MEDICINE AND SURGERY

Course: Principles of the Living Matter

Year: 1st

Period: 1st semester

Credits: 9

Objectives

GENERAL LEARNING GOALS

- *to understand the fundamental principles of thermodynamics and heat transfer*
- *to analyze the thermodynamic properties of chemical reactions*
- *to examine the thermodynamic properties of redox reactions from the perspective of electrochemical processes*
- *to describe the chemo-physical properties of solutions, with special attention to aqueous solutions*
- *to understand the acid/base properties of solutes in aqueous solutions*
- *to describe the relations between forces and motion for point-like and rigid bodies*
- *to understand the physical and chemical properties of organic compounds with special attention to polyfunctional biomolecules*
- *to examine the basis of electricity and electric circuits, with a focus on neuronal conduction*
- *to discuss the most relevant classes of organic reactions, to be able to evaluate the covalent bonds that characterize the more relevant biomolecules*
- *to understand the chemical relations between different functional groups and devise reasonable syntheses*

Prerequisites

Students are supposed to have a basic knowledge of chemistry concepts at high-school level that include the structure and periodic properties of the atoms, ionic and covalent bonds, relative atomic and molecular mass, and the concept of mole. Basic knowledge of algebra, trigonometry, and geometry is also considered a prerequisite.

Attendance

Attendance to teaching activities in presence is mandatory according to the percentage specified by the regulation of the degree course (75%). Students who will not reach the required level of attendance might be prevented from registering for the exam.

Students who falsify attendance to classes or any teaching activities will not be allowed to register for any of the dates published for the first exam session of the semester. They will receive an official warning letter from the Dean of the degree program and the Rector of the University.

Verification of learning

The graded components of the course consist in:

- quizzes, exercises and group activities (CA, continuous assessment): 0-6 points
- a final exam (ESE): 0-27 points

The final score is constituted by the sum of the previous components (CA+ESE), and the pass mark is 18 points. 2nd year students will be evaluated simply based on the ESE and the relative score will be normalized to 33 points.

The Continuous Assessment score will be determined through short activities carried out during the lessons or the Activation of Knowledge events. Interactive tools (preferentially Wooclap) will be employed during the lectures.

The End of Semester Exam (ESE) is composed of a written exam related to the whole program of Physics and Chemistry. ESE is formally divided into three modules reflecting the three parts of the course. Each module is worth 9 points, a minimum of 5 points per module is required to pass the exam and the overall mark (CA+ESE) must be in any case 18 points or higher.
Despite the division into three parts, the ESE must be considered as a whole; a positive partial evaluation in a single part cannot be transferred to a successive session.

Texts

Reference textbook (Physics): *Introduction to Biological Physics for the Health and Life Sciences*, 2nd Edition. Kirsten Franklin, Paul Muir, Terry Scott, Paul Yates. Wiley (2019). ISBN: 978-1-118-93450-0

Reference textbook (Chemistry): J. Smith. *General, Organic and Biological Chemistry*. 5th Edition. McGraw-Hill (2021). ISBN: 1264238592

Handouts from the lectures and tutorials will be available on the LMS site.

Contents

MODULE OF PHYSICS

- *Familiarize with the thermodynamic potentials H (enthalpy), F (Helmholtz free energy) and G (Gibbs free energy)*
- *Analyze and implement the thermodynamic potentials with respect to an open system*
- *Understand the concepts of ideal gas mixtures and liquid solutions*

5. KINEMATICS AND DYNAMICS OF A MATERIAL POINT

***Learning goals**:*

- *Familiarize with the definition of displacement, velocity, and acceleration*
- *Recognize the basic types of linear motion: motion with constant velocity and with constant acceleration*
- *Understand the characteristics of motion in two dimensions and in circle*
- *Understand the concepts of gravitational force and gravitational acceleration*
- *Evaluate and explain Newton's laws of motion and the concept of linear momentum*
- *Illustrate the difference between inertial and non-inertial frames of reference*
- *Explain the concept of work done by a force and the link with the kinetic energy of an object in motion*
- *Understand the concept of elastic force and elastic potential energy*
- *Apply the theorem of the conservation of mechanical energy*
- *Evaluate the difference between conservative and dissipative forces and the definition of potential energy*
- *Illustrate the difference between static and kinetic friction*
- *Evaluate the different ways in which friction depends on the speed of the object in motion and the concept of terminal velocity*

6. MECHANICS OF THE RIGID BODY AND INTRODUCTION TO BIOMECHANICS

***Learning goals**:*

- *Distinguish the conditions for the equilibrium of a material point and those for the equilibrium of a rigid body*
- *Recognize the different classes of levers and pulley systems with respect to the concept of mechanical gain*
- *Illustrate the concepts of moment of inertia and angular momentum*
- *Recognize the analogies between linear and rotational motion*
- *Evaluate and analyse the elastic properties of materials with respect to the case of biological systems*

7. BASICS OF ELECTRICITY AND BIOELECTRICITY

***Learning goals**:*

- *Define the concepts of charges, electric force, and electric field*
- *Understand the definition of electric dipole and electric dipole moment*
- *Explain the rationale behind the electric potential energy and electric potential*
- *Describe the basic notions related to electric current, resistors, and capacitors*
- *Understand the definition of magnetic force and magnetic field*
- *Illustrate Lorentz force on a charged particle in a magnetic field*
- *Define the concept of magnetic dipole moment*
- *Identify the role of electric phenomena in nerve signal conduction*

MODULE OF GENERAL CHEMISTRY

1. THE STRUCTURE OF MATTER, PART A: ATOMS AND MOLECULES

***Learning goals**:*

- *Describe the atomic structure of an atom according to the quantum model*
- *Know the differences between the* s, p *and* d *orbitals*
- *Enunciate and apply the Pauli exclusion principle*
- *Apply the Aufbau principle to the determination of the electronic configuration of atomic species*
- *Be able to analyse the periodic table*
- *Know the definitions of the periodic properties of the atoms (atomic radius, first ionization energy, electron affinity) and discuss how they vary across the periodic table*
- *Discuss the meaning and the application of electronegativity.*
- *Learn the most common charges of monoatomic ions*
- *Describe the characteristics of ionic bonding and covalent bonding and highlight the differences*
- *Distinguish between ions, molecules, covalent solids ad metals*
- *Apply the correct nomenclature to both ionic and covalent compounds*
- *Learn by heart the most common anions*
- *Know what a hydrated salt is and associate it with the correct formula*
- *Be able to sketch the Lewis structure of ions and molecules*
- *Describe the structure of molecules and polyatomic ions in terms of geometry and shape*
- *Discuss the concept of resonance and its importance in the molecular geometry*
- *Discuss the polarity of molecules and ions*
- *Know the identity and the characteristics of a paramagnetic species*
- *Enunciate the Valence Bond theory and discuss the presence of σ and π orbitals in diatomic species*
- *Describe the features of hybrid orbitals*
- *Interpret the structure of simple molecules in terms of hybrid orbitals according to the VB theory*

2. THE STRUCTURE OF MATTER, PART B: THE CONDENSED MATTER

***Learning goals**:*

- *Understand the differences between intramolecular and intermolecular forces*
- *Classify the non-covalent interactions (Wan der Waal forces)*
- *Understand dipole-dipole forces*
- *Individuate the conditions for the occurrence of hydrogen bonding*
- *Discuss the peculiar features of hydrogen bonding and understand the consequence on the biological world*
- *Describe the dipole-induced dipole interaction and introduce the concept of polarizability*
- *Discuss the occurrence and the importance of London forces*
- *Relate the intensity of intermolecular forces with boiling or freezing points*
- *Understand what covalent crystals are and provide significant examples*
- *Discuss the difference between diamond and graphite in terms of the microscopic structure*
- *Discuss the difference between silicon dioxide and carbon dioxide in terms of molecular structure*
- *Individuate the common characteristics of metals*
- *Understand the electron sea model for metals and discuss how such model provides reasonable explanations for the properties of metals*

3. STOICHIOMETRY

***Learning goals**:*

- *Describe the quantitative aspects of chemical reactions through the relationships between moles and the weight of compounds*
- *Understand the meaning of the percent composition of a chemical compound and recognize its relationship with the empirical formula*
- *Balance a given chemical equation by assigning the correct stoichiometric coefficients*
- *Perform calculations on weight relationships between reagents and products (mass of reagent consumed, amount of product formed, …)*
- *Understand the concept of limiting reagent and excess reagents and correctly label the starting materials*
- *Perform stoichiometric calculations based on the limiting reagent*
- *Understand combustion reactions (in excess of oxygen) and be able to predict the empirical formula of a given compound based on the masses of the combustion products*
- *Understand and apply the concept of reaction yield to chemical transformations*
- *Be able to apply the ideal gas law to gaseous systems*
- *Learn the value of the general constant R based on the system of units of measurement employed in the proposed exercises*
- *Understand and apply the concepts of percentage, mole fraction and partial pressure in the context of gaseous mixtures*

4. CHEMICAL THERMODYNAMICS

***Learning goals**:*

- *Define the standard conditions for state functions (H, S, G)*
- *Recognize enthalpy (H) as a form of energy to identify exothermic and endothermic reactions*
- *Understand and apply the concept of molar enthalpy H_m to physical transformations (evaporation, condensation, sublimation, …) and chemical reactions*
- *Understand the concept of formation reaction of a given compound and be able to associate the formation enthalpy H_f*
- *Calculate the standard variation of enthalpy during a chemical reaction ($\Delta_r H°$) starting from the data present on the Thermodynamic Values Table (present on LMS).*
- *Discuss the Hess law and its applications*
- *Recognize entropy (S) as a measure for the dispersion of energy and matter in a system and know its fundamental properties (state function, units of measurements…)*
- *Enunciate and understand the Third Law of Thermodynamics*
- *Predict the variation of entropy in specific cases (phase transitions, Trouton's Rule)*
- *Calculate the variation of entropy during a chemical reaction ($\Delta_r S°$) starting from the data present on the Thermodynamic Values Table (present on LMS).*
- *Predict the spontaneity of a reaction according to the sign of the relative variations in entropy and enthalpy*
- *Define the Gibbs function (free energy, G) in terms of the combination of H and S;*
- *Manipulate the definition of G and derive the physical meaning of G as "free energy".*
- *Understand the relation between the sign of ΔG and the spontaneity of chemical reactions (endergonic/exergonic reactions).*
- *Understand the concept of standard variation of G for a chemical reaction ($\Delta_r G°$) and be able to calculate it starting from the data present in the Thermodynamic Values Table.*
- *Be able to predict the quantitative effect of variations in temperature on the value of $\Delta_r G°$ for a given reaction*

- *Establish the temperature intervals where a reaction is spontaneous, reversible or prohibited.*
- *Predict the amount of heat released during a reaction (thermochemistry)*
- *Define the equilibrium state for a reaction and be able to associate an equilibrium constant K_{eq}.*
- *Be able to express the equilibrium constant in terms of concentrations (K_c) or partial pressures (K_p) and derive its expression from the chemical equation in homogeneous systems*
- *Be able to interconvert K_p and K_c in gaseous systems*
- *Discuss the equilibrium in heterogeneous systems*
- *Evaluate the reaction quotient (Q) and discuss its relationship with the equilibrium constant*
- *Predict the direction of a reaction starting from the concentrations of the involved species and the value of the equilibrium constant*
- *Enunciate Le Chatelier's principle in the context of chemical equilibrium.*
- *Discuss the influence of changes in concentration or pressure on the equilibrium position*
- *Describe the dependence of K_{eq} on the temperature for endothermic and exothermic reactions*
- *Discuss the relationship of ΔG and $\Delta G°$ with Q and K_{eq}.*
- *Analyze the criteria of the spontaneity of a reversible reaction at equilibrium: $\Delta G°$ and K_{eq}.*
- *Be able to build ICE tables and solve problems on equilibrium*

5. CHEMICAL KINETICS

***Learning goals**:*

- *Define the reaction rate and the rate constant for chemical reactions*
- *Discuss the influence of the physical state of the reactants on the reaction rate*
- *Discuss the influence of the concentration (or the partial pressure) of the reactants on the reaction rate*
- *Discuss the influence of the temperature on the reaction rate*
- *Be able to interpret the rate law for a chemical equation and derive the reaction order*
- *Be able to distinguish rate equations of elementary and non-elementary reactions.*
- *Understand the meaning and the importance of the Rate Determining Step in multistep reactions*
- *Make reasonable hypotheses for reaction mechanisms starting from the rate law*
- *Understand and apply the Arrhenius equation*
- *Define the energy of activation and the transition state of an elementary reaction.*
- *Discuss the properties of a catalyst by means of a reaction diagram*
- *Derive and apply the integrated form of the Arrhenius equation*
- *Study and discuss the best conditions for the industrial production of ammonia.*

6. PHASE TRANSITIONS AND COLLIGATIVE PROPERTIES

***Learning goals**:*

- *Describe the surface tension of a liquid and know its causes*
- *Define the vapour pressure of a liquid*
- *Discuss the gas-liquid transition in energetic terms*
- *Define the vapour pressure of a liquid and know its physical meaning*
- *Describe the supercritical state of a substance*
- *Interpret the phase diagram of a given substance*
- *Discuss the properties of an ideal solution*
- *Define the colligative properties*
- *State and apply Raoult's law for non-volatile solutes*
- *Understand boiling point elevation and freezing point depression of solutions and solve relative*

problems

- *Describe the phenomenon of osmotic pressure*
- *Be able to calculate the osmotic pressure of a solution*
- *Define isotonic, hypertonic and hypotonic solutions*
- *Describe the reverse osmosis technology*

7. THE CHEMISTRY OF SOLUTIONS

***Learning goals**:*

- *Discuss the solubility of solids and liquids into liquids*
- *Describe the dissolution process of substances into water*
- *Discuss the energetic aspects of the dissolution of ionic compounds into water*
- *Define the solubility of a compound and the characteristics of a saturated solution*
- *Write the equation for the solubility equilibrium of a salt in water and associate its solubility product constant*
- *Quantitatively relate solubility and the solubility product constant*
- *Calculate the solubility of a salt starting from its solubility product*
- *Discuss the common ion effect on the solubility of ionic compounds*
- *Discuss the solubility of gas into liquids according to Henry's law*
- *Discuss the effect of the temperature on the solubility of gases in liquids*
- *Understand the characteristics of a colloid, provide significant examples and describe the Tyndall effect*

8. ACIDS AND BASES

***Learning goals**:*

- *Discuss the definition of an electrolyte and the differences between weak and strong electrolytes*
- *Define the dissociation degree of an electrolyte*
- *Describe water self-ionization (autoprotolysis) as a reversible reaction*
- *Define the ionic product of water (K_w)*
- *Distinguish among neutral, acidic, and basic solutions with respect to [H_3O^+]*
- *Define the pH, the value of the pH of pure water (pH 7) and that of aqueous solutions of acids and bases*
- *Describe the Arrhenius theory on acids and bases*
- *Discuss the Brønsted-Lowry theory, highlight the differences with the Arrhenius theory and illustrate the concept of conjugate acid/base*
- *Describe the differences between weak and strong acids (and bases)*
- *Learn the most common strong acids*
- *Learn the most common strong bases (hydroxides, hydrides, oxides) and write their reaction with water*
- *Calculate the pH of solutions of strong acids/bases paying attention to the boundary conditions*
- *Calculate the pH of solutions of weak acids/bases using the approximate formula when it is possible*
- *Describe the most common polyprotic acids and calculate the pH of their solutions*
- *Be able to establish the relationship between Ka and Kb of conjugated acids/bases*
- *Define the hydrolysis reaction of salts and establish when a given salt gives an acidic/basic/neutral reaction with water*
- *Calculate the pH of a solution of a salt undergoing hydrolysis*
- *Define the neutralization reaction*

- *Calculate the resulting pH after a neutralization reaction*
- *Discuss the relationship between the acid/base properties of a given molecule and its molecular structure*
- *Describe a buffer solution and discuss its properties in terms of Le Chatelier principle*
- *Derives the Henderson-Hasselbalch equation and apply it to the calculation of the pH of a buffer solution*
- *Be able to calculate the variation of pH of buffer solutions after the addition of strong acids/bases*
- *Define the buffer capacity of a buffer solution*
- *Describe how to prepare a buffer of a given concentration and pH*
- *Analyze the properties of the hydrogen carbonate/carbonic acid buffer*
- *Discuss the Henderson-Hasselbach calculation of the pH of the hydrogen carbonate/carbonic acid buffer and describe the pH regulation in the human body*

9. REDOX CHEMISTRY

***Learning goals**:*

- *Define the oxidation number and describe how to calculate it for each atom in a chemical species*
- *Define what is an oxidation reaction and what is a reduction reaction. Explain why usually we talk about RedOx reactions.*
- *Learn to balance the Redox reactions*
- *Examine the redox reaction between Cu^{2+} and Zn as an example of a spontaneous redox process*
- *Describe how a Daniell's cell in standard conditions is built and discuss its production of electric energy*
- *Employ the cell notation for describing voltaic (or galvanic) cells*
- *Define the standard reduction potential (E°) of single electrodes*
- *Describe a standard hydrogen electrode ad use it as an example for gas electrodes*
- *Apply the E° table employing the NE-SW rule and predict if a given redox reaction is spontaneous or not.*
- *Discuss how some standard potentials vary with pH; in particular, describe what happens to the reduction/oxidation of water when the pH changes*
- *Apply the E° table to predict which metals are stable in water and in which pH interval*
- *Describe the relationship between $\Delta E°$ and $\Delta G°$ for a given reaction*
- *Remember the value and the meaning of the Faraday constant*
- *Use the Nernst equation for calculating the electromotive force of a given galvanic cell in non-standard conditions*
- *Describe how a concentration cell works and calculate its e.m.f.*
- *Discuss how a fuel cell works*
- *Describe what an electrolysis process is focusing on the main differences with galvanic cells*
- *Discuss the necessary requirements for an electrolytic process to occur*
- *Describe the electrolysis of water as a general example*
- *Describe the electrolysis of NaI and highlight the differences with water*
- *Discuss and apply the criterion for predicting which reaction occurs at each electrode*
- *Discuss why some species (Na, K, Mg, F_2…) cannot be obtained through electrolysis of aqueous solutions*
- *Examine how are instead obtained those species*
- *Know and apply Faraday's law of electrochemistry*

MODULE OF ORGANIC CHEMISTRY

1. INTRODUCTION TO ORGANIC CHEMISTRY AND ALKANES

***Learning goals**:*

- *Describe the role of carbon among the many atoms in Nature*
- *Discuss the peculiar chemical features of carbon atom*
- *Classify hydrocarbons into nomenclature groups*
- *Employ the structural formula as a representation for the organic compounds*
- *Describe the general structure of an alkane*
- *Employ the correct IUPAC nomenclature for alkanes*
- *Remember the common nomenclature of the most widely employed alkyl groups*
- *Understand the definition of constitutional isomer and provide examples*
- *Apply the IUPAC nomenclature to cycloalkanes*
- *Understand the definition of geometrical isomer and provide examples*
- *Recognize the functional groups*
- *Draw all the possible isomers associated with a molecular formula*
- *Enunciate the typical properties of alkanes*
- *Employ alkyl radicals as substituents in structural formulae*
- *Describe the mechanism of the radical halogenation of alkanes and employ fish-hook arrows to represent the movement of a single electron*
- *Discuss the selectivity of radical halogenation of alkanes*

2. UNSATURATED HYDROCARBONS, REACTION MECHANISMS, ACIDS AND BASES IN ORGANIC CHEMISTRY

***Learning goals**:*

- *Describe the general structure of alkenes and alkynes*
- *Employ the correct IUPAC nomenclature for alkenes and alkynes*
- *Recognize cis-trans isomerism in alkenes*
- *Employ the electron-pushing technique to describe reaction mechanisms*
- *Recognize electrophiles and nucleophiles from a molecular structure*
- *Describe the electrophilic addition as a general reaction pattern for unsaturated hydrocarbons*
- *Describe the hydration of alkenes*
- *Describe the reaction of alkenes with hydrohalic acids*
- *Describe the reaction of alkenes with molecular halogens*
- *Discuss the stereoselectivity of the addition reactions according to Markownikov's rule*
- *Describe the hydroboration of alkenes and its regioselectivity*
- *Discuss the catalytic reduction of alkenes*
- *Apply the aforementioned addition reactions to alkynes and draw the relative final products*
- *Highlight the keto-enol equilibrium during the hydration of alkynes*
- *Describe Lindlar's catalyst importance in the partial hydrogenation of alkynes*
- *Introduce the acid-base chemistry in an organic chemistry context*
- *Correlate the pK_a value to the strength of an acid*
- *Correlate the pK_a value to the strength of the conjugated base*
- *Evaluate the stability of the conjugate base as a tool for assessing the strength of an acid; consider the influence of electronegativity, the size, the delocalization, the inductive effect and the s-character*

of the atom bearing the negative charge

- *Evaluate the position of organic acid-base equilibria based on pK_a values and assess the spontaneity of the relative reaction*
- *Describe the deprotonation of terminal alkynes and remember the most common bases to carry out the reaction*
- *Calculate the degree of unsaturation of an organic compound starting from the molecular formula and employ it in the determination of possible structures*

3. THE CHEMISTRY OF HALOALKANES

***Learning goals**:*

- *Describe the general structure of haloalkanes*
- *Employ the correct IUPAC nomenclature for haloalkanes*
- *List the possible syntheses for haloalkanes*
- *Discuss the general reactivity of haloalkanes as a typical substrate undergoing nucleophilic substitution*
- *Sketch the mechanism of the nucleophilic substitution and describe the role of the nucleophile and the leaving group*
- *Describe the necessary reagents for the conversion of haloalkanes into alcohols, ethers, thiols, sulfides and nitriles respectively*
- *Describe the reaction with alkyne anions*
- *Describe the reaction with ammonia*
- *Discuss the formation of Grignard's reagents*
- *Describe the features of Grignard's reagents*
- *Analyze the methods of formation of new C-C bonds*

4. STEREOCHEMISTRY

***Learning goals**:*

- *Recall the concept of isomerism and distinguish between constitutional isomers and stereoisomers*
- *Understand the concept of chirality*
- *Discriminate between chiral and non-chiral molecules*
- *Recognize enantiomers as a particular kind of geometrical isomers*
- *Locate chirality centres in molecules*
- *Individuate symmetry elements in molecules*
- *Sketch chiral molecules using Fischer's projections*
- *Predict how many stereoisomers a molecule has*
- *Define diastereomers*
- *Define a meso-compound and state the conditions or its existence*
- *Discuss what a racemic mixture is*
- *Explain the different behaviour of enantiomers in terms of physiological effects*

5. THE CHEMISTRY OF ALCOHOLS

***Learning goals**:*

- *Recognize an alcohol and distinguish between primary, secondary and tertiary alcohols*
- *Discuss the molecular features of alcohols and the consequences on physicochemical parameters (e.g. solubility, boiling point,…)*
- *Apply the IUPAC nomenclature to alcohols*
- *Describe the mechanism of acid-catalysed dehydration of alcohols and consider it as an example of an elimination reaction*
- *Discuss the outcome of an elimination reaction using the Zaitsev rule*
- *Describe the mechanism of the conversion into haloalkanes by means of PBr_3, PCl_3 or $SOCl_2$.*
- *Describe the outcome of the oxidation of an alcohol focusing on the differences between primary, secondary and tertiary compounds.*

6. THE CHEMISTRY OF CARBONYL COMPOUNDS

***Learning goals**:*

- *Recognize aldehydes and ketones*
- *Apply the IUPAC nomenclature to aldehydes and ketones*
- *Discuss the molecular features of aldehydes and ketones and the consequences on physicochemical parameters (e.g. solubility, boiling point,…)*
- *Describe the reactivity of carbonyl compound against nucleophiles highlighting the structure of the tetrahedral intermediate and the importance of acid catalysis for weaker nucleophiles*
- *Discuss the outcome of the reaction with Grignard compounds focusing on the differences between ketones, aldehydes and formaldehyde*
- *Describe the reaction with alkyne anions*
- *Describe the addition reaction of water or alcohols focusing on how to influence the equilibrium position*
- *Employ acetals as protecting groups for carbonyl compounds and provide examples*
- *Analyze the reduction of carbonyl compounds highlighting the differences between catalytic hydrogenation and reaction with metal hydrides*
- *Describe the different reagents that may be employed for the oxidation of aldehydes*
- *Describe the reaction of aldehydes with primary amines*

7. THE CHEMISTRY OF CARBOXYLIC ACID AND AMINES

***Learning goals**:*

- *Recognize carboxylic acids*
- *Apply the IUPAC nomenclature to carboxylic acids*
- *Discuss the molecular features of carboxylic acids and the consequences on physicochemical parameters (e.g. solubility, boiling point,…)*
- *Discuss the Fischer esterification of carboxylic acids focusing on how to control the position of equilibrium*
- *Describe the conversion into carboxylate to be used as a nucleophile (e.g. formation of esters)*
- *Describe the formation of acyl chlorides*
- *Discuss the reduction with lithium aluminium hydride*
- *Recognize amines*

- *Apply the IUPAC nomenclature to amines*
- *Discuss the molecular features of amines and the consequences on physicochemical parameters (e.g. solubility, boiling point,…)*
- *Describe the acid-base reaction of amines with water*

8. THE CHEMISTRY OF CARBOXYLIC ACID DERIVATIVES

***Learning goals**:*

- *Recognize acyl chlorides, anhydrides, esters and amides*
- *Apply the IUPAC nomenclature to acyl chlorides, anhydrides, esters and amides*
- *Describe the reactivity of carbonyl compound against nucleophiles highlighting the structure of the tetrahedral intermediate and discussing how the overall reaction may be considered as a nucleophilic substitution*
- *Discuss the order of reactivity of the four derivatives based on the basicity of the leaving group*
- *Describe all the possible interconversions between all the four derivatives together with the chemical relations to carboxylic acids*
- *Discuss the differences between acid and basic hydrolysis of the esters in terms of reversibility and necessity of a catalyst*
- *Describe the reaction between esters and Grignard reagents*
- *Discuss the reaction between esters (or amides) and lithium aluminium hydride*
- *Describe the general synthesis of amides*

9. AMINOACIDS, PEPTIDES AND PROTEINS

***Learning goals**:*

- *Identify amino acids and distinguish between alpha-, beta- and gamma-compounds*
- *Discuss the chirality in amino acids and represent the relative stereocenter (for instance applying the Fischer projection)*
- *Understand the acid-base characteristics of amino acids and the pH range of existence of zwitterions*
- *Describe what the isoelectric point (pI) is*
- *Establish the protonation state of an amino acid at a given pH and calculate its pI*
- *Describe how a device for electrophoresis works*
- *Describe the peptide bond between two amino acids*
- *Correctly employ the terms dipeptide, tripeptide, tetrapeptide (and so on), oligopeptide, polypeptide and protein*
- *Describe oligopeptides using the three-letter code and the N-C direction*
- *Define the primary structure of a protein sequencing*
- *Understand the fundamental techniques of sequence analysis: complete hydrolysis, reaction with cyanogen bromide, chymotrypsin- and trypsin-mediated degradation and Edman degradation.*
- *Reconstruct the primary sequence of an oligopeptide from degradation data*
- *Determine the chemical structure of an oligopeptide with the aid of the provided tables*
- *Calculate the pI of an oligopeptide with the aid of the provided tables*

10. INTRODUCTION TO CARBOHYDRATES

***Learning goals**:*

- *Provide a general definition of carbohydrates and discuss their general function in living organisms*
- *Employ the correct nomenclature for monosaccharides*
- *Employ the Fischer projection for representing the monosaccharides structure*
- *Describe the configuration of sugars with reference to D- or L- glyceraldehyde*
- *Know by heart the Fischer projection of D-glucose*
- *Distinguish between enantiomers, diastereomers and epimers*
- *Discuss the spontaneous cyclization of monosaccharides*
- *Build the Haworth projection of sugars starting from the Fisher projection (and vice-versa)*
- *Represent the structure of fructose, D-ribose and D-deoxyribose*
- *Describe the reduction of sugars to alditols*
- *Describe the oxidation of sugars to aldonic acids (and define a reducing sugar)*
- *Describe disaccharides and employ the correct nomenclature for the glucosidic bond*
- *Represent maltose, lactose and sucrose*
- *Describe the structure of the most common polysaccharides: amylose, amylopectin, glycogen and cellulose*

11. INTRODUCTION TO LIPIDS

***Learning goals**:*

- *Provide a general definition of lipids and discuss their general function in living organisms*
- *Describe the general structure of fatty acids and their common properties*
- *Describe the general structure of waxes*
- *Describe the general structure of triglycerides (oils and fats)*
- *Discuss the influence of side chains on the physical properties of triglycerides*
- *Discuss the importance of the catalytic reduction of triglycerides*
- *Discuss the saponification reaction of triglycerides*
- *Describe the transesterification of triglycerides and its importance for the biodiesel production*
- *Describe the general structure of phospholipids and explain their importance in the biological world*