**Chemistry BSc – topics of the final examination**

*In the final exam the student presents the main points of a given topic as well as one of the applications/practical aspects, thus draws e.g. the topic 2c.*

**General and Inorganic Chemistry (4 topics)**

1) **The elementary structure of matter.** The atomic structure of matter. Fundamental concepts in Bohr’s and in the quantum mechanical models of the atom. Quantum numbers and their interpretation; the shape of the atomic orbitals. History of the periodic table and its setup based on the electronic structure of the atoms.

*Practical aspects, applications:*

a) Interpretation of the periodicity in the atomic parameters (atomic and ionic radii, ionization energy, electron affinity, electronegativity) and their correlation with the atomic number.

2) **Chemical bonding.** Classification and properties of chemical bonds. Application of the Valance Bond Theory, the Molecular Orbital Theory, and the Valence Shell Electron Pair Repulsion Theory for the explanation of the structure of simple inorganic and organic molecules.

*Practical aspects, applications:*

a) Characterization of σ and π bonds illustrated by arbitrarily chosen examples.

b) The hybridization states of carbon illustrated through appropriate examples.

c) Interpretation of the structure of HF, H2O, NH3 and CH4 molecules.

d) Formation of delocalized covalent bonds: the structures of benzene and simple oxoanions.

3) **Non-metallic elements**. General characterization of the non-metallic elements, some important representatives. Change of the reactivity and oxidation number in the p-block. Properties and practical/environmental importance of the hydrogen and oxygen compounds of p-block non-metals.

*Applications, practical aspects:*

a) General characterization of the halogen elements; relationship between properties and electronic structure.

b) Comparison of oxygen and sulphur as well as the properties and structure of their most important compounds.

c) Comparison of nitrogen and phosphorus as well as the properties and structure of their most important compounds.

d) Comparison of carbon and silicon as well as the properties and structure of their most important compounds.

e) The environmental significance of some important non-metallic elements and their compounds.

4) **Metals**. General characterization of the metals and the metallic bond. Physical and chemical properties, abundance of the metals. General methods for the production of metals.

*Applications, practical aspects:*

a) Major steps in the production of iron and aluminum.

b) Environmental issues of production of metals: principles of cyanide leaching process, Kroll process, electrolysis, and of the processing of sulphide ores and their environmental impacts.

c) Factors affecting the thermal stability and acid-base properties of metal oxides. Applications of metal oxides.

**Physical Chemistry (7 topics)**

5) **Physical equilibria of single- and multi-component systems.** Characterization, description (state equation and state variables) and molecular interpretation of the states of matter. Thermodynamic description of phase transformations: phase equilibrium, phase stability. Phase diagrams, the phase rule. Thermodynamic characterization of mixtures and solutions.

*Applications, practical aspects:*

a) Antifreeze coolant.

b) Extraction.

c) Physico-chemical characterization of the production of bioethanol (distillation, extraction).

d) Everyday phenomena: skating, cooling drinks in clay pots.

e) Osmosis in living systems.

6) **Thermodynamics.** Laws of thermodynamics. Thermodynamic potential functions and their application to determine the direction of spontaneous processes and equilibrium. Thermochemistry. Statistical interpretation of entropy.

*Applications, practical aspects:*

a) Heat engines: operation principles of internal and external combustion engines, refrigerators, heat pumps and air conditioning systems.

b) Thermodynamic characterization of living systems.

7) **Chemical equilibrium.** The equilibrium constant and its relation to thermodynamic and electrochemical functions. The equilibrium law, principle of Le Chatelier: effect of temperature and pressure on the chemical equilibrium. Binding on surfaces: chemisorption and physical adsorption. Langmuir and BET adsorption isotherms.

*Applications, practical aspects:*

a) Tables of thermodynamic data: their use and applications.

b) The physico-chemical aspects of pollution, corrosion, environmental remediation and cleanup.

8) **Reaction kinetics.** Rate and rate equation of chemical reactions; their experimental determination. Kinetics of homogeneous and heterogeneous reactions. Catalysis. Temperature dependence of the reaction rate and its interpretation. The relationship between kinetics and mechanism in simple systems (unimolecular reactions, enzymatic reactions, chain reactions). Non-thermal activation, photochemical reactions.

*Applications, practical aspects:*

a) Catalytic converters of cars.

b) Catalysis in living systems (e.g. catalase enzyme etc.).

c) Ozone hole.

d) Simultaneous use of kinetics and thermodynamics: synthesis of ammonia.

9) **Electrochemistry**. Characterization of electrolytes: theory of electrolytic dissociation, thermodynamics of electrolytes, conductivity. Heterogeneous redox systems: electrodes and electrode potential; chemistry and thermodynamics of galvanic cells, fuel cells; kinetics of electrode processes; corrosion and protection against corrosion.

*Applications, practical aspects:*

(a) Common types of primary (e.g. C/Zn), and secondary (rechargeable) batteries (Pb).

(b) Hydrogen fuel cells.

(c) Electrolytic cells, their applications in laboratory and industry.

10) **Colloids and interfacial phenomena.** Types of colloids (dispersion, associated and macromolecular) and their characterization beyond classical state variables. Size, average size, size distribution, shape. Importance of specific surface area, stability of colloids. Basic methods for determining particle size. Coherent and incoherent systems. The types of interfaces and their characterization, the interfacial layer. Surface tension and related phenomena: wetting, capillary phenomena, properties of curved surfaces. Surfactants and detergents.

*Applications, practical aspects:*

a) Border and interface phenomena in everyday life.

b) Technology of washing, cleaning and gluing.

c) Tubularity.

11) **Nuclear Chemistry.** Structure and stability of nucleus. The concept of radioactivity, kinetics of radioactive decay. Types of radioactive decay, interaction of radiation with matter. Basic nuclear reactions. Nuclear energy production, nuclear power plants. Measurement of radioactive radiation.

*Applications, practical aspects:*

a) Components of environmental radioactivity.

b) Operation of nuclear reactors.

c) Applications of radionuclides (e.g. nuclear medicine, chemical industry).

**Organic Chemistry (6 topics)**

12) **Aliphatic hydrocarbons.** Structure and bonding in saturated and unsaturated hydrocarbons; their preparation and characteristic reactivity.

*Applications, practical aspects:*

a) Energy supply by hydrocarbons (propellants and fuels).

b) Cracking process of alkanes.

c) Polymerization of alkenes.

13) **Aromatic compounds.** Structure and bonding in homo- and heteroaromatic compounds, definition of aromaticity, characteristic reactions.

*Applications, practical aspects:*

a) Industrial preparation and organic synthetic application of aromatic hydrocarbons (toluene, cumene).

b) Electrophilic substitution products of benzene as industrial raw materials.

c) Oxidation products of homoaromatic compounds.

14) **Oxygen-containing organic compounds.** Structure and bonding, preparation and reactivity of compounds containing carbon-oxygen bond (alcohols, enols, phenols, aldehydes, ketones, carboxylic acids and their derivatives).

*Applications, practical aspects:*

a) Industrial production and organic chemical utilization of alcohols (methanol, ethanol, ethyleneglycol).

b) Industrial production and application of phenols.

c) Utilization of formaldehyde and phenol in plastic industry.

d) Synthetic organic utilization of malonic acid and acetoacetic ester.

e) Preparation of polyesters and polycarbonates.

15) **Nitrogen-containing organic compounds.** Structure and bonding, synthesis and reactivity of compounds containing carbon-nitrogen bonds (nitro derivatives, amines, diazonium salts, azo derivatives and imines).

*Applications, practical aspects:*

a) Industrial production and utilization of nitro derivatives (nitrobenzene, TNT).

b) Importanc e of anilines and their derivatives.

c) Preparation of diazonium salts and application in dyestuff industry.

d) Production of polyamides and polyurethans.

16) **Natural compounds.** Characterization of the most important representatives of amino acis, peptides, proteins, carbohydrates, nucleic acids, flavonoids, alkaloids, antibiotics, isoprene and porphyrin derivatives.

*Applications, practical aspects:*

a) The function of proteins in living organisms.

b) The function of carbohydrates in living organisms.

c) The function of nucleic acids in living organisms.

d) Bioactivity of alkaloids and antibiotics.

17) **Major pathways in the metabolism of biomolecules.** Ingestion and digestion of proteins, carbohydrates and fats. Catabolic processes (glycolysis, beta-oxidation, urea cycle, citrate cycle), energy production in the living organism. Anabolic processes (gluconeogenesis, synthesis of fatty acids and amino acids), essential amino and fatty acids.

*Applications, practical aspects:*

a) Therapeutical roles and utilization of enzymes.

b) Vitamines as constituents of coenzymes.

**Analytical Chemistry (5 topics)**

18) **Basics of chemical analysis**. Overview of the chemical and physical methods of analysis from sampling to evaluation. Classification and general description of the classical analytical methods based on their principle of operation.

*Applications, practical aspects:*

a) Rules and devices of sampling.

b) Interpretation of signal and noise in analytical chemistry. Experimental errors. Standard deviation.

19) **Solution equilibria and their use in chemical analysis**. Acid-base theories (Arrhenius, Brönsted, Lewis, Pearson), redox equilibria, complex forming reactions, solubility equilibria of precipitates. Definition of pH and its importance. Application of solution equilibria in the qualitative and quantitative analysis of the compounds of metallic and nonmetallic elements.

*Applications, practical aspects:*

a) Practice of titrations, endpoint detection, working principle of indicators.

b) Acid-base titrations.

c) Redox titrations.

d) Complexometric titrations.

e) Precipitation titrations.

20) **Separation techniques in analytical chemistry.** Extraction, gravimetry and chromatography. Theoretical basis of chromatography (types, principles, instrumentation, separation efficiency, evaluation of chromatograms).

*Applications, practical aspects:*

a) Separation of metal ions with extraction.

b) Practice of HPLC and gas chromatography.

c) Application fields of size exclusion chromatography (SEC).

21) **Spectroscopic methods** **and their applications for structure elucidation and quantitative analysis.** The most common spectroscopic methods and their instrumentation (IR, UV-VIS, NMR, MS and atomic spectrometric methods).

*Applications, practical aspects:*

a) Structure of the spectrometers (main parts, principles).

b) The most important parameters of spectra, factors determining the shapes of lines and bands.

c) Utilization of spectra for identification of components and determination of their concentrations.

22) **Potentiometry and conductometry**. Theoretical basis and instrumentation of potentiometry. Electrodes (classification, structure and operational principles). Membrane equilibria of indicator electrodes. Direct and indirect potentiometry. Principle and devices of conductometry. Direct and indirect conductometry.

*Applications, practical aspects:*

a) Potentiometric titration curves.

b) Conductometric titration curves.

**Applied Chemistry (4 topics)**

23) **Fundamentals of processes in chemical industry. Chemical reactors.** Hydrodynamic processes: Navier−Stokes equation, Bernoulli equation. Thermal and component transfer processes: Fourier’s law, Stefan−Boltzmann law, Fick’s first and second law. Chemical reactors: continuously stirred-tank reactor, plug flow tubular reactor, fluidization reactor, chest oven, tube furnace; contact catalytic reactors.

*Applications, practical aspects:*

a) Pumps, pressure vessel, syphoning.

b) Thermal insulation.

c) Technical solutions of mixing and contact of liquid-liquid, liquid-gas, liquid-solid and gas-solid phases.

24) **Fundamentals of chemical technology. Inorganic chemical technologies.** Basic laws of chemical technology: i) law of large number of parameters, ii) law of cost parameters, iii) law of scale-up, iv) law of automatization. Inorganic chemical technologies: water technology, nitrogen industry, sulphur industry, silicate industry, electrolysis industry, corrosion.

*Applications, practical aspects:*

a) Methods of disinfection and sterilization of water.

b) Fertilisers and their use.

c) Anti-corrosion methods.

25) **Organic chemical technologies.** Processing of coal, crude oil and natural gas. Production of fuels and lubricants. Products of pyrolysis of hydrocarbons. Commodity plastics: production of polyethylene, polypropylene and polyvinyl chloride. Microbiological industries and their products: production of yeast, alcohol, beer and vinegar.

*Applications, practical aspects:*

a) Operation of Otto- and Diesel engines.

b) Requirements for lubricants.

c) Preservation of foods.

26) **Environmental technologies**. Environmental impacts of industrial production, Dalton’s principle. Ranking of waste management of EPA. Additive, production-integrated and product-integrated environmental protection. Formation and management of gaseous, liquid and solid wastes. Management of radioactive and hazardous wastes.

*Applications, practical aspects:*

a) Purification of sewage.

b) Problems of separate waste collection.

c) Contradictions of establishment of waste incineration.