Subject Areas for MSc. Admission Exams at the FCT

An applicant for MSc study at the Faculty of Chemical Technology should have the knowledge which is comparable to bachelors graduating at the Faculty of Chemical Technology. The lists given below are not limiting, and they are intended only to describe the focus of admission exam. The examination discussion may require the general knowledge of other disciplines at the most rudimentary bachelor level as well.

Content

Content 1

Study program Chemistry (AN104) 2

Specialization **Inorganic Chemistry** (AN104A) 2

Specialization **Macromolecular Chemistry** (AN104B) 3

Specialization **Organic Chemistry** (AN104C) 4

Study program Fuel Cells and Hydrogen Engineering (AN110) 6

Study program Chemoinformatics in Medicinal Chemistry (AND111) 8

Study program Materials Science and Technology (AN112) 10

Study program Chemistry (AN104)

Specialization **Inorganic Chemistry** (AN104A)

3 compulsory subject areas:

- Inorganic Chemistry
- Physical Chemistry
- Chemistry and Physics of Materials

Subject area „Inorganic Chemistry“

1. Structure of matter; electronic structure of atoms.
2. Periodic Table.
3. Chemical bonding and chemical reactions.
4. Nonmetallic elements—chemical bonding, properties, reactivity.
5. Polyatomic molecules of nonmetals—structure, chemical bonding, properties.
6. Gaseous and liquid molecular compounds of nonmetals.
7. Monatomic ions in aqueous solutions and their salts.
8. Oxoanions in aqueous solutions and crystalline solids.
9. Coordination compounds.
10. Structure, chemical bonding, and properties of metals.
11. Metals and intermetallic phases—reactivity and production.
12. Simple solid oxides and inorganic polymers.
13. Binary non-oxide solid compounds of metals and nonmetals.
14. Species and phases in chalcophilic environments.

Subject area „Physical Chemistry“

1. Ideal gas equation of state, p–V diagram of a real fluid, critical parameters.
2. First and second laws of thermodynamics.
3. Work, heat, internal energy, enthalpy, entropy, Helmholtz energy, and Gibbs energy.
4. Heat capacities, calculations of heat during the heating of substances and during phase transitions, heat of reaction, Hess’s and Kirchhoff’s laws.
5. Phase equilibria in one-component systems, Clapeyron equation, Clausius–Clapeyron equation, phase diagram of a pure substance.
6. Phase equilibria in binary systems, Raoult’s law, Henry’s law, Gibbs’ phase rule, lever rule.
7. Chemical equilibrium in simple reactions, equilibrium constant, and mass balance.
8. Electrochemical processes, Faraday’s laws, galvanic cells, and Nernst’s equation.
9. Chemical kinetics of simple reactions, reaction order, rate constant, and reaction half-life.

Subject area „ Chemistry and Physics of Materials“

1. Chemical bonding in solids; types of chemical bonds.
2. Structure of solids; crystal defects; amorphous materials.
3. Functional properties of materials—mechanical, electrical, magnetic, and optical.
4. Metallic materials—preparation, structure, and properties.
5. Ceramics and glasses—preparation, structure, and properties.
6. Polymers—synthesis, structure, and properties.
7. Conductors, semiconductors, insulators, and superconductors.
8. Materials with specific optical and magnetic properties.
9. Material degradation.

Specialization **Macromolecular Chemistry** (AN104B)

3 compulsory subject areas:

- Organic Chemistry
- Macromolecular Chemistry
- Characterization Methods of Polymer Materials

Subject area „Organic Chemistry“

1. Alkanes and cycloalkanes—structure, reactivity, and constitutional, configurational, and conformational isomerism.
2. Alkenes, vinyl and allyl compounds—structure, properties, and reactions at carbon-carbon double bond.
3. Dienes—Classification and reactivity (Diels-Alder reactions).
4. Organomagnesium and Organolithium Compounds—structure and properties, basic reactions.
5. Arenes – sulfonation, nitration, alkylation, and directing effects of substituents.
6. Alcohols and phenols – preparation, properties, and fundamental reactions.
7. Carbonyl compounds – structure and properties, and fundamental reactions.
8. Carboxylic acids and their functional derivatives.

Subject area „Macromolecular Chemistry“

1. Constitution, configuration, and conformation of macromolecules.
2. Molar mass of polymers.
3. Thermal behavior of polymers in relation to their structure.
4. Structural requirements for the polymerizability of monomers.
5. Radical polymerization and copolymerization of vinyl monomers.
6. Ionic polymerization of vinyl and cyclic monomers.
7. Coordination polymerization of alkenes.
8. Step-growth polymerization —polycondensation, polyaddition.

Subject area „Characterization Methods of Polymer Materials“

1. Characterization of the flow behavior of thermoplastics, thermosets, and elastomers.
2. Monitoring and characterization of crosslinking reactions in polymers.
3. Short-term mechanical testing of polymers.
4. Creep and stress relaxation behavior of polymers.
5. Dynamic-mechanical testing.
6. Electrical conductivity and dielectric properties of polymers.
7. Thermal analysis techniques for polymer characterization.

Specialization **Organic Chemistry** (AN104C)

3 compulsory subject areas:

- Organic Chemistry
- General and Inorganic Chemistry
- Physical Chemistry

Subject area „Organic Chemistry“

1. Alkanes and cycloalkanes—Structure, reactivity and stereochemistry.
2. Alkenes—structure, and reactivity, Electrophilic and radical addition reactions, stability of carbocations and radicals. Stereochemistry of alkenes.
3. Alkynes—acidity, formation and alkylation of acetylides, and addition reactions to carbon–carbon triple bonds.
4. Haloalkanes—structure and properties. Nucleophilic substitution reactions, mechanisms. Stereochemical aspects of nucleophilic substitutions.
5. E1 and E2 elimination reactions—competition with nucleophilic substitution, dehydrohalogenation, and dehydration reactions.
6. Conjugated multiple bonds—allylic carbocations, dienes, their stereochemistry, and reactivity.
7. Aromatic hydrocarbons—Aromaticity, electrophilic aromatic substitution reactions, reaction mechanism, and fundamental substitution reactions.
8. Alcohols and phenols—Structure, acidity, reactions with nucleophiles, dehydration and oxidation of alcohols.
9. Carbonyl compounds—structure, nucleophilic addition to the carbonyl group, and carbonyl condensation reactions.
10. Carboxylic acids and their derivatives—structure, acidity, and nucleophilic acyl substitution reactions.

Subject area „General and Inorganic Chemistry“

1. Structure of matter and atomic structure.
1. Periodic law and the periodic table of elements.
2. Chemical bonding and chemical reactions.
3. Nonmetallic elements—Chemical bonding, properties, and reactivity.
4. Polyatomic molecules of nonmetals—structure, chemical bonding, and properties.
5. Gaseous and liquid molecular compounds of nonmetals.
6. Monoatomic ions in aqueous solution and their salts.
7. Oxyanions in aqueous solution and crystalline solids.
8. Coordination compounds.
9. Structure, chemical bonding, and properties of metals.
10. Metals and intermetallic phases—reactivity, extraction, and applications.
11. Solid oxides and inorganic polymers.
12. Binary solid compounds of metals and nonmetals.
13. Chemical species and phases in chalcophilic environments.

Subject area „Physical Chemistry“

1. Basic thermodynamic concepts—thermodynamic systems, process, and state functions.
2. Behavior of gases, Ideal gas equation of state and real gas behavior.
3. First law of thermodynamics—internal energy, heat, work.

4. Enthalpy, heat of reaction, standard enthalpy of formation. Hess’s law, and Kirchhoff's laws.
5. Second law of thermodynamics—entropy and entropy changes in selected processes.
6. Helmholtz and Gibbs energy—their physical significance and the third law of thermodynamics.
7. Partial molar quantities, activity, chemical potential and standard states.
8. Phase equilibria in one-component systems—Clapeyron equation.
9. Gibbs phase law, vapor-liquid equilibria in ideal systems, phase diagrams.
10. Solubility of gases in liquids, phase equilibria in condensed systems.
11. Material balance of chemical reactions, equilibrium constant, and equilibria in electrolyte solutions.
12. Equilibrium composition. Reactions in gaseous phase.
13. Faraday´s law of electrolysis, galvanic cells, and Nernst equation.
14. Fundamental concepts of chemical kinetics—reaction rate and integration of rate equations.

Study program Fuel Cells and Hydrogen Engineering (AN110)

3 compulsory subject areas:

- Chemical Engineering
- Physical chemistry
- General and Inorganic Chemistry

Subject area „Chemical Engineering“

1. Basic terminology. Systems. Principles of balancing. Mass and mole balance.
2. Balance of energy. Bernoulli equation.
3. Flow of fluid through pipes. Transport of fluids, pumps. Flow of fluid through porous medium.
4. Filtration, types of filters, filtration rate.
5. Balance of enthalpy.
6. Heat transfer, transfer coefficient. Heat exchange by conduction and convection.
7. Heat exchangers: types and design. Evaporators: types and design.
8. Diffusion separation processes. Mass transfer equipment. Equilibrium plate.
9. Liquid extraction of immiscible solvents: equipment, single-stage, repeated and countercurrent extraction.
10. Flash and differential distillation of binary mixtures.
11. Rectification in staged column.
12. Drying of solids, enthalpic humidity chart. Batch and continual dryers.
13. Chemical reactors and bioreactors, basic types. Material balance.
14. Chemical process equipment.

Subject area „Physical Chemistry“

1. Basic terminology, thermodynamic system, thermodynamic process, state properties.
2. State behavior of gases, equation of state of ideal gas. Real gas and its behavior.
3. 1st law of thermodynamics. Internal energy, heat, work.
4. Enthalpy, heat of reaction, standard enthalpy of formation. Hess and Kirchhoff's laws.
5. 2nd law of thermodynamics, entropy. Entropy changes on selected processes.
6. Helmholtz and Gibbs energy, their significance. 3rd law of thermodynamics.
7. Partial molar quantities, activity, chemical potential, standard states.
8. Phase equilibria in single-component systems, Clapeyron equation.
9. Gibbs phase law, vapor-liquid equilibrium in ideal systems, phase diagrams.
10. Solubility of gases in liquids, equilibria in condensed systems.
11. Material balance of chemical reactions. Equilibrium constant. Equilibria in electrolyte systems.
12. Equilibrium composition. Reactions in gaseous phase.
13. Faraday´s law, galvanic cells, Nernst equation.
14. Basic terms of chemical kinetics, reaction rate, integration of rate equations.

Subject area „General and Inorganic Chemistry“

1. Structure of substances. Structure of atom.
1. Periodic law and the periodic system of elements.
2. Chemical bond and chemical reactions.
3. Non-metal elements. Chemical bonding, properties, and reactivity.
4. Polyatomic molecules of non-metals - structure, chemical bonding, and properties.

5. Gaseous and liquid molecular compounds of non-metals.
6. Monoatomic ions in an aqueous solution and their salts.
7. Oxyanions in an aqueous solution or crystals.
8. Coordination compounds.
9. Structure, chemical bonding, and properties of metals.
10. Metals and intermetallic phases - reactivity, extraction, and use.
11. Solid oxides and inorganic polymers.
12. Binary solid compounds of metals and non-metals.
13. Phases and species of chalcophilic environments.

Study program Chemoinformatics in Medicinal Chemistry (AND111)

3 compulsory subject areas:

- Organic Chemistry
- Biochemistry
- Physical chemistry

Applicants are expected to demonstrate a general understanding of the key concepts of chemistry, as the purpose of the assessment is to verify knowledge at a general level. Candidates with an undergraduate background in these areas of chemistry are therefore not required to undertake any extensive additional preparation.

Subject area "Organic Chemistry"

1. Alkanes and cycloalkanes. Structure, reactivity. Stereochemistry of alkanes and cycloalkanes.
2. Alkenes, structure, and reactivity. Electrophilic and radical addition reactions, stability of carbocations and radicals. Stereochemistry of alkenes.
3. Alkynes. Acidity of alkynes, formation of acetylides, alkylation of acetylides. Reactivity of the triple bond in addition reactions.
4. Haloalkanes, structure and properties. Nucleophilic substitution reactions, mechanisms. Stereochemical aspects of nucleophilic substitutions.
5. E1 and E2 elimination reactions and their relation to nucleophilic substitution reactions. Dehydrohalogenation and dehydration reactions.
6. Conjugated multiple bonds. Allyl cations, dienes, their stereochemistry, and reactivity.
7. Aromatic hydrocarbons. Aromaticity, electrophilic substitution reactions, mechanism. Fundamental substitution reactions.
8. Alcohols and phenols. Structure, acidity, reactions with nucleophiles. Dehydration and oxidation of alcohols.
9. Carbonyl compounds. Structure, nucleophilic addition reactions to carbonyl group. Carbonyl condensations.
10. Carboxylic acids and their derivatives. Structure, acidity, nucleophilic acyl substitution reactions.

Subject area "Biochemistry"

1. Amino acids, peptides, proteins
2. Enzymes – structure, nomenclature, kinetics
3. Nucleotides, nucleic acids
4. The genome and its organization
5. Replication, DNA polymerase
6. Transcription

7. Translation, post-translational modifications
8. Aerobic and anaerobic respiration, photosynthesis
9. Citric acid cycle and glyoxylate cycle

Subject area “Physical Chemistry”

1. Basic terminology, thermodynamic system, thermodynamic process, state properties.
2. State behavior of gases, equation of state of ideal gas. Real gas and its behavior.
3. 1st law of thermodynamics. Internal energy, heat, work.
4. Enthalpy, heat of reaction, standard enthalpy of formation. Hess and Kirchhoff's laws.
5. 2nd law of thermodynamics, entropy. Entropy changes on selected processes.
6. Helmholtz and Gibbs energy, their significance. 3rd law of thermodynamics.
7. Partial molar quantities, activity, chemical potential, standard states.
8. Phase equilibria in single-component systems, Clapeyron equation.
9. Gibbs phase law, vapor-liquid equilibrium in ideal systems, phase diagrams.
10. Solubility of gases in liquids, equilibria in condensed systems.
11. Material balance of chemical reactions. Equilibrium constant. Equilibria in electrolyte systems.
12. Equilibrium composition. Reactions in gaseous phase.
13. Faraday´s law, galvanic cells, Nernst equation.
14. Basic terms of chemical kinetics, reaction rate, integration of rate equations.

Study program Materials Science and Technology (AN112)

2 compulsory subject areas:

- Materials Science
- Physical Chemistry

1 of 4 compulsory-optional subject areas:

- General and Inorganic Chemistry
- Macromolecular Chemistry
- Crystallography and Mineralogy
- Transport Phenomena and Materials Technology

Subject area "Materials Science"

1. Materials – definition, classification
2. Iron – production, classification of iron alloys
3. Steel, cast iron – properties, important types
4. Nonferrous alloys – based on Al, Cu, Zn, Pb, Mg, Ti, Ni and precious metals.
5. Glass – raw materials, production, properties, types
6. Oxide and non-oxide ceramics – raw materials, production, properties, types
7. Silicate ceramics and refractories – raw materials, production, properties, types
8. Inorganic binders – raw materials, production, properties, types
9. Semiconductors, carbon-based materials
10. Polymeric materials – types, structure, properties, production
11. Termoplastics, thermosets, elastomers
12. Composite materials – classification, properties, production
13. Mechanical and thermophysical properties of materials
14. Electrical, magnetic and optical properties of materials

Subject area „Physical Chemistry"

1. Basic terminology, thermodynamic system, thermodynamic process, state properties.
2. State behavior of gases, equation of state of ideal gas. Real gas and its behavior.
3. 1st law of thermodynamics. Internal energy, heat, work.
4. Enthalpy, heat of reaction, standard enthalpy of formation. Hess and Kirchhoff's laws.
5. 2nd law of thermodynamics, entropy. Entropy changes on selected processes.
6. Helmholtz and Gibbs energy, their significance. 3rd law of thermodynamics.
7. Partial molar quantities, activity, chemical potential, standard states.
8. Phase equilibria in single-component systems, Clapeyron equation.
9. Gibbs phase law, vapor-liquid equilibrium in ideal systems, phase diagrams.
10. Solubility of gases in liquids, equilibria in condensed systems.
11. Material balance of chemical reactions. Equilibrium constant. Equilibria in electrolyte systems.
12. Equilibrium composition. Reactions in gaseous phase.
13. Faraday´s law, galvanic cells, Nernst equation.
14. Basic terms of chemical kinetics, reaction rate, integration of rate equations.

Subject area "General and Inorganic Chemistry"

1. Structure of substances. Structure of atom.
2. Periodic law and the periodic system of elements.
3. Chemical bond and chemical reactions.
4. Non-metal elements. Chemical bonding, properties, and reactivity.
5. Polyatomic molecules of non-metals - structure, chemical bonding, and properties.
6. Gaseous and liquid molecular compounds of non-metals.
7. Monoatomic ions in an aqueous solution and their salts.
8. Oxyanions in an aqueous solution or crystals.
9. Coordination compounds.
10. Structure, chemical bonding, and properties of metals.
11. Metals and intermetallic phases - reactivity, extraction, and use.
12. Solid oxides and inorganic polymers.
13. Binary solid compounds of metals and non-metals.
14. Phases and species of chalcophilic environments.

Subject area "Macromolecular Chemistry"

1. Introduction and historical development, nomenclature of polymers.
2. Structure of macromolecules, molecular weight.
3. Molecular structure and properties of polymers.
4. Polymerizability of low molecular substances.
5. Free radical polymerization - elemental reactions.
6. Kinetics of free radical polymerization.
7. Free radical copolymerization.
8. Ionic polymerization and copolymerization.
9. Insertion polymerization, polymerization practice.
10. Ring-opening polymerization.
11. Step-growth polymerization - characterization, reactivity of monomer functional groups.
12. Polycondensation - mechanism and kinetics, molecular weight distributions.
13. Polyadditions - typical syntheses.
14. Reactions of polymers.

Subject area "Crystallography and Mineralogy"

1. Crystal structure classification (crystal systems, point groups, space groups).
2. Crystal chemistry (structure types).
3. Crystal physics (tensors).
4. Principles of X-ray diffraction (XRD).
5. XRD quantitative phase analysis (Bragg equation).
6. XRD quantitative phase analysis (Rietveld method).
7. Special topics in XRD (amorphous phases, grain size determination).
8. Crystal optics and polarization microscopy.
9. Traditional classification of minerals.
10. Traditional classification of silicates.
11. Oxides, carbonates and silicates as rock-forming minerals.

12. Chemical analysis of minerals by X-ray fluorescence (XRF) and energy-dispersive spectroscopy (EDS).
13. Raw materials for the metal industry (ores).
14. Raw materials for glass, ceramics and inorganic binders (silica, clays, carbonates).

Subject area ”Transport Phenomena and Materials Technology“

1. Balance equations (mass, linear and angular momentum, energy, entropy inequality).
2. Constitutive equations (Fourier’s law of heat conduction, Ohm’s law of electrical conduction, Newton’s law of viscosity, Fick’s first law of diffusion, Darcy’s law of filtration).
3. Partial differential equations (Fourier-Kirchhoff equation, Navier-Stokes equation, Fick’s second law).
4. Initial and boundary conditions.
5. Coordinate systems (Cartesian, cylindrical, spherical).
6. Basics of analytical and numerical solution of PDEs (overview).
7. Rheology (flow curve, apparent viscosity, velocity profile).
8. Heating and cooling processes (conduction, convection, radiation).
9. Chemical reactions and their kinetics.
10. Non-Newtonian fluid mechanics (extrusion, injection molding).
11. Filtration and fluid flow through porous media (fluid permeability, Kozeny-Carman)
12. Drying and debinding processes.
13. Sintering processes.
14. Diffusion in solids.