Faculty of Medicine, Masaryk University, Brno

Syllabus of the subject-matter required for the Admission Examination

CHEMISTRY

Atoms and molecules. Subatomic particles, atomic and mass numbers. Relative atomic mass of an element, molecular mass of a compound. Amount of a substance, the mole of an element or a compound, Avogadro´s constant. Diatomic elements. The molar mass of a compound, the molar volume of gases at standard temperature and pressure.

Names and formulas of common inorganic ions and compounds (translation of a name to a formula, naming of a compound given the formula). Stoichiometric calculations from chemical formulas. Chemical equations, balancing equations, mass relations in chemical reactions. Calculations of reacting masses, amounts of substances (and volumes of gases) from chemical equations.

Atomic structure, the electron configuration of elements, the successive filling of the energy sublevels and orbitals by electrons. Valence electrons, *s*, *p*, and *d* elements. The Periodic Table of elements, established names of some groups of elements. The periodicity of the properties of the elements. The positions of the representative (*s* and *p*) elements in the table. Transition (*d* and *f*) elements, the locations of the metals, and nonmetals.

Chemical bonds. The octet rule. Single and multiple covalent bonds, coordinate covalent bond. The typical numbers of covalent bonds for nonmetals. Spatial orientation of covalent bonds, hybridization of atomic orbitals, shapes of simple molecules. Polar covalent bond, electronegativity, polar and nonpolar molecules. The ionic bond and ionic compounds. Weak intermolecular bonding (the hydrogen bond).

Solutions - expressing the composition of solutions: mass fraction (percentage by mass), amount-of-substance concentration (molarity), and mass concentration, calculations. Equivalent amounts of acids and bases required for neutralization (titration of an acid with a base). Solutions of nonelectrolytes and electrolytes, dissociation and ionization of electrolytes, strong and weak electrolytes. Concentrations of ions in solutions of strong electrolytes.

Types of chemical reactions. Protolytic reactions: Definition of acids and bases (Brønsted), conjugate pairs. Amphoteric compounds and ions. Strong acids and bases. Weak acids and bases, ionization constants. Ionization of water, the ionic product of water. Concentration of hydrogen ions, the pH value. Solutions of strong acids and bases - calculations (for a given concentration or pH value). Hydrolysis of ions (classification of aqueous solutions of the salts as acidic, alkaline, or essentially neutral).

Oxidation-reduction reactions, oxidizing agents and reducing agents. Balancing redox equations. Half equations in redox reactions and the numbers of electrons lost or gained.

Heats of reaction and other enthalpy changes. Hess´s law. Reaction rate, factors that influence reaction rates. Chemical equilibrium, equilibrium constants, and the general relationship for the equilibrium concentrations of reactants and products. Factors that influence equilibria (changes in temperature, concentration, and pressure).

Hydrogen and oxygen, properties, ionic and covalent hydrides and oxides; acid-forming, basic, and amphoteric oxides. Water. Characterictics of some of the elements (chlorine, sulphur, nitrogen, phosphorus, carbon, silicon, alkali metals and alkaline earth metals, iron,

copper, aluminium and zinc) and of their important compounds (oxides, hydroxides, covalent hydrides, oxyacids, and salts).

Bonds in organic compounds, typical properties of organic compounds. Types of reactions in organic chemistry (reactions by addition, elimination, dehydration, condensation, hydrolysis, oxidation, reduction, etc.). Notation of structural and abbreviated (rational) formulas. Isomerism – various types of structural isomerism and stereoisomerism.

Nomenclature of organic compounds: Systematic IUPAC names – general principles in systematic nomenclature: functional names of hydrocarbons and of some groups of compounds, substitutive names for the most organic compounds. Application of these principles in the nomenclature of hydrocarbons and some important groups of organic compounds. The trivial (or semisystematic) names for the most common compounds.

Hydrocarbons, names for the groups derived from hydrocarbons. Saturated and unsaturated hydrocarbons, arenes – chemical formulas, typical reactions. Organic halides, nitrocompounds, amines – various types and important structures, basicity of amines, formation of amides.

Alcohols and phenols – classification, typical reactions (esterification, ethers, oxidation of alcohols, quinones). Aldehydes and ketones - oxidation and reduction, formation of acetals. Carboxylic acids – reactivity of the carboxyl group. Survey of the common names and structures of the most important carboxylic acids (monocarboxylic and dicarboxylic, saturated and unsaturated, hydroxyacids, ketoacids), names for acyls. Acid halides, anhydrides, esters, amides, nitriles. Urea.

Heterocyclic compounds – names and structures of the various common types. The purine and pyrimidine bases of nucleic acids. Uric acid.

Saccharides - classification, biological importance, structure of monosaccharides (acyclic oxo-forms, hemiacetal cyclic forms, anomers), formation of glycosides. Reducing and non-reducing disaccharides, polysaccharides.

Lipids - fatty acids bound in lipids, acylglycerols, hydrolysis of fats and oils, saponification, soap. Main constituents of phospholipids. Steroids – the structure of the steroid ring system, biological roles of some sorts of steroid compounds.

Structures, common and systematic names of the twenty standard (proteinogenous) amino acids, polarity of the side chains. Peptide bond. Proteins – the primary structure, general features of secondary, tertiary, and quaternary structure. Disulfide cross-links, hydrogen bonds and other noncovalent interactions stabilizing the secondary and tertiary structure of proteins, denaturation of proteins. Two main classes of proteins.

The general structure of nucleic acids: components of nucleosides and nucleotides, the types of bonds connecting the components, phosphodiester bonds in polynucleotides. The double helix of DNA. The function of DNA and of three major types of RNA in transcription of the genetic code and protein biosynthesis.

Six main classes of enzymes. Important hydrolases of the digestive tract. Common chemical names of vitamins. The anabolic and catabolic character of metabolic pathways, importance of biological oxidations in catabolism of nutrients, high-energy (macroergic) compounds and the energetic yield of metabolism. The role of the citric acid cycle and the mitochondrial electron-transport chain. The end products of anaerobic and aerobic glucose degradation, ß-oxidation of fatty acids, the nitrogenous end-products of amino acid and purine catabolism.

Examples of admission test questions

In each question, only one answer is correct at the most (i.e., one or none):

- What would be the volume of 12 g of gaseous oxygen at standard temperature and pressure? (The answer should be rounded off to three significant digits.)

  (A) 8.40 L (B) 192 L (C) 16.8 L (D) 22.4 L

- Calculate the pH of a 0.05 mol L^{-1} solution of potassium hydroxide:

  (A) 6.50 (B) 12.5 (C) 13.0 (D) 12.7

- Which of the following is the acid-forming oxide?

  (A) Ag_2O (B) CO (C) Mn_2O_7 (D) N_2O

- Give the common name of the compound whose condensed formula is $HOOC\text{-}CH_2\text{-}CH(OH)\text{-}COOH$:

  (A) Lactic acid (B) oxaloacetic acid (C) acetoacetic acid (D) tartaric acid

- Which of the following heterocycles is a part of the haemoglobin molecule?

  (A) Purine (B) porphin (C) pyridine (D) indole

Recommended literature:

An Overview of Chemistry, Táborská E., Dostál J., Masaryk University Brno, 2010

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PHYSICS

The students should understand the following physical principles and concepts, as well as, apply them in simple examples and calculations. Knowledge of basic SI units is also unavoidable.

A) Basic concepts
Fundamental and derived SI units, standard prefixes of units (multiples and submultiples), vectors, scalars, addition of vectors.
B) Mechanics of a particle and rigid body
Uniform rectilinear motion, uniformly accelerated motion (particle position, velocity and acceleration calculation), free fall, Newton laws of motion, force, momentum, impulse of a force, weight, density, torque, static and kinetic friction, uniform circular motion (frequency, angular frequency, centripetal acceleration), work, power, efficiency, kinetic energy, potential energy of a body in field of gravity, elasticity (normal stress, linear strain, Hooke's law, modulus of elasticity), Newton principle of universal gravitation (understanding the formula, gravitational acceleration, potential of the gravitational field.
C) Wave motion and sound
Basic concepts (period, frequency, phase velocity), instantaneous displacement of an oscillating body, its velocity a and acceleration, travelling and standing waves, transverse and longitudinal waves, destructive and constructive interference, intensity of wave motion (radiation), oscillating mass on a spring, oscillating pendulum, audible sound and ultrasound, intensity and level of sound intensity.
D) Mechanics of fluids
Ideal or perfect liquid, pressure (Pascal principle, hydrostatic pressure, units, hydraulic press), Archimedes principle, force of buoyancy, viscosity, laminar and turbulent flow, equation of continuity, Bernoulli's equation, surface tension, capillary elevation and depression, pressure in the bubble (Laplace's formula).
E) Principles of thermodynamics
Basic concepts (thermodynamic systems, states and processes), reversible and irreversible processes, thermodynamics (Kelvin) temperature, ideal gas law (state equation of ideal gas), universal gas constant, pV-diagrams, equations for isothermal, isosteric, isobaric and adiabatic process, thermal expansion and contraction of solids, heat, heat capacity, specific heat capacity, 1^{st} law of thermodynamics, equation of thermal conductivity, latent heats, 2^{nd} law of thermodynamics (working cycle of the Carnot ideal engine), absolute and relative air humidity.
F) Theory of electricity
Electric charge, conductors, Coulomb's law, dielectric constant, electric field intensity, potential and potential difference (voltage), electrical capacity of a parallel-plate capacitor, capacitors in parallel and in series, electric current, Ohm's law, resistivity, conductivity, temperature coefficient of resistance, Kirchhoff's laws, resistors in parallel and in series, electrical power and heating effect, thermoelectric phenomenon, Faraday's law of electrolysis, Faraday's constant, N-type and P-type semiconductors, properties of P-N junction, principle of a transistor.
G) Magnetism and electromagnetism

Force acting between two magnetic poles, magnetic permeability, magnetic flux and flux density, magnetic force, magnetic field due to a straight wire or coil, magnetic force exerted on a conductor passed by current, Fleming's rule, magnetic force between two parallel conductors, definition of ampere in SI, magnetic deflection of a moving electron, electromagnetic induction, Lenz's law, voltage induced in straight wire, self-inductance of a coil, alternating current, effective values of current and voltage, electric power of alternating current, impedance (capacitance, inductance), AC transformer.

H) Optics

Basic properties of light and optical media, speed of light, reflection and refraction of light (Snell's law, critical angle), lenses, so-called lens-maker's equation, sign convention, dioptric power, converging and diverging lens, lens equation, linear magnification, mirror (imaging equation and magnification), basic optical properties of human eye, microscope and its magnification, light spectrum, interference of light, polarised light, photometry (luminous intensity, luminous flux, illumination).

I) Theory of relativity

Dilation of time, contraction of length, relativistic addition of velocities, relativistic mass, energy and mass equivalence principle.

J) Quantum, atomic and nuclear physics

Unit “electron volt”, mole, Avogadro's constant, excitation of atoms, de Broglie matter waves, principal quantum number, orbital quantum number, magnetic quantum number, Pauli's exclusion principle, emission and absorption light spectra, principle of X-ray tube, photoelectric effect, Compton scattering, structure of atom nucleus, nuclides, isotopes, nuclear binding energy, principle of a nuclear reactor, alpha-decay, beta-decay, gamma-decay, neutron radiation, fission of heavy nuclei, law of radiation decay, Becquerel, Geiger-Mueller counter.

Recommended literature:

Mornstein, Vojtěch. *An Overview of Physics*. Brno : Masaryk University, Medical Faculty, 2010. 80 p. ISBN 978-80-210-5192-8.

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BIOLOGY

General characteristics of living systems

A brief survey of the classification system. Acellular, unicellular and multicellular organisms. Bacteria. Cyanobacteria. Viruses. Medically important yeasts and molds. Medically important plants and protozoa. Medically important worms and insects. Basic characteristics of vertebrata and mammals. Milestones in biology and medicine.

Cell biology

Cell theory. Chemical composition of the cell. Structure and function of proteins. Structure and function of nucleic acids. Saccharides and lipids. Prokaryotic and eukaryotic cell – basic differences. Biomembranes and membrane organelles, structure, function. Cytoskeletal system. Cell movement. Membrane transport. Endocytosis and exocytosis. Energy transformation in mitochondria and chloroplasts. Transcription and translation. DNA replication. Structure of cell nucleus. Cell cycle. Mitosis. Meiosis. Stem cells. Cell differentiation. Cancer cell.

Genetics

Genetic information. DNA. RNA. Protein. Expression of genetic information. Heredity and variability. Basic genetic terms. Gene and genotype. Allele. Homozygote and heterozygote. Character and phenotype, Dominance and recessivity. Gene and its expression. Prokaryotic and eukaryotic chromosomes. Meiosis. Segregation and recombination of chromosomes in diploid organisms. Mendel´s laws. Autosomal and gonosomal inheritance. Genetic tasks. Mutations. Karyotype. Chromosomal aberrations. DNA technology.

Human biology

Homeostasis. Tissues of the human body. Skeleton and muscles. Respiratory system and its function. Body fluids. Blood. Blood groups and transfusion. Immune system and defense mechanisms. Circulatory system and its function. Lymph and its circulation. Digestive system and nutrition. Body temperature and its maintenance. Urinary system. Excretory system. Skin and its functions. Endocrine glands. Hormones and hormonal regulation. Nervous system. Senses. Human reproduction and reproductive organs. Gametogenesis. Sexual reproduction. Human development. Human genetics.

Evolution

Origins of the live. Origin of the cells. Basics of evolution. Chemical evolution. Paleontological evidence of the earliest forms of life. Darwinian evolution. Classification of living systems. Acellular organisms.

Ecology

Abiotic and biotic factors. Biosphere. Ecosystems. Population explosion. Building of sustainable society.

Recommended literature:

Matthew Stubbs MBBS BSc, Narin Suleyman BSc, Crash Course Cell Biology and Genetics Updated Print + eBook edition 4th Edition. 2015. ISBN-13: 978-0723438762 ISBN-10: 0723438765

Neil A. Campbell, Jane B. Reece, Lisa Urry, Michael L. Cain et.al, Biology: A Global Approach (10th International Edition) - 2014. Pearson Education Limited (Verlag) 978-1-292-00865-3 (ISBN)

Sylvia S. Mader Dr., Michael Windelspecht. Human Biology. McGraw-Hill Education; 15 edition (January 27, 2017). ISBN-13: 978-1259689796. ISBN-10: 1259689794