UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

COURSE SYLLABUS

Physical Chemistry of Biological Systems

2324-3-E0201Q078

Aims

Provide the student with the basic tools of thermodynamics and chemical kinetics for understanding and modeling biochemical systems and processes.

Knowledge and understanding:
At the end of the course the student knows:
- the nature of Thermodynamics and the concept of thermodynamic representation of physical reality
- the first three laws of Thermodynamics
- the concept of spontaneity in terms of entropy and free energy
- the concept of equilibrium and the non-phenomenological derivation of the equilibrium constant
- the concept of reaction rate and its applications
- the kinetic concept of reaction mechanism
- the derivation of the Michaelis-Menten equation in terms of chemical kinetics

Ability to apply knowledge and understanding:
At the end of the course the student is able to:
- calculate the variations of thermodynamic quantities
- apply the criterion of spontaneity in terms of free energy
- use experimental data to deduce a reaction rate law and calculate the relative rate constant
- verify a reaction mechanism

Making judgements.
At the end of the course the student is able to:
- apply the laws of Thermodynamics correctly and critically

Communication skills.
Knowing how to deal with simple problems of thermodynamics and kinetics, exposing orally with the properties of language the procedure applied and the results obtained

Learning skills
Be able to apply the acquired knowledge to different contexts from those presented during the course, and to understand the topics covered in the scientific literature concerning the thermodynamic aspects of biological processes

Contents

To provide the student with the basic tools of thermodynamics and chemical kinetics for the understanding and modeling of biochemical systems and processes.

Detailed program

Description of macroscopic systems. Nature of thermodynamics. Thermodynamic representation of physical reality. Changing the status of a system. Work and heat.

Energy and the first law of thermodynamics. First law of thermodynamics. The measurement of heat as a state variable. Enthalpy. Thermal capacity. Enthalpy variations. Enthalpy variation in phase transformations. State of aggregation of the matter.

Entropy, second and third law of thermodynamics. Spontaneous processes. Second law of thermodynamics. Criterion of spontaneity in terms of entropy. Degeneration of a state and entropy. Boltzmann equation. Examples of spontaneous processes: thermal equilibrium; phase equilibrium. Third law of thermodynamics. Residual entropy.

Free energy and equilibrium. Gibbs free energy and Helmholtz free energy. Criterion of spontaneity in terms of free energy. Systems with only one component: phase equilibrium. Systems with multiple components: mixing equilibrium; ideal and real solutions; standard states. Chemical potential and its dependence on the composition. Reaction equilibrium: the equilibrium constant; variations of free standard energy; dependence of ?G and K on temperature. Chemical equilibria in systems of biological interest: hydrophobic interactions.

Systems far from equilibrium. Transport phenomena. Elements of thermodynamics of systems far from equilibrium.

Kinetics and mechanism of discontinuous reactions. Reaction velocity. Speed ??law, velocity constant and reaction order. Kinetic equations for reactions of various order. Experimental determination of the reaction order and reaction velocity. Elementary stages and reaction mechanism. Relationship between equilibrium constant and velocity constant. Construction of a reaction mechanism. Dependency of the velocity constant of an elementary reaction from the temperature; Arrhenius equation. Relationship between velocity constant and activation energy. Enzyme catalysis; derivation of the Michaelis-Menten equation; competitive and non-competitive inhibition; substrate inhibition.

Prerequisites

Background: simple notions of Physics (Energy and its forms). Simple mathematical concepts (meaning of derivative and integral, differential). Knowledge of stoichiometry.
Specific prerequisites: none.
General prerequisites: Students can take the exams of the third year after having passed all the exams of the first year of the course.

Teaching form

Lectures and numerical exercises will be held in the classroom.

Teaching language: italian.

Textbook and teaching resource

Notes of the lessons.

Recommended textbooks:

- Atkins, Ratcliffe, Wormald, de Paula, Physical Chemistry for the Life Sciences, Third Edition, Oxford UP, 2023
- Prigogine, Kondepudi, Termodinamica, Bollati Boringhieri, 2002
- Roussel, “A Life Scientist’s Guide to Physical Chemistry”, Cambridge, 2012
- E. Schrödinger, “Che cos'è la vita?”, Adelphi 1995
- E. Tiezzi, “Tempi storici, tempi biologici”, Donzelli 2005

Semester

First semester

Assessment method

The assessment of learning takes place with a final oral examination, no ongoing tests are planned.

At the beginning of the oral exam, several multiple-choice questions will be submitted to the student as an initial verification of what has been learned. The answers must always be motivated and linked to broader concepts.
Further in-depth questions will be asked on the topics covered in class, with particular regard to free energy and chemical equilibrium (for the thermodynamic part) and to the kinetic laws (for the kinetic part).

In the final examination, as far as possible, the student will be evaluated on the basis of the following criteria:
1) knowledge and ability to understand;
2) ability to connect different concepts;
3) reasoning autonomy;
4) ability to correctly use scientific Language

Office hours

Contact: on demand, upon request by mail to lecturer.

Sustainable Development Goals

CLIMATE ACTION