Recommended books:

Morris Hein; Susan Arena Introduction to chemistry

Barron‘s SAT Subject Test Chemistry

Avril Higton, Mike Clemmet, Elaine Golding, and Alan V. Jones Access to Chemistry

STUDENT ACHIEVEMENTS ARE ASSESSED IN 4 TOPICS:

1. Chemical experiment. General chemical calculations.

2. Atomic theory. Chemical periodicity.

3. Chemical reactions. Rate and equilibrium of chemical reactions. Acids and bases.

4. Structure, properties and application of organic compounds. Life chemistry.

1. CHEMICAL EXPERIMENT. GENERAL CHEMICAL CALCULATIONS

1.1. **Chemical experiment**

1.1.1. Name and know the use of the following chemical vessels and appliances:

Test tube, beaker, measuring cylinder, pipette, flasks: conical, flat-bottomed and round-bottomed, volumetric, measuring and Wurth flasks, funnel, condenser (refrigerator), evaporating dish, stopper with a gas discharge tube, burette.

1.1.2. Assign a hazard label according to the properties of the substances given.

1.1.3. Identify carbonates by gas evolution in reaction with acids and write the reaction equations.

1.1.4. Identify ammonium ions by characteristic odour and/or discoloration of the indicator when the test object is exposed to a hydroxide solution and write the reaction equations.

1.1.5. Identify chloride, bromide, iodide, sulphate and carbonate ions by the formation of characteristic precipitate and write the reaction equations.

1.1.6. Identify calcium, barium, silver, copper (II) ions by the formation of characteristic precipitate and write the reaction equations.

1.1.7. Identify sodium and potassium compounds by the flame colour.

1.1.8. Determine the solution acidity using indicators

1.1.9. Know how to obtain O_2 (from H_2O_2, H_2O), H_2 (from H_2O, Zn and HCl) and CO_2 (from carbonates), how to collect and identify the resulting gas, write the equations of the respective reactions.

1.1.10. Know how to obtain, collect and recognize ethene gas, write the identification reaction with potassium permanganate solution.

1.1.11. Identify glycerol with copper (II) hydroxide by a characteristic colour change. Identify the aldehydes with copper (II) hydroxide or silver (I) oxide in ammonia solution and write the equations of the corresponding reactions.

1.1.12. Identify glucose as an aldehyde and as a polyhydroxy alcohol, write the equations of the respective reactions.

1.1.13. Know how to prepare a solution of the required mass percent concentration. Know how to prepare a solution of the required molar concentration.

1.1.14. Know how to separate mixtures by evaporation, filtration, distillation, crystallization.

1.1.15. Know how to use the titration method for neutralization of acids and bases.

1.1.16. Explain the rules for safe handling of sulfuric acid based on its properties.

1.1.17. Mathematically process the provided research data, present the obtained data with diagrams and graphs.

1.2. **Chemical calculations**

1.2.1. Perform calculations using formulas or proportions:

w (%) = $m_{substance}$ / m_{total} x100%

$$\rho = \frac{m}{V};\ n = \frac{N}{N_A};$$

$$n = \frac{m}{M};\ n = \frac{V}{V_M};$$

$$c = \frac{n}{V};\ \eta = \frac{m_{practical}}{m_{theoretical}} \cdot 100\ \%,$$

$$\eta = \frac{V_{practical}}{V_{theoretical}} \cdot 100\ \%,$$

$$\eta = \frac{n_{practical}}{n_{theoretical}} \cdot 100\ \%.$$

1.2.2. Apply the law of gas volume ratios in problem solving.

1.2.3. Calculate the amount, mass or volume of the reacting or formed substance by the given reaction equation, when the quantity, mass or volume of other substances involved in the reaction is known. Calculate the amount, mass or volume of the products according to the given reaction equation, when the amounts, masses or volumes of the two starting materials are given; calculate the quantities, masses or volumes of the remaining unreacted substances.

1.2.4. Perform calculations according to the reaction equation when a change in the mass or volume of any of the reactants or reaction products is given; calculate the change in mass or volume of the substance during the reaction.

1.2.5. Calculate the amount, mass, volume of the starting material with impurities from the given reaction equations, where the amount, mass, volume of the product is known, and vice versa.

1.2.6. Calculate the composition of the mixture when only one substance is involved in the reaction.

1.2.7. Calculate the mass fraction of binary compounds by the given material formula and vice versa.

1.2.8. Determine the formulas of starting materials when the amount, mass or volume of their reaction products are known.

2. ATOMIC THEORY. CHEMICAL PERIODICITY

2.1. **Atomic structure**

2.1.1. Describe the atomic structure of the elements of the first four periods by indicating the number of protons in the nucleus and the number of electrons in each layer.

2.1.2. Determine the number of neutrons in the nucleus when the mass number is given. Describe isotope.

2.1.3. Properly use the terms: atom, molecule, ion, oxidation state, atomic number, mass number, mole, molar mass, atomic mass of an element, formula unit.

2.1.4. Indicate the similarities and differences between atoms and ions. Describe changes in electronic structure when an atom turns into an ion.

2.2. **Periodic Law, Periodic Table of Elements**

2.2.1. Explain the structure of the Periodic Table of Elements based on the modern periodic law and the structure of the atom.

2.2.2. Relate the period and major (A) group numbers of an element with the number of electron layers and the number of valence electrons.

2.2.3. Based on the number of valence electrons, predict the highest and lowest oxidation states of elements in the main (A) groups and write example formulas of the binary compounds.

2.2.4. Indicate the position of these groups of elements - alkali metals, alkaline earth metals, halogens and inert gases - in the Periodic Table and describe the features of their electronic structure.

2.2.5. Describe the arrangement of metals and non-metals in the Periodic Table. Explain how the radius, electrical negativity, metallic and non-metallic properties of main-group elements change across a period.

2.2.6. Explain how the acidic and basic properties of the oxides of main-group elements change according to the position of the oxide-forming element in the Periodic Table.

2.2.7. Explain how the acidic and basic properties of non-metallic hydrogen compounds change within a group or a period, depending on the position of the non-metal in the Periodic Table.

2.2.8. Compare the chemical activity of halogens (Cl_2, Br_2, I_2) and write the example reactions.

2.3. **Chemical bond**

2.3.1. Explain the types of chemical bond in relation to the difference in electrical negativity of the participating chemical elements.

2.3.2. Give examples of ionic, covalent nonpolar and covalent polar bond formation.

2.3.2. Explain the differences in the properties of ionic, covalent molecular, covalent non-molecular compounds (e.g. SiO_2, diamond, graphite), linking these differences to their structures.

2.3.3. Explain the formation of covalent non-polar and covalent polar bonds in diatomic molecules, give examples.

2.3.4. Link the structure of the N_2 molecule with its inertness, describe the metallic bond and link it with metallic properties

2.3.5. Explain the formation of a coordination bond in H_3O^+ and NH_4^+ ions.

2.3.6. Explain the hydrogen bond between H_2O, NH_3, alcohol, and carboxylic acid molecules.

2.3.7. Define what allotropic forms are and provide examples (oxygen and carbon).

3. CHEMICAL REACTIONS. REACTION RATE AND EQUILIBRIUM. ACIDS AND BASES

3.1. **Chemical reactions and energy**.

3.2. **Reaction rate**. Provide examples of slow and fast chemical reactions.

3.2.1. Explain how the reaction rate depends on the frequency of collisions of the reacting particles.

3.2.2. Explain the dependence of the chemical reaction rate on the nature of the reagents.

3.2.3. Explain how the chemical reaction rate depends on concentration and temperature.

3.2.4. Describe the action of catalysts and enzymes, give examples of their use.

3.2.5. Explain how the chemical reaction rate depends on the surface area of solids and the pressure of gaseous substances.

3.2.6. Explain the relationship between gas pressure and concentration.

3.2.7. Explain the concept of a chemical reaction mechanism by examining the following examples: chlorination of methane to form chloromethane, and addition of hydrogen bromide and bromine to ethene.

3.2.8. Explain the concept of a reversible chemical reaction and provide examples.

3.2.9. Explain the change in the rate of forward and reverse reactions during the reaction.

3.2.10. Describe chemical equilibrium as a dynamic state in which forward and reverse reactions occur at the same rate.

3.2.11. Write the formula of equilibrium constant for a given homogeneous reaction and explain what equilibrium constant value indicates.

3.2.12. Explain the equilibrium shift by Le Chatelier’s principle when pressure, concentration and temperature change.

3.2.13. Explain the catalyst influence on a reversible reaction and why the catalyst does not change the equilibrium position.

3.2.14. Describe the physical properties of NH_3, indicate the most important applications.

3.2.15. Write the reaction equation for SO_3 reaction with H_2O.

3.2.16. Explain the influence of pressure, temperature and concentration of reactants on the reaction rate and equilibrium position of the ammonia synthesis.

3.2.17. Describe the reaction of obtaining sulphur (VI) oxide from sulphur (IV) oxide as a reversible reaction in production of sulfuric acid.

3.3. **Acids and bases**

3.3.1. Describe the physical properties of water, the structure and polarity of the water molecule. Explain the formation of hydrogen bond between water molecules and its influence on the physical properties of water.

3.3.2. Explain the effect of temperature on the dissolution rate and the amount of dissolved substance. Using the solubility curves, calculate the mass of the substance that will dissolve or precipitate from the solution as the temperature of the solution changes.

3.3.3. Explain the dissociation of electrolytes into ions by the polarity of water molecules.

3.3.4. Indicate the differences in electrical conductivity of aqueous solutions and classify substances into non-electrolytes, weak (weak acids, ammonia, water) and strong (soluble salts, soluble salts, soluble metals) electrolytes.

3.3.4. Explain the concepts of strong acid, strong base, and weak acid, weak base. Describe strong and weak acids by ionization constant K_a.

3.3.5. From the given reaction equation, indicate whether an exchange reaction can take place. Write complete and net ionic reaction equations.

3.3.6. Write the equations of the reactions between a base and H_2SO_4 to form sulphate and hydrogen sulphate.

3.3.7. Explain water hardness. Indicate the main methods of water softening. Write the equations of temporary and constant water hardness removal reactions (by heating, with phosphates or carbonates).

3.3.8. Write the equations of thermal decomposition reactions of insoluble carbonates ($CaCO_3$, $MgCO_3$) and hydrogen carbonates ($Ca(HCO_3)_2$, $Mg(HCO_3)_2$, $NaHCO_3$).

3.3.9. Determine the acidity of solution using indicators and a pH scale. Explain how the pH of a solution is related to the molar concentration of hydrogen and hydroxide ions.

3.3.10. Calculate the pH in solutions of strong acids and bases.

3.3.11. Explain the hydrolysis reaction of weak acid salts (CO_3^{2-}, CH_3COO^-) and why the solutions of these salts will be basic.

3.3.12. Explain why solutions of salts formed from strong acids and strong bases are neutral.

3.3.13. Describe acidic, basic oxides, give examples, and write chemical equations for obtaining acids and bases from oxides (Na2O, CaO, and CO2). Indicate that amphoteric oxides ZnO and Al_2O_3 react with acids and soluble hydroxides. Indicate neutral oxides, provide examples. Describe the effects of CO on the human body.

3.3.14. Write the reaction equations of basic oxides of group IIA metals with acids and acidic oxides (CO_2, SO_2, and SO_3).

3.3.15. Write the equations for the reactions of CO_2, SO_2, SO_3 with NaOH and $Ca(OH)_2$ to form two types of salts.

3.3.16. Describe the physical properties of non-metals (H_2, O_2, N_2, and Cl_2). Describe the acidic and basic properties of non-metallic hydrogen compounds (NH_3, HCl).

3.4**. Oxidation-reduction reactions and their application**

3.4.1. Calculate the oxidation state of the element in the compound. Calculate the oxidation state of elements in ions.

3.4.2. Indicate oxidizing and reducing agents in the given oxidation-reduction reaction equation. Balance the simple oxidation-reduction equation.

3.4.3. Describe the combustion reaction as an oxidation-reduction reaction with oxygen.

3.4.4. Identify which metal will react with non-oxidizing acids (e.g., hydrochloric acid, dilute sulfuric acid), write the equations of the reactions. Explain the reaction of copper with oxidizing acids (concentrated and dilute nitric acid and concentrated sulfuric acid) and write the reaction equations.

3.4.5. Explain the displacement reactions of one metal by another from aqueous salt solutions based on the metal activity and write the reaction equations. Explain the reactions of aluminium and zinc with acid and base solutions and write the equations of the reactions.

3.4.6. Explain and write the equations for the reactions of obtaining iron and copper from Fe_2O_3 and CuO, respectively, when the reducing agent is C, CO or H_2.

3.4.7. Explain the reactions of group IA and IIA metals with water and the reaction equations. Indicate the most important applications of IA and IIA groups metal compounds (Na_2CO_3, NaOH, $NaHCO_3$, CaO, $Ca(OH)_2$, $CaCO_3$).

3.4.8. Describe iron corrosion as a slow oxidation-reduction reaction, indicate ways to slow down corrosion, and explain its economic damage. Indicate that corrosion of metals is caused by water vapour, O_2, CO_2, SO_2 and other compounds dissolved in water acting as electrolytes. Indicate ways to slow down the corrosion of metals.

3.4.9. Describe what an alloy is, give examples of steel, bronze, duralumin use.

3.4.10. Indicate the importance of electrolysis in obtaining and refining metals, forming metal coatings. Explain the processes involved in the electrolysis of copper (II) chloride in aqueous solution using copper electrodes.

3.4.11. Explain the electrolysis processes that take place in the molten sodium chloride and in an aqueous solution of sodium chloride.

3.4.12. Explain the processes of electrolysis of copper (II) chloride in aqueous solution using inert electrodes.

4. STRUCTURE, PROPERTIES AND APPLICATION OF ORGANIC COMPOUNDS. LIFE CHEMISTRY

4.1. **Structure, properties and application of organic compounds**

4.1.1. Give examples of alkanes (from C1 to C5), write their molecular, condensed structural and expanded structural formulas of ethene and ethyne. Explain the concepts of homologue, homologous sequence. Write and be able to use the general formula of the homologous sequence of paraffins.

4.1.2. Give examples of alkenes and alkynes (from C3 to C6), write their molecular, condensed structural and expanded structural formulas. Write and be able to use the general formula of homologous order of alkenes and alkynes. Explain the spatial structure of methane, ethane, ethene, and ethyne molecules.

4.1.3. Describe isomers as compounds of the same chemical composition but different structures, give examples. Explain the isomerism of the carbon atom chain, substituent position, double bond position, cis and trans isomerism.

4.1.4. When writing the names of organic compounds, apply the basic rules of the IUPAC nomenclature. Form the names of straight-chain alkanes, alkenes and alkynes from C1 to C10.

4.1.5. Write structural formulas and name isomers of saturated hydrocarbons from C4 to C5.

4.1.6. Name various hydrocarbons substituted with methyl and ethyl. Name various hydrocarbons containing up to two halogen atoms.

4.1.7. Describe the structure of a benzene molecule. Name benzene homologues having up to eight carbon atoms in the molecule. Know the trivial name styrene.

4.1.8. Describe the functional group of alcohols. Name saturated mono-, di-, and trihydroxy alcohols. Know the trivial names ethylene glycol and glycerol.

4.1.9. Describe the functional group of aldehydes. Form aldehyde names from C1 to C6. Know the trivial name formaldehyde.

4.1.10. Describe the ketone propanone as a secondary alcohol oxidation product and its use. Know the trivial name acetone.

4.1.11. Identify and describe the functional groups of aldehyde and carboxylic acid in the structural formulas of organic compounds. Know the trivial name acetic acid. Name monocarboxylic acids from C1 to C6. Know the trivial names. Assign a compound to saturated or unsaturated carboxylic acids according to the general formula given.

4.1.12. Describe the structure of esters. Name esters with up to 4 carbon atoms.

4.1.13. Identify the amino group in the structural formulas of organic compounds and assign the compound to the amine class. Describe the functional group of amines, explain the concepts of primary, secondary, tertiary amine. Form traditional names for amines with methyl and ethyl groups. Compare basic properties of primary and secondary amines and ammonia.

4.1.14. Write the structural formula of the simplest amino acid. Describe the functional groups of amino acids

4.1.15. Write the equations of methane, ethene combustion, reaction of ethene with H_2. Describe polymerization of ethene. Explain the physical and chemical properties of methane, ethene, ethyne (combustion reactions, methane substitution reaction with Cl_2, ethene addition reactions with H_2, halogens, hydrogen halides, H_2O, ethyne addition reaction with H_2). Write the equations of the reactions to produce ethene from ethanol and ethyne from calcium carbide.

4.1.16. Explain the physical and chemical properties of benzene (combustion, substitution reaction with Br_2, HNO_3).

4.1.17. Indicate that the hydrocarbons are completely combusted to carbon (IV) oxide and water. Write and balance the combustion equations for saturated hydrocarbons (C1 to C6).

4.1.18. Classify the reactions of organic substances into substitution, addition, elimination and oxidation-reduction reactions.

4.1.19. Explain how to obtain alcohols, aldehydes and carboxylic acids from each other using oxidation-reduction reactions.

4.1.20. Describe the physical properties of methanol and ethanol, write the combustion equations. Describe alcohols as compounds that can participate in elimination and oxidation-reduction reactions, give examples of such reactions. Classify alcohols into primary, secondary and tertiary.

4.1.21. Explain the effects of methanol, ethanol and ethane diol on the body, indicate the use of these alcohols

4.1.22. Describe the physical properties of acetic acid and indicate areas of use.

4.1.23. Write the equations of reactions of carboxylic acids with hydroxides, basic oxides, salts (carbonates).

4.1.24. Write the equations for the formation of the simplest esters, name the reactants and the substances formed. Write the equations of hydrolysis of the simplest esters, name the reactants and the substances formed.

4.1.25. Properly use the terms monomer, polymer. Explain the principles of formation of polymers.

4.2. **Life chemistry**

4.2.1. Indicate fats as esters of glycerol and fatty acids.

4.2.2. Explain the differences in the physical properties and structure of animal and vegetable fats.

4.2.3. Describe the products obtained in the saponification reaction. Explain that alkaline fat hydrolysis applies to soap production. Write the equations of fat hydrolysis (with H_2O and NaOH), describe the obtained products.

4.2.4. Explain the significance of fat as energy source for the body.

4.2.6. Describe amines as basic substances. Write the equation for reaction of methylamine with HCl.

4.2.7. Describe amino acetic acid as an amphoteric compound (e.g. reaction with HCl and NaOH).

4.2.8. Using the schemes provided, explain that proteins are polymers of various amino acids. Find peptide bond in structural protein formulas. Write the reaction equation for dipeptide formation.

4.2.9. Describe primary and secondary protein structures. Explain the importance of hydrogen bonding to secondary protein structure.

4.2.10. Write the dipeptide hydrolysis equation, describe the products obtained.

4.2.11. Describe the hydrolysis and metabolism of proteins in the body.

4.2.12. Explain the structure of nucleic acids using the schemes provided.

4.2.13. Indicate the functional groups in the condensed structural formulas of glucose and fructose. Recognize cyclic glucose and fructose molecules in the structural formulas provided.

4.2.14. Write the equations of glucose formation during photosynthesis and glucose oxidation in the respiratory process using molecular formulas.

4.2.15. Indicate that sucrose is a compound made of glucose and fructose.

4.2.16. Know that starch and cellulose are natural polymers. Write glucose polycondensation reactions to form starch and cellulose.

4.2.17. Describe the importance of starch to the body. Describe the starch hydrolysis reaction and the significance of it for the body.