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, with a special attention to biomedical applications*
- *to analyze the chemical and thermodynamic properties of chemical reactions*
- *to examine the thermodynamic properties of redox reactions under the perspective of electrochemical processes*
- *to describe the chemico-physical properties of solutions, with a special attention to aqueous solutions*
- *to evaluate the acid/base characteristics of solutes in aqueous solutions*
- *to describe the relations between forces and motion for point-like and rigid bodies*
- *to recognize the biomechanical aspects associated with the motion of the human body*
- *to understand physical and chemical properties of organic compounds with a special attention to polyfunctional biomolecules*
- *to discuss the most relevant classes of organic reactions, to be able to evaluate the covalent bonds that characterize the more relevant biomolecules*
- *to analyse a few organic reactions that occur in a chemical context and be able to compare them with those catalysed by enzymes in a biological system*

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 as prerequisites.

Contents

- *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*

6. MECHANICS OF THE MATERIAL POINT

***Learning goals**:*

- *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*
- *Evaluate the difference between conservative and dissipative forces and the definition of potential energy*
- *Apply the theorem of the conservation of mechanical 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*

7. 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*
- *Understand the concepts of center of mass and mechanical stability*
- *Recognize the different classes of levers and pulley systems with respect to the concept of mechanical gain*
- *Explain and apply the laws of rotational motion and the concepts of moment of inertia and angular momentum*
- *Understand how to represent and evaluate the forces and torques acting on the musculoskeletal system of the human body*
- *Evaluate and analyse the elastic properties of materials with respect to the case of biological systems*

MODULE OF CHEMISTRY

1. THE STRUCTURE OF MATTER

***Learning goals**:*

- *Be able to analyse the periodic Table and the periodic properties of atoms*
- *Discuss the meaning and the application of electronegativity.*
- *Describe the properties of ions, ionic bond, and covalent bond*
- *Distinguish between ions, molecules, covalent solids ad metals*
- *Be able to write the structure of atoms and molecules according to Lewis' structures*
- *Describe the structure of molecules and polyatomic ions.*
- *Discuss the concept of resonance*
- *Describe the characteristics of hybrid orbitals*
- *Discuss the polarity of molecules.*
- *Discuss the different types of interatomic and intermolecular forces*
- *Relate the intensity of intermolecular forces with boiling or freezing points*

2. STOICHIOMETRY

***Learning goals**:*

- *Describe quantitative aspects of reaction through the relationships between moles and weight of compounds*
- *Be able to solve simple problems of stoichiometry*
- *Correctly apply the common nomenclature to chemical compounds*

3. 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*
- *Discuss the Hess law and its applications*
- *Discuss the Gibbs function (free energy, G) as the thermodynamic state function that allows to predict spontaneity of chemical reactions (endergonic/exergonic reactions).*
- *Predict the heat released during a reaction (thermochemistry)*
- *Be able to draw the reaction diagram of endergonic /exergonic reactions*
- *Describe the main characteristics of irreversible and reversible reactions*
- *Analyze the characteristics of reversible reactions and define the reaction quotient (Q)*
- *Describe the conditions to be satisfied to reach the chemical equilibrium of a reversible reaction*
- *Define the equilibrium constant (K_{eq}) and its relationship with Q.*
- *Describe the effects of Le Chatelier's principle on a chemical equilibrium.*
- *Discuss the influence of changes of 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 spontaneity of a reversible reaction at equilibrium: $\Delta G°$ and K_{eq}.*
- *Be able to build ICE table and solve problems on equilibrium*

4. CHEMICAL KINETICS

***Learning goals**:*

- *Define the reaction rate and the rate constant in chemical kinetics*
- *Be able to distinguish rate equations of elementary and non-elementary reactions.*
- *Define the energy of activation and the transition state of an elementary reaction.*
- *Discuss the properties of a catalysts by means of a reaction diagram.*
- *Understand and apply the Arrhenius equation*
- *Study and discuss the best conditions for the industrial production of ammonia.*
- *Be able to solve problems on chemical kinetics*

5. PHASES AND PHASE TRANSITIONS

***Learning goals**:*

- *Recall the ideal gas law*
- *Define the vapor pressure of a liquid*
- *Interpret the phase diagram of a given substance*

6. THE CHEMISTRY OF SOLUTIONS

***Learning goals**:*

- *Describe the properties of aqueous solutions of electrolytes and non-electrolytes*
- *Describe the properties of solutions of solutes with limited solubility in water*

- *Be able to calculate the concentration of aqueous solutions*
- *Discuss the properties of an ideal solution*
- *Define the colligative properties*
- *Understand boiling point elevation and freezing point depression of solutions*
- *Describe the phenomenon of osmotic pressure*
- *Be able to calculate the osmotic pressure of a solution*
- *Define isotonic, hypertonic and hypotonic solutions*
- *Be able to distinguish between isosmotic and isotonic solutions*
- *Be able to predict the ionic concentrations in saturated solutions*
- *Solve problems on colligative properties*

7. ACIDS AND BASES

***Learning goals**:*

- *Describe water self-ionization as a reversible reaction*
- *Define the ionic product of water (Kw)*
- *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*
- *Discuss the Brønsted-Lowry theory and illustrate the concept of conjugate acid/base*
- *Describe the irreversible reaction of HCl with water to illustrate the characteristic of a strong acid*
- *Recognize the value of Ka as an indicator of the strength of the acid*
- *Describe the strong base NaOH as the solution of an ionic compound that fully dissociate in Na^+ and OH^-*
- *Be able to calculate the pH of solutions of strong acids/bases*
- *Analyse the difference between the Keq (Kc) of the reaction of a weak acid with water and the modified equilibrium constant Ka*
- *Be able to calculate the approximate value of the pH of a solution of weak acids/bases*
- *Be able to establish the relationship between Ka and Kb of conjugated acids/bases*
- *Calculate the pH of conjugated acids/bases solutions*
- *Calculate the pH of the solution after reaction of salt formation (neutralization and excess/defect of reactants)*
- *Evaluate the pH value of aqueous solutions of salts*
- *Analyse the applications of Le Chatelier principle to the acid/base equilibrium*
- *Discuss the properties of a buffer solution in terms of Le Chatelier principle*
- *Discuss the Henderson-Hasselbach equation for the calculation of the pH of a buffer solution*
- *Be able to calculate 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*
- *Discuss the characteristics of the polyprotic acids, with special regards to carbonic and phosphoric acids*
- *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*
- *Analyze the properties of the dihydrogen/hydrogen phosphate buffer*

8. REDOX CHEMISTRY

***Learning goals**:*

- *Define the main classes of reactions, with a special mention to oxidation/reduction 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 a Daniell's cell in standard conditions and discuss its production of electric energy*
- *Describe the experimental redox that is related to a Daniell's cell*
- *Define the standard reduction potential (E°) of single electrodes*
- *Discuss the possibility of calculating the standard potential E° of a galvanic cell from the standard reduction potential of single electrodes*
- *Discuss the redox reaction that occur between reductants and oxidants according to the standard reduction potentials of single half-cells*
- *Evaluate the free energy ($\Delta G°$) of a galvanic cell in standard conditions*
- *Be able to explain the Nernst equation and its applications*
- *Be able to calculate the reduction potential of half cells in conditions different from standard*
- *Be able to calculate the potential of concentration cells*

9. INTRODUCTION TO ORGANIC CHEMISTRY

***Learning goals**:*

- *Introduction to the chemistry of carbon*
- *Introduction to organic nomenclature*
- *Stereochemistry: constitutional isomers, stereoisomers, chirality, diastereomers, enantiomers*
- *Chemistry and structure*

10. REACTIVITY OF ORGANIC COMPOUNDS

***Learning goals**:*

- *Halogenoalkanes*
- *Alkenes and aromatic compounds*
- *Exercises*
- *Aromatic compounds*
- *Alcohols, thiols, phenols*
- *Aldehydes and ketones*
- *Carboxylic acids*
- *Amines*
- *Derivative of carboxylic acids*

11. BIOMOLECULES

***Learning goals**:*

- *Aminoacids, proteins and enzymes*
- *Sugars and carbohydrates*
- *Lipids*

Teaching Methods

The course is organized on **two distinct levels**:

- *knowledge transfer* – the students will access recorded lectures and be addressed to textbook chapters, scientific articles and other studying material in order to acquire the *notions* needed to master the topics at hand; these activities will be programmed in the daily schedule but can be performed by the students at the times most convenient for them;

- *knowledge activation* – interactive lectures, tutorials, and question and answer sessions will help the student to fully understand, assimilate and frame the acquired notions in an organized general perspective, and to clearly and linearly explain the complex issues of the functioning of living systems; these activities will be held synchronously online or with the physical presence of the students.

Verification of learning

The End of Semester Exam (ESE) is the final exam which includes a written test with multiple-choice questions related to the whole program of Physics and Chemistry and an oral examination only for the Chemistry module (General and Organic). A minimum of 16 in each module is required to pass the written test if the mark of the whole ESE is ≥ 18. The final mark is calculated as follows: 1/3 of the mark obtained in the Physics module (only written), 2/3 of the mark obtained in the Chemistry modules (written and oral).

Besides the End of Semester Exam (ESE), students will be offered the opportunity to take three Intermediate Tests (ITs), programmed during the course, following the division in modules. For the single ITs, the pass mark is 16/33. The final mark after the ITs is calculated as the average of the three marks, and the minimum positive evaluation is 18/33 (no oral examination). Should a student not pass (i.e., mark < 16/33) only one of the ITs, he/she can retake that part at the ESE. Students who have passed the ITs but are not completely satisfied with the final mark may also retake one of the parts at the ESE.

Texts

Reference textbook (Physics): Joseph W. Kane, Morton M. Sternheim. *Physics*. 3rd Edition. Wiley (1988). Available at Humanitas University library.

Reference textbook (Chemistry): J. Smith. *General, Organic and Biological Chemistry*. 4th Edition. McGraw-Hill (2019). ISBN: 978-0-07-340276-5

A handout from the lectures and tutorials of Physics and Chemistry will be available on the LMS site.