GDAŃSK UNIVERSITY OF TECHNOLOGY

Subject card

Subject name and code	Physical Chemistry , PG_00054877		
Field of study	Biotechnology		
Date of commencement of studies	October 2025	Academic year of realisation of subject	2026/2027
Education level	first-cycle studies	Subject group	Obligatory subject group in the field of study Subject group related to scientific research in the field of study
Mode of study	Full-time studies	Mode of delivery	at the university
Year of study	2	Language of instruction	Polish
Semester of study	3	ECTS credits	6.0
Learning profile	general academic profile	Assessment form	exam
Conducting unit	Department of Physical Chemistry -> Faculty of Chemistry -> Faculties of Gdańsk University of Technology		
Name and surname of lecturer (lecturers)	Subject supervisor	prof. dr hab. inż. Jacek Czub	
	Teachers		

Lesson types

Lesson type	Lecture	Tutorial	Laboratory	Project	Seminar	SUM
Number of study hours	45.0	15.0	0.0	0.0	15.0	75
E-learning hours included: 0.0						

Learning activity and number of study hours

Learning activity	Participation in didactic classes included in study plan	Participation in consultation hours	Self-study	SUM
Number of study hours	75	8.0	67.0	150

Subject objectives

The aim of the course is to learn the physical laws governing (bio)chemical processes and to provide theoretical tools for describing and predicting these processes.

Learning outcomes

Course outcome	Subject outcome	Method of verification
K6_U02	is abble to apply the acquired theoretical knowledge of thermodynamics and chemical kinetics to the solution of practical tasks of a problematic nature. Is abble to create schemes for solving problems of varying degrees of difficulty and solve computational tasks in the field of thermodynamics and kinetics of (bio)chemical systems.	[SU1] Assessment of task fulfilment [SU2] Assessment of ability to analyse information [SU3] Assessment of ability to use knowledge gained from the subject
K6_W02	has knowledge of the laws of thermodynamics and kinetics governing the course of (bio)chemical reactions and processes and also the phase behavior of biological systems. has knowledge to interpret the thermodynamic and kinetic properties of biomolecular systems in the context of intermolecular interactions. acquires theoretical knowledge of the most important experimental techniques used in molecular biotechnology; learns to communicate newly acquired knowledge and present the results of their work in an understandable and communicative manner	[SW1] Assessment of factual knowledge [SW2] Assessment of knowledge contained in presentation [SW3] Assessment of knowledge contained in written work and projects

Subject contents

Course content – lecture

- Fundamentals of chemical thermodynamics: ideal gas, equipartition, internal energy, work, heat, temperature and heat capacity; first law, Joule and Joule–Thomson experiments, enthalpy; thermochemistry, reaction enthalpy, Hess's and Kirchhoff's laws; second and third laws; entropy, statistical thermodynamics, Boltzmann distribution; Gibbs and Helmholtz free energies, spontaneity criteria, chemical potential, and interpretation of thermodynamic parameters.
- Phase equilibria: one-, two-, and three-component systems; Clausius–Clapeyron equation, phase diagrams, Gibbs phase rule; mixing; ideal and real solutions, Raoult's and Henry's laws, activities and standard states; colligative and osmotic properties; liquid–vapour and liquid–liquid equilibria, basics of distillation, rectification, and extraction; partition coefficient, logP; protein folding and membrane phase behaviour.
- Chemical equilibrium and bioenergetics: Gibbs energy and equilibrium constant, effects of temperature and pressure; ATP, ion gradients, cellular work, and coupling of non-spontaneous processes.
- Electrochemistry: ionic conductivity; electrochemical cells, electrodes, and half-cells; voltage, cell thermodynamics, Nernst equation; reduction potentials, redox reactions, potentiometry, electron-transfer chains; lithium-ion batteries.
- Chemical kinetics: reaction rates; rate laws, reaction orders, rate constants, integration of simple kinetic equations; elementary and complex reactions; links between kinetics and thermodynamics, temperature dependence, Gibbs energy profiles, kinetic and thermodynamic control; enzymatic catalysis, Michaelis–Menten model, chain reactions.
- Transport phenomena: diffusion, Brownian motion, random walks; diffusion equation, Einstein–Smoluchowski relation, Stokes equation, viscosity; membrane transport; ion solvation and Grotthuss mechanism; diffusion in external potential and Smoluchowski equation; theories of conformational changes and reaction rates; electrophoresis.

Course content – exercises

- Thermodynamics and thermochemistry: the ideal gas equation; first law of thermodynamics; thermodynamic cycles; thermochemistry: Hess and Kirchhoff laws, the second law of thermodynamics; absolute entropy; Gibbs and Helmholtz free energy
- Phase equilibria: phase transitions in a one-component system; the Clausius-Clapeyron equation; liquid-vapor equilibrium in a two-component system
- Chemical equilibrium: reaction equilibrium constant; relationship between the equilibrium constant ant the standard Gibbs energy of reaction; van't Hoff's isotherm; dependence of reaction equilibrium constant on temperature, van Hoff's isobar.
- Kinetics of chemical reactions: determination of the order of the reaction, rate constant, activation energy, reaction half-lifes

Course content – seminar

- Familiarizing students with good practices in scientific presentation.
- Discussion of elementary aspects of molecular interactions theory.
- Interpretation of models that introduce empirical corrections to fundamental physical chemical theories.
- Simple statistical and information-theoretic intepretation of entropy.
- Review of applications of modern spectro- and microscopic methods for the analysis of physicochemical properties of biological materials.
- Discussion of calorimetry methods that enable measurement of thermodynamics of processes involving biomacromolecules and their complexes.
- Description of physicochemical fundamentals of modern methods of structural biology.
- Physicochemical characterization of biological membrane systems.
- Applications of basic thermodynamic and kinetic models to solve complex research problems, including an analysis of metabolic processes.

Prerequisites and co-requisites

General chemistry: knowledge of basic concepts.

Mathematics: elements of differential and integral calculus, elements of probability theory

Physics: basic physical quantities, basic mechanics and electrostatics.

Assessment methods and criteria

Subject passing criteria	Passing threshold	Percentage of the final grade
Presentation on a given topic (seminar)	50.0%	10.0%
Mid-term test (2, practicals)	50.0%	20.0%
Presentation of the solved problem (seminar)	50.0%	10.0%
Final written exam	50.0%	60.0%

Recommended reading

Basic literature

1. P. W. Atkins, J. De Paula. "Physical chemistry", PWN
2. I. N. Levine. "Physical Chemistry", McGraw-Hill
3. Uruska I. (redakcja), Zbiór zadań z chemii fizycznej, Wydawnictwo PG
4. Uruska I., Zbiór zadań testowych z chemii fizycznej, Wydawnictwo PG
5. Internet resources: wikipedia, lecture notes, etc.

Supplementary literature

1. G. Barrow. "Physical chemistry", PWN
2. D. W. Ball. "Physical Chemistry", Thompson / Brooks-Cole
3. K. Pigoń, Z. Ruziewicz, "Physical chemistry", PWN,
4. D. M. Zuckerman "Statistical physics of biomolecules", CRC Press

eResources addresses

Example issues/ example questions/ tasks being completed	(a) sample presentation topics 1. The van der Waals equation (gas compression isotherms, physical interpretation of coefficients in the vdW equation, phase transition curves predicted by this equation, Maxwell construction: a sample ad hoc solution 2. FRET (Forster resonance, efficiency of energy transfer vs chromophore distance and orientation, confocal microscopy, sample applications - conformational transitions in the ATP synthase or transcription initiation by DNAPol, smFRET) 3. Atomic force microscopy (working principle, anchoring biomacromolecules to the tip/surface, applications: protein unfolding, mechanical mapping) (b) sample projects 1. Membrane proteins are crucial in the cell's response to the environment, e.g., through modulation of ion permissivity. Here, we will see how the amino acid sequence affects the protein's interaction with the bilayer. 2. By analyzing the effect of single amino acid mutations, we can gain indirect insight into the mechanisms of protein folding. In this case, we will investigate the impact of a single key residue on the folding and unfolding kinetics of an extremely stable protein. Selected exam questions: 1. Substrate A can be converted to two products B and C. The standard Gibbs energy and Gibbs energy of activation for product B are -50 and 80 kJ/mol, respectively, and for product C, -15 and 20 kJ/mol, respectively. Which product will dominate when the reaction is carried out at a low temperature, and which when at a high temperature allowing for reaching equilibrium? Why? How can the concentration ratio of both products be determined at low temperatures?2. It is known that stretching a rubber band involves conformational ordering of polymer molecules in the rubber; the resulting entropy decrease accounts for the main force opposing the deformation. Is the force exerted by the rubber band greater or smaller after heating? Why?3. The folding process of a certain protein was studied in a calorimeter with a heat capacity of 0.4 kJ K. It was found that at 330 K, unfolding of 0.01 mole of this protein is accompanied by a 1 K decrease in calorimeter temperature. Knowing that the entropy change upon folding of this protein is -0.1 kJ/(mol K), determine which form of the protein, folded or unfolded, dominates in the cell in equilibrium (T = 300 K). Assume that for the folding process Cp = 0. How can the molar fractions of the folded and unfolded forms be determined from these data (do not calculate the final values, just indicate the formula and plug in the data)?
Practical activites within the subject	Not applicable