Chemistry

JAMB UTME Syllabus: topics and objectives

Aim. This syllabus prepares you for the UTME in Chemistry. It tests whether you can: (1) understand the basic principles and concepts of chemistry; (2) interpret scientific data relating to chemistry; (3) work out the links between chemistry and the other sciences; and (4) apply chemistry to industry and everyday life.

How to use it. The left column lists what the topic covers. The right column lists what you should be able to do after studying it. Tick each objective off as you master it, and practise past questions on each topic.

1. SEPARATION OF MIXTURES AND PURIFICATION OF CHEMICAL SUBSTANCES

TOPICS / CONTENTS	OBJECTIVES: candidates should be able to
• Elements, compounds and mixtures; chemical and physical changes; pure and impure substances • Boiling, density, freezing and melting points • Separation methods: evaporation, simple and fractional distillation, sublimation, re-crystallisation, paper and column chromatography, simple and fractional crystallisation, magnetisation, decantation, filtration, centrifugation	1. Distinguish elements, compounds and mixtures 2. Differentiate chemical from physical changes, and pure from impure substances 3. Use boiling and melting points as tests of purity 4. Identify the properties of the parts of a mixture 5. State the principle behind each separation method 6. Apply the principles of separation to everyday life

2. CHEMICAL COMBINATION

TOPICS / CONTENTS	OBJECTIVES: candidates should be able to
• Laws of definite, multiple and reciprocal proportions; law of conservation of matter • Chemical symbols, formulae and equations, and their uses • Relative atomic mass based on $^{12}C = 12$ • The mole concept and stoichiometry of reactions	1. Deduce the chemical laws from given statements, expressions and data 2. Do simple calculations on formulae, equations, chemical composition and the mole concept 3. Deduce the stoichiometry of chemical reactions

3. KINETIC THEORY OF MATTER AND GAS LAWS

TOPICS / CONTENTS	OBJECTIVES: candidates should be able to
• Evidence for the kinetic theory: melting, vaporisation, boiling, freezing and condensation in terms of molecular motion and Brownian movement • Laws of Boyle, Charles, Avogadro, Gay-Lussac, Graham and Dalton (partial pressure); molar volume and atomicity of gases • Ideal gas equation PV = nRT • Vapour density and relative molecular mass • Ideal and real gases	1. Use the theory to tell solids, liquids and gases apart and to explain changes of state 2. Draw conclusions from molecular motion 3. Deduce the gas laws from given statements and expressions and interpret their graphs 4. Do simple calculations based on the gas laws and equations 5. State why real gases deviate from ideal behaviour

4. ATOMIC STRUCTURE AND BONDING

TOPICS / CONTENTS	OBJECTIVES: candidates should be able to
• Atoms, molecules and ions; the work of Dalton, Millikan, Rutherford, Moseley, Thomson and Bohr • Atomic structure: four quantum numbers, rules for arranging electrons in orbitals, electron configuration, atomic number, mass number and isotopes (examples from elements 1 to 20); shapes of s and p orbitals • Periodic table and periodicity: families (alkali metals, alkaline-earth metals, halogens, noble gases, transition metals); trends in ionisation energy, ionic radii, electron affinity, electronegativity, electrical and thermal conductivity • Chemical bonding: electrovalency, covalency, hydrogen bonding, metallic bonding, coordinate bonds (e.g. $[Fe(CN)_6]^{3-}$, $[Fe(CN)_6]^{4-}$, $[Cu(NH_3)_4]^{2+}$, $[Ag(NH_3)_2]^{+}$), van der Waals forces • Shapes of simple molecules: linear (H_2, O_2, Cl_2, HCl, CO_2), non-linear (H_2O), tetrahedral (CH_4), pyramidal (NH_3)	1. Distinguish atoms, molecules and ions and state the contributions of each scientist 2. Work out the numbers of protons, neutrons and electrons from atomic and mass numbers 3. Apply the rules for arranging electrons in an atom 4. Identify elements with isotopes, relate isotopy to mass number and do simple isotope calculations 5. Tell the shapes of the orbitals apart and find the number of electrons in s and p orbitals 6. Relate atomic number to an element's place in the periodic table and relate properties within groups 7. Explain trends across periods and down groups 8. Differentiate the types of bonding, deduce bond type from electron configuration and relate bonding to properties 9. Differentiate the shapes of molecules

5. NUCLEAR CHEMISTRY

TOPICS / CONTENTS	OBJECTIVES: candidates should be able to
• Radioactivity: types, properties and detection of radiation • Natural and artificial radioactivity • Nuclear stability and radioactive decay • Nuclear fusion and fission	1. Distinguish ordinary chemical reactions from nuclear reactions 2. Differentiate natural from artificial radioactivity 3. Compare the properties of the types of nuclear radiation 4. Do simple half-life calculations and balance simple nuclear equations 5. Identify the applications of radioactivity

6. SOLUBILITY

TOPICS / CONTENTS	OBJECTIVES: candidates should be able to
• Unsaturated, saturated and supersaturated solutions; solubility curves and simple deductions (solubility in mol per dm^3); simple calculations • Solvents for fats, oil, perspiration and paints; removing stains • True and false solutions: suspensions and colloids (harmattan haze and water paints as suspensions; fog, milk, blood, aerosol spray, emulsion paints and rubber solution as colloids)	1. Distinguish the types of solution and interpret solubility curves 2. Calculate how much solute dissolves in a given amount of solvent at a given temperature 3. Show that solubility depends on temperature 4. Relate the nature of solvents to their uses 5. Differentiate true solutions, suspensions and colloids, and give examples

7. ENVIRONMENTAL POLLUTION

TOPICS / CONTENTS	OBJECTIVES: candidates should be able to
• Air: natural gaseous constituents and their proportions (nitrogen, oxygen, water vapour, carbon(IV) oxide, noble gases); why composition varies; air as a mixture and uses of noble gases • Air pollution: H_2S, CO, SO_2, oxides of nitrogen, chlorofluorocarbons and dust; sources and effects • Water pollution: sewage and oil • Soil pollution: oil spillage; biodegradable and non-biodegradable pollutants	1. Give reasons why air is a mixture and state the principle used to separate its components 2. State why the composition of air varies and the uses of its constituents 3. Identify the types, sources and effects of pollution and classify pollutants as biodegradable or not 4. Identify ways of controlling pollution

8. ACIDS, BASES AND SALTS

TOPICS / CONTENTS	OBJECTIVES: candidates should be able to
• General properties and uses; acid-base indicators; basicity of acids; normal, acidic, basic and double salts • Acid defined as an H_3O^+ source or proton donor; naturally occurring organic acids (ethanoic, citric, tartaric); alums as double salts • Preparing salts by neutralisation, precipitation and action of acids on metals; oxides and trioxocarbonate(IV) salts • Conductance of molar solutions of strong and weak acids and bases, and its link to the amount of ions • pH and pOH scales, simple calculations, importance of pH, buffer solutions • Acid-base titrations • Hydrolysis of salts (e.g. NH_4Cl, $AlCl_3$, Na_2CO_3, CH_3COONa)	1. Distinguish acids from bases and identify their types 2. Determine the basicity of acids and use indicators to tell acidity from alkalinity 3. Identify the methods of preparing salts and classify salts 4. Relate degree of dissociation to strength of acids and bases and to conductance 5. Do simple pH and pOH calculations; state the importance of pH and the uses of buffers 6. Choose the right indicator, read titration curves and do calculations based on the mole concept 7. Balance equations for hydrolysis of salts and say whether the solution is acidic, basic or neutral

9. OXIDATION AND REDUCTION (REDOX)

TOPICS / CONTENTS	OBJECTIVES: candidates should be able to
• Oxidation as gain of oxygen; reduction as loss of oxygen (with hydrogen) • Oxidation and reduction as electron transfer • Oxidation numbers: change in oxidation number, balancing simple equations • IUPAC naming of inorganic compounds using oxidation numbers • Tests for oxidising and reducing agents	1. Identify the ways of expressing oxidation and reduction and classify reactions as oxidation or reduction 2. Balance redox equations and work out oxidation numbers 3. Count the electrons transferred in a redox reaction 4. Name the redox species and tell oxidising from reducing agents 5. Use oxidation numbers to name inorganic compounds and relate reagents to their oxidising or reducing ability

10. ELECTROLYSIS

TOPICS / CONTENTS	OBJECTIVES: candidates should be able to
• Electrolytes and non-electrolytes; Faraday's laws • Electrolysis of dilute H_2SO_4, aqueous $CuSO_4$, $CuCl_2$, dilute and concentrated NaCl, and fused NaCl; factors affecting discharge of ions • Uses: purifying metals such as copper; producing Al, Na, O_2, Cl_2 and NaOH • Electrochemical cells: electrochemical series (K, Ca, Na, Mg, Al, Zn, Fe, Sn, Pb, H, Cu, Hg, Ag, Au); half-cell reactions and electrode potentials (simple calculations) • Corrosion as an electrolytic process; cathodic protection, painting, electroplating, greasing and oiling	1. Distinguish electrolytes from non-electrolytes 2. Do calculations treating the faraday as a mole of electrons 3. Identify suitable electrodes, write the electrode reactions and find the products 4. Identify the factors that affect the products of electrolysis and its uses 5. State the importance of the electrochemical series and identify electrochemical cells 6. Calculate electrode potentials from half-cell equations 7. Identify methods of protecting metals from corrosion

11. ENERGY CHANGES

TOPICS / CONTENTS	OBJECTIVES: candidates should be able to
• Heat changes (ΔH) in physical and chemical processes, e.g. dissolving or reacting Na, NaOH, K, NH_4Cl with water; endothermic (+ΔH) and exothermic (-ΔH) reactions • Entropy as order and disorder: mixing of gases, dissolving salts • Spontaneity: ΔG = 0 at equilibrium; ΔG above or below zero as the test for non-spontaneity or spontaneity	1. Determine the types of heat change in physical and chemical processes and interpret graphs of heat changes 2. Relate the physical state of a substance to how ordered it is 3. Determine the conditions for a reaction to be spontaneous 4. Relate ΔH, ΔS and ΔG as driving forces of reactions 5. Solve simple problems using $\Delta G = \Delta H - T\Delta S$

12. RATES OF CHEMICAL REACTION

TOPICS / CONTENTS	OBJECTIVES: candidates should be able to
• Factors that change reaction rate: temperature (HCl with $Na_2S_2O_3$ or Mg), concentration or pressure (HCl with $Na_2S_2O_3$, HCl with marble, iodine clock), surface area (powdered versus lump marble), catalyst (decomposition of H_2O_2 or $KClO_3$ with MnO_2) • Reaction rate curves • Activation energy: Arrhenius' law and collision theory (qualitative); effect of light, e.g. halogenation of alkanes	1. Identify the factors that affect reaction rate and the effect of each one 2. Choose suitable catalysts and say how to moderate these effects 3. Interpret reaction rate curves and solve simple rate problems 4. Relate reaction rate to the kinetic theory of matter 5. Explain the importance of activation energy and read its value from rate curves

13. CHEMICAL EQUILIBRIA

TOPICS / CONTENTS	OBJECTIVES: candidates should be able to
• Reversible reactions and the factors that decide the position of equilibrium; dynamic equilibrium • Le Chatelier's principle and its industrial uses; equilibrium constant • Simple examples: steam on iron, N_2O_4 and NO_2 (no calculations)	1. Identify the factors that affect the position of equilibrium and predict their effects 2. State the industrial processes where Le Chatelier's principle matters 3. Determine the effects of these factors on the equilibrium constant

14. NON-METALS AND THEIR COMPOUNDS

TOPICS / CONTENTS	OBJECTIVES: candidates should be able to
• Hydrogen: commercial production, laboratory preparation, properties, uses, test • Halogens: chlorine as the representative element; preparation, properties, uses; hydrogen chloride and hydrochloric acid; chlorides and their test • Oxygen: preparation, properties, uses, production from liquid air; acidic, basic, amphoteric and neutral oxides; ozone as an allotrope • Water: composition, solvent properties, dissolved gases; hard and soft water and softening; treatment for town supply; water of crystallisation, efflorescence, deliquescence, hygroscopy • Sulphur: allotropes and uses; SO_2; trioxosulphate(IV) acid and salts; H_2SO_4 (contact process, dilute acid, oxidising and dehydrating agent, uses); H_2S; tests for SO_4^{2-}, SO_3^{2-}, SO_2, S^{2-}, H_2S • Nitrogen: laboratory preparation, production from liquid air; ammonia (Haber process, properties, uses, ammonium salts); trioxonitrate(V) acid and salts; oxides of nitrogen; the nitrogen cycle; tests for NH_4^+, NH_3, NO_3^- • Carbon: allotropes; CO_2 and tests for CO_3^{2-}, HCO_3^-; CO and its effect on blood; coal and destructive distillation; coke, gasification and synthesis gas	1. Predict the reagents for lab and industrial preparation of these gases and compounds 2. Identify and compare their properties and uses 3. Specify the test for each gas and compound, including Cl^- 4. Identify the allotropes of oxygen, sulphur and carbon and say why ozone matters 5. Classify oxides of oxygen and describe their properties 6. Identify the uses of water and the effects of dissolved gases; explain hardness, its causes and removal 7. Describe water treatment for town supply and tell efflorescence, deliquescence and hygroscopy apart 8. Specify how H_2SO_4, H_2SO_3, NH_3 and HNO_3 are prepared, with their properties and uses 9. State the properties of N_2O, NO and NO_2 and why the nitrogen cycle matters 10. Predict the effects of CO on humans and identify the forms, uses and products of coal, coke and synthesis gas

15. METALS AND THEIR COMPOUNDS

TOPICS / CONTENTS	OBJECTIVES: candidates should be able to
• General properties of metals • Alkali metals (sodium): NaOH (electrolysis of brine, uses), Na_2CO_3 and $NaHCO_3$ (Solvay process, uses), NaCl (sea water, recovery, test for Na^+) • Alkaline-earth metals (calcium): CaO, $Ca(OH)_2$, $CaCO_3$; cement and setting of mortar; test for Ca^{2+} • Aluminium: purifying bauxite, electrolytic extraction, properties, uses; test for Al^{3+} • Tin: extraction, properties and uses • First transition series: electron configuration, oxidation states, complex ions, coloured ions, catalysis • Iron: extraction, properties, forms, uses, steel versus iron; tests for Fe^{2+} and Fe^{3+} • Copper: extraction, properties, uses; $CuSO_4$; test for Cu^{2+} • Alloys: steel, stainless steel, brass, bronze, type-metal, duralumin, soft solder, permalloy, alnico (constituents and uses)	1. State the general properties of metals, the extraction method that suits each, and compare their reactivity 2. Specify the uses of the metals and the tests for metallic ions 3. Describe how compounds of sodium and calcium are produced, and compare their reactivity and uses 4. State the composition of cement and how bauxite is purified 5. Specify the ores of tin and relate its extraction to its properties and uses 6. Identify the properties of first-row transition metals, explain them, and name simple complexes 7. Choose the right extraction method for iron and copper and relate their properties to their uses 8. Identify the forms of iron and how to prepare $CuSO_4$ 9. State the constituents and uses of the alloys, and compare them with pure metals

16. ORGANIC COMPOUNDS

TOPICS / CONTENTS	OBJECTIVES: candidates should be able to
• Tetravalency of carbon, general formulae, IUPAC naming, empirical formulae of each class • Alkanes: homologous series, substitution reactions, halogenated products, structural isomerism (up to six carbons); petroleum: fractional distillation, cracking, reforming, petrochemicals, octane number • Alkenes: structural and geometric isomerism, addition and polymerisation (polythene, synthetic rubber, vulcanisation) • Alkynes: ethyne from carbides, reactions and properties; aromatic hydrocarbons such as benzene • Alkanols: primary, secondary, tertiary; ethanol by fermentation and from petroleum; local examples (gin from palm wine); glycerol; Lucas test • Alkanals and alkanones and tests to tell them apart; alkanoic acids (neutralisation, esterification, ethanedioic acid, benzene carboxylic acid) • Alkanoates: fats and oils; saponification; soap and margarine; soaps versus detergents; amines (primary, secondary, tertiary) • Carbohydrates: mono-, di- and polysaccharides, tests for sugars, reaction with conc. H_2SO_4, hydrolysis of cellulose and starch, uses • Proteins: primary structure, hydrolysis, tests (ninhydrin, biuret, Millon's, xanthoproteic); enzymes • Polymers: natural and synthetic rubber; addition and condensation polymerisation; thermoplastics and thermosetting plastics	**1.** Name organic compounds from their formulae, relate names to structures and classify by functional group **2.** Relate the tetravalency of carbon to chain formation (catenation) **3.** Work out empirical and molecular formulae from data **4.** Derive isomers and distinguish the types of isomerism **5.** Classify hydrocarbons, tell each class apart by properties and tests, and state their uses **6.** Describe crude oil as a mixture of hydrocarbons and relate its fractions to their properties, uses and quality improvement **7.** Distinguish the polymerisation processes and describe vulcanisation **8.** Distinguish aliphatic from aromatic hydrocarbons and relate benzene's properties to its structure **9.** Compare the classes of alkanols, alkanals, alkanones, alkanoic acids and amines, and explain how ethanol is produced and used as an alternative fuel **10.** Identify natural sources of alkanoates; specify how soap, detergent and margarine are made and tell soap from detergent **11.** Compare the classes of carbohydrates, their tests, hydrolysis products and uses **12.** Identify the structure of proteins, their hydrolysis and tests **13.** Distinguish natural from synthetic polymers, addition from condensation polymerisation, and thermoplastics from thermosetting plastics

17. CHEMISTRY AND INDUSTRY

TOPICS / CONTENTS	OBJECTIVES: candidates should be able to
• Chemical industries: types, raw materials and relevance • Biotechnology	**1.** Classify chemical industries by product and identify their raw materials **2.** Distinguish fine from heavy chemicals and state the relevance of each industry **3.** Relate industrial processes to biotechnology

18. ASTRONOMICAL CHEMISTRY

TOPICS / CONTENTS	OBJECTIVES: candidates should be able to
• Solar system, planets and satellites • Composition of the earth: atmosphere, lithosphere and hydrosphere	**1.** State the composition of the solar system and list the planets **2.** Identify the segments of the earth **3.** Name the earth's natural satellite and the smallest planet, which is also the farthest from the sun