

Subject card

Subject name and code	Specialization lecture: Statistical mechanics in chemistry, PG_00117810						
Field of study	Chemistry						
Date of commencement of studies	October 2026	Academic year of realisation of subject			2026/2027		
Education level	Master's studies	Subject group			Obligatory subject group in the field of study Optional subject group		
Mode of study	full-time studies	Mode of delivery			at the university		
Year of study	1	Language of instruction			English		
Semester of study	2	ECTS credits			3.0		
Learning profile	academic	Assessment form			credit		
Conducting unit	Faculty of Chemistry -> Rector						
Name and surname of lecturer (lecturers)	Subject supervisor		prof. dr hab. Józef Liwo				
	Teachers		prof. dr hab. Józef Liwo				
Lesson types	Lesson type	Lecture	Tutorial	Laboratory	Project	Seminar	SUM
	Number of study hours	30.0	0.0	0.0	0.0	0.0	30
	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	30		5.0		40.0	75
Subject objectives	Acquiring by the student the basics of statistical mechanics and its application in chemistry.						

Learning outcomes	Course outcome	Subject outcome	Method of verification
	[CHEMMU2_K01] Knows the limitations of her/his own knowledge; understands the need for further education and can inspire other people to do so.	The student identifies her/his deficiencies in Chemistry, Physics, and Mathematics and learns the ways of extending the understanding of chemical phenomena on atomistic basis.	[SK1] oral statement/conversation/discussion [SK5] implementation of a problem task
	[CHEMMU2_W06] Applies mathematics to the extent necessary to understand, describe and model chemical processes of medium complexity.	The student applies appropriate methods of calculus and linear algebra.	[SW1] oral statement/conversation/discussion [SW5] implementation of a problem task
	[CHEMMU2_U02] Critically assesses the results of conducted, performed observations and theoretical calculations and discusses errors.	The student applies methods of statistical mechanics to solve chemical problems.	[SU5] implementation of a problem task
	[CHEMMU2_W05] Has extended knowledge in the field of the specialisation studied.	The student learns applications of statistical mechanics to describing chemical systems and phenomena at the upper-intermediate level and applies the methods of calculus and linear algebra.	[SW1] oral statement/conversation/discussion [SW5] implementation of a problem task
	[CHEMMU2_U11] Communicates in English in accordance with the requirements specified for level B2 of the Common European Framework of Reference for Languages.	The student acquires the English-language terminology of statistical mechanics.	[SU5] implementation of a problem task
[CHEMMU2_K06] Undertakes research tasks consciously and responsibly, understanding the social aspects of the practical application of the acquired knowledge and skills and the responsibility related to it.	The student applies methods of statistical mechanics to solve chemical problems.	[SK5] implementation of a problem task	
Subject contents	Geometry and energy surfaces of molecules, probability, random variables, averages, fluctuations. Density of states. Ensembles. Boltzmann's law. Energy equipartition. Partition function and its relation with system properties. Energy, entropy, free energy and their molecular interpretation. Entropy and information theory. Simple applications of statistical mechanics: blackbody, crystals. Multi-particle systems: the Bose-Einstein and Fermi-Dirac statistics. Partition functions of gases of non-interacting atoms, diatomic, and polyatomic molecules. Calculation of thermodynamic properties of gaseous substances. Calculations of equilibrium constants of chemical reactions in the gas phase. Non-ideal gases: the Mayer diagrams. Liquids: radial distribution functions and potentials of mean force. Statistical-mechanical theory of coarse graining. Statistical mechanics and molecular simulations.		
Prerequisites and co-requisites	Quantum Mechanics, Physical Chemistry, Linear Algebra, Calculus.		
Assessment methods and criteria	Subject passing criteria	Passing threshold	Percentage of the final grade
	Assignment of problem sets	51.0%	100.0%
Recommended reading	Basic literature	1. D. McQuarrie: Statistical Mechanics 2. R. Leach: Molecular Modeling: Principles and Applications	
	Supplementary literature	1. K. Huang, Statistical Mechanics 2. F. Reif, Statistical Mechanics 3. R.P. Feynman, Lectures in Statistical Mechanics	
	eResources addresses		

<p>Example issues/ example questions/ tasks being completed</p>	<p>1. There are two apples and two oranges in a box. Somebody took a fruit from that box at random. What is the probability that we get an orange when taking another fruit at random?</p> <p>2. To what temperature would gaseous oxygen in the ground triplet state (^3g, degeneracy 3) have to be heated to get 0.1 % of it excited to the singlet (1g, degeneracy 1) state? Singlet oxygen has energy by 21 kcal/mol higher than triplet oxygen</p> <p>3. The partition coefficient of terminally-blocked L-methionine (Ac-L-Met-NHMe) between n-octanol (n-oct) and water (wat) at $t = 25\text{ C}$ is equal to $P = x_{\text{noct}}/x_{\text{wat}} = 0.25$, where x_{noct} and x_{wat} denote the molar fractions of L-methionine in the n-octanol and water phase, respectively (data from Fauchère and Pliska, Eur. J. Med. Chem., 18, 369-375, 1983). Determine the difference of the chemical potentials of L-methionine in the two phases ($\mu_{\text{noct}} - \mu_{\text{wat}}$) at $t = 25\text{ C}$.</p> <p>4. Demonstrate that the grand partition function of a system of non-interacting fermions with two energy levels with energies e_1 and e_2 can be expressed as $\Omega = [1 + \exp(-\beta e_1)] [1 + \exp(-\beta e_2)]$</p> <p>5. Calculate the mole fractions of lithium (Li) atoms in the first and in the second excited state at its boiling temperature ($t = 1330\text{ C}$). The degeneracy of the ground electronic state (term $^2\text{S}_{1/2}$) is $g_0 = 2$, while the degeneracies and the excitation energies of the first and the second excited states (terms $^2\text{P}_{1/2}$ and $^2\text{P}_{3/2}$, respectively), are $g_1 = 2$, $\epsilon_1 = 1.85\text{ eV}$ and $g_2 = 4$, $\epsilon_2 = 1.85\text{ eV}$, respectively.</p>
<p>Work placement</p>	<p>Not applicable</p>

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