallic/non-metallic character.

(b) Salts

- describe the techniques used in the preparation, separation and purification of salts (methods for preparation should include precipitation and titration together with reactions of acids with metals, insoluble bases and insoluble carbonates)
- describe the general rules of solubility for common salts to include nitrates, chlorides (including silver and lead), sulfates (including barium, calcium and lead), carbonates, hydroxides, salts of Group I cations and ammonium salts
- suggest a method of preparing a given salt from suitable starting materials, given appropriate information.

(c) Ammonia

- describe the use of nitrogen, from air, and hydrogen, from the cracking of crude oil, in the manufacture of ammonia
- state that some chemical reactions are reversible, e.g. manufacture of ammonia
- describe the essential conditions for the manufacture of ammonia by the Haber process
- describe the displacement of ammonia from its salts.

8. The Periodic Table

(a) Periodic trends

- describe the Periodic Table as an arrangement of the elements in the order of increasing proton (atomic) number
- describe how the position of an element in the Periodic Table is related to proton number and electronic structure
- describe the relationship between group number and the ionic charge of an ion of an element

- explain the similarities between the elements in the same group of the Periodic Table in terms of their electronic structure
- describe the change from metallic to non-metallic character from left to right across a period of the Period Table
- describe the relationship between group number, number of valency electrons and metallic/ non-metallic character
- predict the properties of elements in Group I and Group VII using the Periodic Table.

(b) Group properties

- describe lithium, sodium and potassium in Group I (the alkali metals) as a collection of relatively soft, low-density metals showing a trend in melting point and in their reaction with water
- describe chlorine, bromine and iodine in Group VII (the halogens) as a collection of diatomic, nonmetals showing a trend in colour, state and their displacement reactions with solutions of other halide ions
- describe the elements in Group 0 (the noble gases) as a collection of monatomic elements that are chemically unreactive and hence important in providing an inert atmosphere, e.g. argon and neon in light bulbs; helium in balloons; argon in the manufacture of steel
- describe the lack of reactivity of the noble gases in terms of their electronic structures.

(c) Transition elements

- describe typical transition elements as metals having high melting point, high density, variable oxidation state and forming coloured compounds
- state that the elements and/or their compounds are often able to act as catalysts.

9. Metals

(a) Properties of metals

- describe the general physical properties of metals as solids having high melting and boiling points, malleable, good conductors of heat and electricity in terms of their structure
- describe alloys as a mixture of a metal with another element, e.g. brass; stainless steel
- identify representations of metals and alloys from diagrams of structures
- explain why alloys have different physical properties to their constituent elements.

(b) Reactivity series

- place in order of reactivity calcium, copper, (hydrogen), iron, lead, magnesium, potassium, silver, sodium and zinc by reference to
  (i) the reactions, if any, of the metals with water, steam and dilute hydrochloric acid,
  (ii) the reduction, if any, of their oxides by carbon and/or by hydrogen
- describe the reactivity series as related to the tendency of a metal to form its positive ion, illustrated by its reaction with
  (i) the aqueous ions of the other listed metals
  (ii) the oxides of the other listed metals
- deduce the order of reactivity from a given set of experimental results
- describe the action of heat on the carbonates of the listed metals and relate thermal stability to the reactivity series.

(c) Extraction of metals

- describe the ease of obtaining metals from their ores by relating the elements to their positions in the reactivity series.

(d) Recycling of metals

- describe metal ores as a finite resource and hence the need to recycle metals, e.g. recycling of iron
- discuss the social, economic and environmental issues of recycling metals.

(e) Iron

- describe and explain the essential reactions in the extraction of iron using haematite, limestone and coke in the blast furnace
- describe steels as alloys which are a mixture of iron with carbon or other metals and how controlled use of these additives changes the properties of the iron, e.g. high carbon steels are strong but brittle whereas low carbon steels are softer and more easily shaped
- state the uses of mild steel, e.g. car bodies; machinery, and stainless steel, e.g. chemical plants; cutlery; surgical instruments
- describe the essential conditions for the corrosion (rusting) of iron as the presence of oxygen and water; prevention of rusting can be achieved by placing a barrier around the metal, e.g. painting; greasing; plastic coating; galvanizing
- describe the sacrificial protection of iron by a more reactive metal in terms of the reactivity series where the more reactive metal corrodes preferentially, e.g. underwater pipes have a piece of magnesium attached to them.

10. Air

- describe the volume composition of gases present in dry air as being approximately 78% nitrogen, 21% oxygen and the remainder being noble gases (with argon as the main constituent) and carbon dioxide
- name some common atmospheric pollutants, e.g. carbon monoxide; methane; nitrogen oxides (NO and NO_2); ozone; sulfur dioxide; unburned hydrocarbons
- state the sources of these pollutants as
  (i) carbon monoxide from incomplete combustion of carbon-containing substances
  (ii) nitrogen oxides from lightning activity and internal combustion engines
  (iii) sulfur dioxide from volcanoes and combustion of fossil fuels
- describe the reactions used in possible solutions to the problems arising from some of the pollutants named above
  (i) the redox reactions in catalytic converters to remove combustion pollutants
  (ii) the use of calcium carbonate to reduce the effect of ‘acid rain’ and in flue gas desulfurisation
- discuss some of the effects of these pollutants on health and on the environment
  (i) the poisonous nature of carbon monoxide
  (ii) the role of nitrogen dioxide and sulfur dioxide in the formation of ‘acid rain’ and its effects on respiration and buildings
- discuss the importance of the ozone layer and the problems involved with the depletion of ozone by reaction with chlorine-containing compounds, chlorofluorocarbons (CFCs)

- describe the carbon cycle in simple terms, to include
    (i) the processes of combustion, respiration and photosynthesis
    (ii) how the carbon cycle regulates the amount of carbon dioxide in the atmosphere
- state that carbon dioxide and methane are greenhouse gases and may contribute to global warming, give the sources of these gases and discuss the possible consequences of an increase in global warming.

11. Organic Chemistry

(a) Fuels and crude oil

- name natural gas, mainly methane, and petroleum as sources of energy
- describe petroleum as a mixture of hydrocarbons and its separation into useful fractions by fractional distillation
- name the following fractions and state their uses
    (i) petrol (gasoline) as a fuel in cars
    (ii) naphtha as the feedstock and main source of hydrocarbons used for the production of a wide range of organic compounds in the petrochemical industry
    (iii) paraffin (kerosene) as a fuel for heating and cooking and for aircraft engines
    (iv) diesel as a fuel for diesel engines
    (v) lubricating oils as lubricants and as a source of polishes and waxes
    (vi) bitumen for making road surfaces
- describe the issues relating to the competing uses of oil as an energy source and as a chemical feedstock.

(b) Alkanes

- describe a homologous series as a group of compounds with a general formula, similar chemical properties and showing a gradation in physical properties as a result of increase in the size and mass of the molecules, e.g. melting and boiling points; viscosity; flammability
- describe the alkanes as a homologous series of saturated hydrocarbons with the general formula C_nH_{2n+2}
- draw the structures of branched and unbranched alkanes, C_1 to C_4, and name the unbranched alkanes methane to butane
- define isomerism and identify isomers
- describe the properties of alkanes (exemplified by methane) as being generally unreactive except in terms of combustion and substitution by chlorine.

(c) Alkenes

- describe the alkenes as a homologous series of unsaturated hydrocarbons with the general formula C_nH_{2n}
- draw the structures of branched and unbranched alkenes, C_2 to C_4, and name the unbranched alkenes ethene to butene
- describe the manufacture of alkenes and hydrogen by cracking hydrocarbons and recognise that cracking is essential to match the demand for fractions containing smaller molecules from the refinery process

- describe the difference between saturated and unsaturated hydrocarbons from their molecular structures and by using aqueous bromine
- describe the properties of alkenes (exemplified by ethene) in terms of combustion, polymerization and the addition reactions with bromine, steam and hydrogen
- state the meaning of polyunsaturated when applied to food products
- describe the manufacture of margarine by the addition of hydrogen to unsaturated vegetable oils to form a solid product.

(d) Alcohols

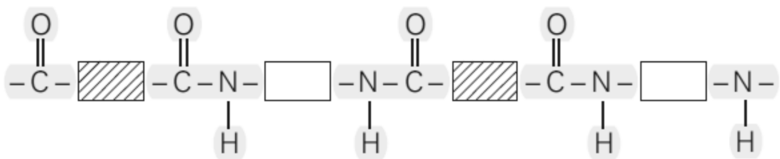
- describe the alcohols as a homologous series containing the –OH group
- draw the structures of alcohols, C_1 to C_4, and name the unbranched alcohols methanol to butanol
- describe the properties of alcohols in terms of combustion and oxidation to carboxylic acids
- describe the formation of ethanol by the catalysed addition of steam to ethene and by fermentation of glucose
- state some uses of ethanol, e.g. as a solvent; as a fuel; as a constituent of alcoholic beverages.

(e) Carboxylic acids

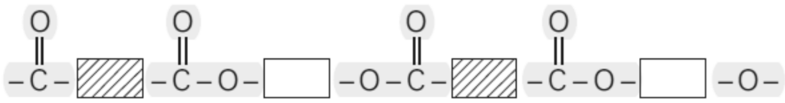
- describe the carboxylic acids as a homologous series containing the $–CO_2H$ group
- draw the structures of carboxylic acids, methanoic acid to butanoic acid, and name the unbranched acids, methanoic acid to butanoic acid
- describe the carboxylic acids as weak acids, reacting with carbonates, bases and some metals
- describe the formation of ethanoic acid by the oxidation of ethanol by atmospheric oxygen or acidified potassium manganate(VII)
- describe the reaction of a carboxylic acid with an alcohol to form an ester, e.g. ethyl ethanoate
- state some commercial uses of esters, e.g. perfumes; flavourings; solvents.

(f) Macromolecules

- describe macromolecules as large molecules built up from small units, different macromolecules having different units and/or different linkages
- describe the formation of poly(ethene) as an example of addition polymerisation of ethene as the monomer
- state some uses of poly(ethene) as a typical plastic, e.g. plastic bags; clingfilm
- deduce the structure of the polymer product from a given monomer and vice versa
- describe nylon, a polyamide, and Terylene, a polyester, as condensation polymers, the partial structure of nylon being represented as



and the partial structure of Terylene as



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

- state some typical uses of man-made fibres such as nylon and Terylene, e.g. clothing; curtain materials; fishing line; parachutes; sleeping bags
- describe the pollution problems caused by the disposal of non-biodegradable plastics.