GDAŃSK UNIVERSITY OF TECHNOLOGY

Subject card

Subject name and code	Physical Chemistry , PG_00054877		
Field of study	Biotechnology		
Date of commencement of studies	October 2026	Academic year of realisation of subject	2027/2028
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 prepare students to explain and predict physicochemical processes occurring in biological systems using the principles of thermodynamics, phase and chemical equilibria, electrochemistry, kinetics, and transport phenomena, as well as to solve quantitative problems and present the results of physicochemical analyses.

Learning outcomes

Course outcome	Subject outcome	Method of verification
K6_U02	Iis able to apply theoretical knowledge of thermodynamics and chemical kinetics to analyse processes occurring in (bio)chemical systems and to solve practical problems of both a conceptual and quantitative nature. The student is able to develop solution strategies for problems of varying complexity, analyse the results obtained, and present the reasoning process and the outcomes of their work in a clear and comprehensible manner.	[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, as well as the phase behaviour of biological systems; understands the relationships between the thermodynamic and kinetic properties of biomolecular systems and the intermolecular interactions occurring within them; has theoretical knowledge of the principal experimental techniques used in molecular biotechnology and of the physicochemical principles underlying the interpretation of the results obtained using these techniques.	[SW1] Assessment of factual knowledge [SW2] Assessment of knowledge contained in presentation

Subject contents

Course content – lecture

1. Thermodynamics: ideal gas, equipartition, internal energy, work, heat, temperature, heat capacity; first law, Joule/Joule–Thomson experiments, enthalpy; thermochemistry, reaction enthalpy, Hess's/ Kirchhoff's laws; second law, entropy, statistical thermodynamics, Carnot cycle/heat-engine efficiency, Boltzmann distribution; Gibbs/Helmholtz energies, spontaneity, reversibility, fundamental equations; third law, reaction entropy, chemical potential, Gibbs-Duhem relation; molecular interpretation of thermodynamic quantities.
2. Phase equilibria: one-, two-, three-component systems; Clausius–Clapeyron relation, phase diagrams, Gibbs phase rule; mixing; ideal/real solutions, Raoult's/Henry's laws, activities, standard and biochemical states; colligative/osmotic properties; liquid-vapor/liquid–liquid equilibria, distillation, rectification, extraction; Gibbs triangle; protein folding, phospholipid membrane phases, partition coefficient/logP.
3. Equilibrium and bioenergetics: Gibbs energy, equilibrium constant; cellular energy storage, ATP, ion gradients, cellular work, driving nonspontaneous processes; pressure/temperature effects.
4. Electrochemistry: ionic conductivity; electrodes, half-cells, cell voltage/thermodynamics, Nernst equation, cells incl. lithium-ion batteries; reduction potentials, redox direction, respiratory/photosynthetic electron chains, potentiometry.
5. Kinetics: rates, measurement; rate laws, reaction orders, rate constants, integration; elementary, complex, chain reactions; near-equilibrium reactions, kinetics-thermodynamics relations, temperature effects, Gibbs-energy profiles, kinetic/thermodynamic control; enzyme catalysis, Michaelis–Menten model.
6. Transport: diffusion, Brownian motion, membrane transport; random walk, diffusion equation/solutions, Einstein-Smoluchowski relation, Stokes law, viscosity; ion solvation, Grotthuss mechanism; diffusion in an external potential, Smoluchowski equation; reaction/conformational rate theories; electrophoresis.

Course content – exercises

1. Thermodynamics and thermochemistry: ideal gas equation of state; the first law of thermodynamics; thermodynamic cycles; thermochemistry: Hess's and Kirchhoff's laws; the second law of thermodynamics; absolute entropy; Gibbs and Helmholtz free energies.
2. Phase equilibria: phase transitions in one-component systems; the Clausius–Clapeyron equation; liquid–vapour equilibrium in binary systems.
3. Chemical equilibrium: reaction equilibrium constant; relationship between the equilibrium constant and Gibbs free energy; the van 't Hoff reaction isotherm; temperature dependence of the equilibrium constant; the van 't Hoff isobar.
4. Chemical kinetics: determination of reaction order, reaction rate constant, activation energy, and reaction half-life.

Course content – seminar

1. Principles of preparing and delivering scientific presentations and clearly presenting the results of physicochemical analyses.
2. Discussion of elementary aspects of molecular interactions theory.
3. Interpretation of models that introduce empirical corrections to fundamental physical chemical theories.
4. Simple statistical and information-theoretic intepretation of entropy.
5. Review of applications of modern spectro- and microscopic methods for the analysis of physicochemical properties of biological materials.
6. Discussion of calorimetry methods that enable measurement of thermodynamics of processes involving biomacromolecules and their complexes.
7. Description of physicochemical fundamentals of modern methods of structural biology.
8. Physicochemical characterization of biological membrane systems.
9. 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. Uruska I. (redakcja), Zbiór zadań z chemii fizycznej, Wydawnictwo PG 3. Uruska I., Zbiór zadań testowych z chemii fizycznej, Wydawnictwo PG 4. I. N. Levine. "Physical Chemistry", McGraw-Hill 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) Examples of presentation topics

1. The van der Waals equation -- gas compression isotherms; the meaning of the coefficients in the van der Waals equation; phase-transition curves predicted by the equation; the Maxwell construction as an ad hoc solution.
2. FRET -- Förster resonance energy transfer; the dependence of transfer efficiency on the relative positions and orientations of the chromophores; confocal microscopy; examples of applications, such as conformational transitions in ATP synthase or transcription initiation by DNA polymerase; single-molecule FRET (smFRET).
3. Atomic force microscopy -- the operating principle of the microscope; attachment of biomacromolecules to the AFM tip or substrate; applications, including protein unfolding and mechanical mapping.

(b) Examples of problem-based tasks analysed during seminars

1. Membrane proteins play an important role in regulating communication between the cell and its external environment, including through ion transport. In this task, we will investigate how the amino acid sequence of a protein affects its interactions with the cell membrane.
2. Analysis of the effects of single-amino-acid mutations provides an indirect means of investigating protein-folding mechanisms. In this case, we will examine how mutation of a residue responsible for the exceptional stability of a particular bacterial protein affects its folding and unfolding kinetics.

Selected examination questions

1. Substrate A can be converted into two products, B and C. The standard Gibbs energy and Gibbs activation energy for the formation of product B are −50 and 80 kJ/mol, respectively, whereas the corresponding values for product C are −15 and 20 kJ/mol. Which product will predominate when the reaction is carried out at a low temperature, and which will predominate at a high temperature that allows equilibrium to be established? Explain your answer. How can the concentration ratio of the two products under low-temperature conditions be determined?

2. Stretching a rubber band is known to involve increased ordering of the polymer molecules in the rubber; the resulting decrease in entropy is the main force opposing further stretching. After being heated, will a stretched rubber band offer greater or lower resistance to stretching? Explain why.

3. The folding of a particular protein was studied in a calorimeter with a heat capacity of 0.4 kJ/K. It was found that, at 330 K, the unfolding of 0.01 mol of the protein was accompanied by a 1 K decrease in the temperature of the calorimeter. Given that the entropy change of the system during protein folding is −0.1 kJ/(mol·K), determine whether the folded or unfolded form of the protein predominates at equilibrium in a cell at T=300 K. Assume that $\Delta C_p=0$ for the folding process. How can these data be used to determine the mole fractions of the folded and unfolded forms of the protein? Do not calculate the final values; provide the relevant equation and substitute the data.

Practical activites within the subject

Not applicable