Contents of the written admission test

From a database 100 multiple-choice questions (in english) are selected by the computer subdivided in the following topics:

Curriculum Chemical Sciences (SC)

Analytical chemistry	10 questions
Organic chemistry	20 questions
Inorganic chemistry	20 questions
Physical chemistry	20 questions
Pharmaceutical science	20 questions
Biotechnology	10 questions

Curriculum Pharmaceutical Sciences (SF)

Analytical chemistry	10 questions
Organic chemistry	20 questions
General chemistry	20 questions
Pharmaceutical chemistry	20 questions
Pharmaceutical technology	20 questions
Biotechnology	10 questions

Each candidate can freely choose which questions to answer, but should respond to 60 questions in total (no penalty is given for a wrong answer). In case more questions are answered, the first 60 questions will be considered , independent on whether the answers are correct or wrong. The correction procedure is computerized and is anonymous. Only after correction the result is associated to the name of the candidate. In recent years 75% of the candidates passed the threshold value for admission to the interview.

To facilitate preparation for the admission test, a detailed list of arguments for each area is given on the following pages.

ANALYTICAL CHEMISTRY (SC+SF - 10 questions)

Data Acquisition and Use of Statistics
- Errors
- Statistical considerations

Solutions and Standardization
- Concentration terms
- Primary standards

Homogeneous Equilibria
- Acid-base
- Oxidation-reduction
- Complexometry

Heterogeneous Equilibria
- Gravimetric analysis
- Solubility
- Precipitation titrations
- Chemical separations

Instrumental Methods
- Electrochemical methods
- Spectroscopic methods
- Chromatographic methods
- Thermal methods
- Calibration of instruments

Environmental Applications

Radiochemical Methods
- Detectors, applications

INORGANIC CHEMISTRY (SC – 20 questions)

Atomic Structure
- The Periodic Table
- The Schrödinger Equation
- Periodic Properties of Atoms

Simple Bonding Theory
- Lewis Electron-Dot Diagrams
- Valence Shell Electron-Pair Repulsion
- Molecular Polarity
- Hydrogen Bonding

Molecular Orbitals
- Generation of Molecular Orbitals from Atomic Orbitals
- Molecular Orbitals from s Orbitals
- Molecular Orbitals from p Orbitals
- Molecular Orbitals from d Orbitals
- Nonbonding Orbitals

Acid–Base and Donor–Acceptor Chemistry
- Arrhenius Concept
- Brønsted–Lowry Concept
- Lewis Acid–Base Concept and Frontier Orbitals
- Intermolecular Forces
- Hard and Soft Acids and Bases

The Crystalline Solid State
- Structures of Binary Compounds
- Thermodynamics of Ionic Crystal Formation

Chemistry of the Main Group Elements
- General Trends in Main Group Chemistry
- Physical Properties
- Electronegativity
- Ionization Energy
- Chemical Properties

Coordination Chemistry
- Nomenclature
- Isomerism
- Coordination Numbers and Structures
- Bonding Theories
- Crystal Field Theory
- Ligand Field Theory
- The Jahn–Teller Effect

Coordination Chemistry: Reactions and Mechanisms
- Substitution Reactions
- Linear Free-Energy Relationships
- Associative Mechanisms
- The Conjugate Base Mechanism
- The Kinetic Chelate Effect
- Stereochemistry of Reactions
- Substitution in trans Complexes
- Substitution in cis Complexes
- Substitution Reactions of Square-Planar Complexes
- Kinetics and Stereochemistry of Square-Planar Substitutions
- The trans Effect
- Oxidation–Reduction Reactions
- Inner-Sphere and Outer-Sphere Reactions
- Conditions for High and Low Oxidation Numbers

Organometallic Chemistry

- The 18-Electron Rule
- Square-Planar Complexes
- Ligands in Organometallic Chemistry
- Hydride and Dihydrogen Complexes
- Ligands Having Extended π Systems
- Bonding between Metal Atoms and Organic π Systems
- Linear π Systems
- Cyclic π Systems
- Alkyl and Related Complexes
- Carbene Complexes
- Carbyne (Alkylidyne) Complexes

Organometallic Reactions and Catalysis

- Oxidative Addition and C-H Bond Activation
- Reductive Elimination and Pd-Catalyzed Cross-Coupling
- Sigma Bond Metathesis
- Reactions Involving Modification of Ligands
- Organometallic Catalysts
- Heterogeneous Catalysts

ORGANIC CHEMISTRY (SC+SF – 20 questions)

The Structures of Organic Molecules
- Structural components of organic molecules
- Systematic nomenclature: IUPAC names
- Constitutional isomers and hydrocarbon substituents

Bonding in Organic Molecules
- Lewis structures
- Bond properties
- Resonance structures
- Hybrid orbitals and shapes of molecules
- Delocalized π-electron systems
- Noncovalent interactions

The Conformations of Organic Molecules
- Conformations of acyclic compounds
- Conformations of cyclic compounds
- Conformations of substituted cyclohexanes and cyclic compounds

The Stereochemistry of Organic Molecules
- Geometric isomers of alkenes
- Chirality and enantiomers
- Diastereomers
- Fischer projections

Chemical reactions and mechanisms
- General aspects of reactions
- Acid-base reactions
- Reaction mechanisms
- Reaction coordinate diagrams

Substitution reactions of alkyl halides
- The SN1-reaction and the SN2-reaction of alkyl halides

Substitution reactions of alcohols and related compounds
- Substitution reactions of alcohols
- Substitution reactions of ethers and epoxides
- Substitution reactions of thiols and thioethers

Elimination reactions of alkyl halides, alcohols and related compounds
- The E1-reaction
- The E2-reaction

Addition reactions of alkenes and alkynes
- Electrophilic addition reactions of alkenes
- Electrophilic addition reactions of alkynes
- The formation of carbon-carbon bonds
- Hydroboration reactions of π-bonds
- The addition of carbenes to π-bonds

Addition reactions of conjugates dienes
- The structures of dienes
- Bonding in conjugated dienes
- Electrophilic addition to conjugates dienes

Oxidation and reduction reactions
- Oxidation states in organic molecules
- Hydrogenation reactions
- Oxidation reactions of alkenes
- Oxidation reactions of alcohols
- Oxidation reactions of amines

Free radical reactions
- Free radical halogenation reactions
- Reduction via radical intermediates
- Free radical addition reactions

- Oxidation via radical intermediates

Proton and carbon NMR spectroscopy

- Chemical shifts and proton equivalence
- Spin coupling
- Interpreting and predicting 1H NMR spectra
- Carbon NMR spectra

Determining the structures of organic molecules

- Mass spectrometry
- Infrared spectroscopy

Organometallic reagents and chemical synthesis

- Carbon-carbon fond formation
- Organomagnesium and lithium compounds
- Transition metal organometallic compounds

Asymmetric reactions and synthesis

- Chiral compounds
- Enantiomeric resolution
- Asymmetric synthesis

The chemistry of benzene and its derivatives

- Structural aspects of aromatic molecules
- Electrophilic substitution reactions of benzene
- Electrophilic substitution reactions of benzene derivatives
- Nucleophilic substitution reactions of benzene derivatives
- Aromatic diazonium salts

Nucleophilic addition reactions of aldehydes and ketones

- General aspects of nucleophilic addition reactions
- Nucleophilic addition reactions
- Reduction reactions of aldehydes and ketones
- Oxidation reactions of aldehydes and ketones

Addition-substitution reactions of aldehydes and ketones

- Hemiacetals and acetals
- Acetals as protecting groups
- Carbohydrates

Addition-elimination reactions of aldehydes and ketones

- Compounds with carbon-nitrogen double bonds
- Imines, enamines, ylides

Addition-elimination reactions of carboxylic acids and derivatives

- Reactions of carboxylic acids
- The chemistry of acid chlorides, thioesters, and anhydrides
- The chemistry of esters
- The chemistry of amides
- The chemistry of nitriles
- Reactions with organometallic compounds
- Reduction reactions of carboxylic acids and derivatives

The acid-base chemistry of carbonyl compounds

- Acidity of carbonyl compounds
- Enols and enolate ions
- Reactions of enolate ions
- Dicarbonyl compounds

The nucleophilic addition reactions of enolate ions

- The aldol reaction
- The Claisen-condensation

Conjugate addition reactions of unsaturated carbonyl compounds

- α,β-Unsaturated carbonyl compounds
- Conjugate addition reactions
- Conjugate addition reactions of carbanions

The chemistry of polycyclic and heterocyclic arenes

- Polycyclic aromatic compounds
- Pyridine, pyrrole, azoles and related heterocycles

Amino acids, peptides, and proteins

- Amino acids
- Chemical synthesis of amino acids
- Peptide synthesis and analysis

Molecular recognition and catalysis

- Crown ethers, cryptands, cyclodextrins
- Recognition and catalysis using hydrogen bonds
- Structure-reactivity correlation
- Kinetics of organic reactions
- Kinetic and thermodynamic control on selectivity

PHYSICAL CHEMISTRY (SC – 20 questions)

Thermodynamics
- The gas laws
- The van der Waals equation
- The principle of corresponding states
- Work, heat, and energy
- The internal energy
- Expansion work
- Heat transactions and enthalpy
- Standard enthalpy changes and enthalpies of formation
- The temperature-dependence of reaction enthalpies
- State functions
- Exact and inexact differentials
- Changes in internal energy
- The Joule–Thomson effect
- The dispersal of energy
- Entropy, entropy changes accompanying specific processes
- The Third Law of thermodynamics
- The Helmholtz and Gibbs energies
- Standard reaction Gibbs energies
- Supercritical fluids
- Partial molar quantities
- The thermodynamics of mixing
- The chemical potentials of liquids
- Colligative properties
- The activities of regular solutions
- The activities of ions in solution
- Phases, components, and degrees of freedom
- The phase rule
- Two-component systems
- Vapour pressure diagrams
- Temperature–composition diagrams
- The Gibbs energy minimum
- The description of equilibrium
- The response of equilibria to pressure
- The response of equilibria to temperature
- Half-reactions and electrodes
- Varieties of cells
- The electromotive force
- Standard potentials
- Applications of standard potentials

Quantum theory & molecular structure
- Wave–particle duality
- The Schrödinger equation
- The uncertainty principle
- The postulates of quantum mechanics
- A particle in a box
- Motion in two and more dimensions
- Tunnelling
- Vibrational motion
- Rotation in two and three dimensions
- Spin
- Time-independent perturbation theory
- Time-dependent perturbation theory
- The structure of hydrogenic atoms

- Atomic orbitals and their energies
- Spectroscopic transitions and selection rules
- The structures of many-electron atoms
- The orbital approximation
- Self-consistent field orbitals
- The spectra of complex atoms
- Singlet and triplet states
- Spin–orbit coupling
- Term symbols and selection rules
- The Born–Oppenheimer approximation
- Molecular orbital theory
- The hydrogen molecule-ion
- Homonuclear diatomic molecules
- Heteronuclear diatomic molecules
- Molecular orbitals for polyatomic systems
- The Hückel approximation
- The prediction of molecular properties
- Operations and symmetry elements
- Vanishing integrals and selection rules

Molecular spectroscopy

- Experimental techniques
- The intensities of spectral lines
- Linewidths
- Pure rotation spectra
- Moments of inertia
- The rotational energy levels
- Rotational transitions
- Molecular vibrations
- Selection rules
- Anharmonicity
- Vibration–rotation spectra
- The vibrations of polyatomic molecules
- Normal modes
- Infrared absorption spectra of polyatomic molecules
- Symmetry aspects of molecular vibrations
- The electronic spectra of diatomic molecules
- The electronic spectra of polyatomic molecules
- Fluorescence and phosphorescence
- Dissociation and predissociation
- General principles of laser action
- Applications of lasers in chemistry
- The energies of electrons in magnetic fields
- The energies of nuclei in magnetic fields
- Magnetic resonance spectroscopy
- The chemical shift
- The fine structure
- Electron paramagnetic resonance
- The g-value
- Hyperfine structure

Statistical thermodynamics & chemical kinetics

- Configurations and weights
- The molecular partition function
- The internal energy
- The statistical entropy
- The canonical ensemble
- The thermodynamic information in the partition function

- Independent molecules
- The molecular partition function
- Electric dipole moments
- Polarizabilities
- Empirical chemical kinetics
- Experimental techniques
- The rates of reactions
- Integrated rate laws
- Reactions approaching equilibrium
- The temperature dependence of reaction rates
- Elementary reactions
- Consecutive elementary reactions
- Unimolecular reactions
- The rate laws of chain reactions
- Explosions
- Stepwise polymerization
- Chain polymerization
- Features of homogeneous catalysis
- Enzymes
- Kinetics of photophysical and photochemical processes
- Complex photochemical processes
- Collision theory
- Diffusion-controlled reactions
- Transition state theory
- Thermodynamic aspects
- The rates of electron transfer processes
- Theory of electron transfer processes

PHARMACEUTICAL CHEMISTRY (SF – 20 questions)

Principles of Medicinal Chemistry

- Physical, chemical and pharmaceutical properties of drugs;
- Hit discovery strategies;
- Hit to lead optimization strategies;
- Structure-based and mechanism-based design methods;
- Combinatorial chemistry;
- General concepts on pharmacodynamics, pharmacokinetics and drug metabolism.

Mechanisms of Drug Action

- antibiotics,
- antifungals,
- antileprotics
- antituberculous drugs,
- antimalarials,
- anthelmintics,
- amoebicides,
- antiprotozoals,
- antivirals,
- antineoplastic drugs,
- antipyretics,
- analgesics,
- bronchodilators,
- antitussives,
- mucolytics,
- decongestants,
- β-receptor blockers,
- calcium channel blockers,
- diuretics,
- cardiac glycosides,
- antiarrhythmics,
- antianginals,
- vasoconstrictors,
- vasodilators,
- antihypertensive drugs,
- psychedelics,
- hypnotics,
- anaesthetics,
- antipsychotics,
- antidepressants (including tricyclic antidepressants, monoamine oxidase inhibitors, lithium salts, and selective serotonin reuptake inhibitors - SSRIs),
- antiemetics,
- anticonvulsants/antiepileptics,
- anxiolytics,
- barbiturates,
- movement disorder (e.g. Parkinson's disease) drugs,
- stimulants (including amphetamines),
- benzodiazepines,
- dopamine antagonists,
- antihistamines,
- cholinergics,
- anticholinergics,
- emetics,
- cannabinoids,
- 5-HT (serotonin) antagonists.,
- hormone replacement.

PHARMACEUTICAL TECHNOLOGY AND DRUG DELIVERY (SF – 20 questions)

A good knowledge of main drug delivery systems is expected, in particular:
- Current methodologies in preparation of conventional pharmaceutical dosage forms and advanced formulations.
- Background in physical pharmaceutics and biopharmaceutics.
- Knowledge of main physicochemical and biopharmaceutical properties of major classes of pharmaceutical structural ingredients, namely polymers, lipids, surfactants, sugars etc
- Familiarity with classical analytical techniques for physicochemical and biopharmaceutical characterization of ingredients and dosage forms.
- Basic principles dictating the selection and the design of dosage forms, traditional formulations and micro- and nanopharmaceuticals.
- Concepts of bioavailability, pharmacokinetics and drug availability.
- Knowledge of principles of controlled drug delivery and drug targeting.
- Biopharmaceutical performance of solubilizers, stabilizers, targeting agents, cell penetrating enhancers, mucoadhesive materials, stimuli sensitive materials.
- Principles of pharmaceutical technology
- Bioavilability
- Membrane transport mechanisms: paracellular and transcellular pathways. Passive, active, facilitated, pinocytosis, ion-pairing. Influx and efflux pumps.
- Principles of pharmacokinetics: non compartmental and compartmental analyses. Monocompartimental model with and without absorption step, binocompartimental model with and without absorption step, pharmacokinetic parameter analysis.
- Drug release: principles and mechanisms
- Dissolution and solubility, physical state, polymorphism, micro and nanoization, micellesm cyclodextrins etc.
- Preformulation and micrometrics
- Particle size, particle shape, porosity, surface area
- Density of powders, flow of powders
- Mechanical properties: elasticity, plasticity etc.
- Principles of rheology
- Main processes of pharmaceutical technology: mixing and blending, milling, dessication.
- Solid forms: tablets and capsules,
- Disperesed systems: suspensions and emulsions,
- Injectables and sterilization, lyophilization.
- Aerosols,
- Topical systems,
- Polymeric and inorganic microparticles
- Colloidal systems polymeric nanoparticles, inorganic nanoparticles, liposomes, micelles , polymersomes, physical assemblies, polymer bioconjugates, solid lipid nanoparticles.
- Cyclodextrins,
- pH sensitive formulations, stimuli-sensitive drug delivery systems,
- Hydrogels
- Principles of drug targeting

BIOTECHNOLOGY (SC+SF – 10 questions)

MOLECULAR BIOLOGY
Nucleic acid structure
DNA replication
Transcription in Prokaryotes and Eukaryotes
RNA maturation
Translation
Most important techniques: electrophoresis, blotting, cloning, polymerase chain reaction (PCR)

BIOCHEMISTRY
Structures and properties of amino acids and proteins
Protein folding and post-translational modifications
Protein-protein interaction
Cooperativity and allostery in macromolecules
Catalysis and enzyme kinetic
Structure and properties of lipids and membranes
Molecular mechanisms of signal transduction
Glycolysis, Krebs cycle, oxidative phosphorylation

MICROBIOLOGY
Structural and metabolic properties/characteristics of prokaryotic and eukaryotic microorganisms
Microbial growth
Relevant industrial fermentation processes

GENETIC ENGINEERING
Recombinant DNA technologies
Production of heterologous proteins
Main techniques for the isolation and characterization of proteins and peptides
DNA sequencing

BIOINFORMATICS
Databases of interests to Biotechnologies and data mining
Tools to retrieve, analyze and compare protein and nucleic acid sequences
Consensus sequences, functional motifs and profiles
Protein structure comparison and modelling

“OMIC” SCIENCES
Isolation and purification of genomic DNA
DNA genomic libraries
Genetics and Physics mapping of a genome
Basic concepts of Transcriptomics and Proteomics

PHARMACEUTICAL SCIENCE (SC – 20 questions)

Principles of Medicinal Chemistry

- Physical, chemical and pharmaceutical properties of drugs;
- Hit discovery strategies;
- Hit to lead optimization strategies;
- Structure-based and mechanism-based design methods;
- Combinatorial chemistry;
- General concepts on pharmacodynamics, pharmacokinetics and drug metabolism.
- Drug targets and target recognition
- Biodrugs

Principles of Pharmaceutical Technologies

- Background in physical pharmaceutics and biopharmaceutics.
- Knowledge of main physicochemical and biopharmaceutical properties of major classes of pharmaceutical structural ingredients, namely polymers, lipids, surfactants, sugars etc
- Familiarity with classical analytical techniques for physicochemical and biopharmaceutical characterization of ingredients and dosage forms.
- Principles of pharmaceutical technology
- Bioavailability
- Drug release: principles and mechanisms
- Dissolution and solubility, physical state, polymorphism, micro and nanoization, etc.
- Particle size, particle shape, porosity, surface area
- Density of powders, flow of powders
- Mechanical properties: elasticity, plasticity etc.
- Principles of rheology
- Dispersed systems: suspensions and emulsions,
- Polymeric and inorganic microparticles
- Colloidal systems polymeric nanoparticles, inorganic nanoparticles, liposomes, micelles, polymersomes, physical assemblies, polymer bioconjugates, solid lipid nanoparticles.
- Cyclodextrins
- Hydrogels
- Principles of drug targeting

GENERAL CHEMISTRY (SF – 20 questions)

Atoms and electronic configuration
Chemical compounds
Chemical bonding
Solutions and Their Physical Properties
Solutions and colligative properties
Chemical reactions
State diagrams
Principles of Chemical Equilibrium
Equilibria in solution: solubility, pH, complex formation
Electrochemistry
Equilibria in the gas phase
Periodic Table and Some Atomic Properties
Coordination compounds