POZNAN UNIVERSITY OF TECHNOLOGY

EUROPEAN CREDIT TRANSFER AND ACCUMULATION SYSTEM (ECTS)

COURSE DESCRIPTION CARD - SYLLABUS

Course name
Chemical and process thermodynamics [S1TCh2E>TCiP]

Course

Field of study
Chemical Technology

Year/Semester
2/3

Area of study (specialization)
–

Profile of study
general academic

Level of study
first-cycle

Course offered in
English

Form of study
full-time

Requirements
compulsory

Number of hours

Lecture
30

Laboratory classes
30

Other
0

Tutorials
0

Projects/seminars
0

Number of credit points

6,00

Coordinators

dr hab. Maciej Galiński prof. PP
maciej.galinski@put.poznan.pl

Lecturers

Prerequisites

Students: have knowledge in general chemistry (writing chemical reactions, converting concentrations, knowledge of laboratory glassware and basic laboratory equipment). have knowledge in mathematics and physics enabling the introduction of problems in physical chemistry (basic laws of physics, differential calculus). are able to prepare solutions of specific concentrations. are aware of further development of their competences.

Course objective

To familiarise students with basic problems in physical chemistry at the academic level in the field of: thermodynamic functions (the first and second laws of thermodynamics, the Gibbs free energy, thermochemistry,the thermodynamic equation of state), phase equilibrium - one-component and multi-component systems, surface and chemical equilibrium, colloidal systems and energy sources.

Course-related learning outcomes

Knowledge:
Students will be able to formulate and explain the basic theories of surface phenomena, heat engines and energy sources. K_W03, K_W10

Students will be able to define the basic concepts and laws of thermodynamics, determine the basic limitations and scope of their applicability; describe phenomena and processes in thermodynamics. K_W03, K_W10

Skills:
Students will be able to obtain information from literature, databases and other sources; interpret it as well as draw conclusions and formulate and substantiate opinions. K_U01
Students will be able to plan and carry out measurements of basic physicochemical parameters. K_U22, K_U23
Students will be able to apply the principles of thermodynamics in the implementation of chemical processes. K_U23
Students will have the self-study skills in the subject. K_U05
Students will be able to elaborate, describe and present results of an experiment or theoretical calculations. K_U09

Social competences:
Students will be aware of the responsibility for jointly performed tasks. They will be able to work as a team. K_K03
Students will understand the need for further training and developing their professional competences. K_K01

Methods for verifying learning outcomes and assessment criteria

Learning outcomes presented above are verified as follows:

Lecture: The knowledge acquired during the lecture is verified during the written exam. The exam consists of 3 open questions for the same number of points and and 15 test questions. Minimum threshold: 53% points.
Laboratory classes: the course passing is based on points received for the individual exercise description. Passing exercises from: 56%
If the classes will be held remotely, the forms of course assessments will remain unchanged and will be carried out with the use of tools provided by the Poznań University of Technology (the e-courses platform).

Programme content

Issue related to chemical and process thermodynamics.

Course topics

Lecture:
1. Introduction and Basics Definitions
System and surroundings. Thermodynamic parameters. Variables and units. Energy distribution. Thermal energy. The average thermal energy of particles. Maxwell-Boltzmann distribution. Temperature, (zeroth Law of the thermodynamics). Temperature scales. Thermodynamic temperature scale. Perfect gas. Real gas. Definition of compression factor. Real gas description using a polynomial (Viral equation). Virial coefficient - Boyle temperature. Van der Waals molecular interactions. Real gas description using a van der Waals equation. Van der Waals isotherm, perfect gas isotherm.
2. First law of thermodynamics
Internal energy - total energy of a system. Energy balance of the reaction (process) - internal energy balance. The difference of energy contained in products and substrates exchanged with the environment. Varieties of work: electrical, surface expansion, volumetric. How internal energy is stored? Volume work - equation. Work and Heat are not a function of the state. The total differential of internal energy. Heat capacity definition, Heat capacity - temperature dependence. Internal Energy description by T and P. Enthalpy definition.
3. Heat capacity
Heat capacity at constant p and V, CP and CV relation. Heat capacity for ideal gas. Expansion of the ideal gas to vacuum, Joule Experiment- internal energy as only temperature dependence parameter. Joule-Thompson experiments -ideal and real gases.
4. Adiabatic process
Reversible and irreversible adiabatic processes. Work and heat at the adiabatic process.

5. Second Law of thermodynamics
The concept of entropy as a chaos assessment. Total entropy may increase but cannot decrease. Total entropy changes as the sum of the entropy of the system and surroundings changes. Reversibility of the processes. Third law of thermodynamics. Entropy as a time arrow. The direction of the processes. Examples and calculations
6. Gibbs energy(G) and free energy (F) as entropy-derived parameters
Gibbs energy - the fundamental equation of chemical thermodynamics. Work and heat depend on how the process is carried out. State function. Isobaric and isochoric process. Adiabatic changes Definition of Gibbs energy. Definition of Helmholtz energy. When to use which function (p = const. or v = const.).
7. Thermochemistry 1
Standardization of thermodynamic functions. Standard enthalpies of formation. Specification of reference state. Standard entropy. The entropy of substances near Kelvin zero. Calorimetric measurement of entropy of a substance.
8. Thermochemistry 2
Temperature dependence of the heat reaction - Hess's Law. The equilibrium of the reaction. Free Enthalpy and equilibrium constant relation. Temperature influence of the equilibrium constant - van't Hoff equation. Pressure dependence of the equilibrium constant - van Laar equation
9. Phase equilibrium - one component system
Gibbs phase rule. Melting, evaporation, sublimation. Phase diagrams: liquid-vapour. Temperature dependence of vapour pressure, Clausius-Clapeyron equation. Liquid heating curves. Boiling phenomenon - boiling point. Dependence of boiling point on pressure. The heat of evaporation, the heat of condensation. Cooling by evaporation of water. Cavitation. Liquid - solid transformation. Dependence of melting point on pressure. Solid state-vapour transition: sublimation. Dependence of the vapour pressure over a solid on temperature. Temperature dependence of vapour pressure for liquid-gas, liquid-solid and solid-gas equilibria. Phase diagram of a one-component system. Different solid phases
10. Phase equilibrium - multi-component systems
Thermal analysis. Phase diagrams. Liquid-gas phase equilibria for multi-component systems. Distillation, fractional distillation. Azeotropes. Crude oil distillation, agricultural alcohol distillation. Liquid-solid phase equilibria for multi-component systems. Crystallization, purification. Simple eutectic mixture. Eutectics of solid solutions, phase diagram. Eutectic mixture with a chemical connection between the components. Peritectic mixture. Structure of eutectic alloys. Metal alloys, examples
11. Heat machines
Heat engine. Working principle - heat tank, cooler. Heat engine efficiency. Carnot cycle. Steam engine. Turbine engine. Stirling's engine. Heat pumps, the principle of operation. The efficiency of the cooler and heat pump.
12. Solutions 1.
Ideal solutions and mixtures. Partial molar quantities, chemical potential, chemical potential dependence on pressure and temperature. Excess values of mixing. Types of solutions.
13. Solutions 2
Extraction, osmosis, reverse osmosis - description. Membranes. Boiling and melting points of solutions. Component dependency. Clausius-Clapeyron equation for vaporisation, cryoscopic and ebullioscopic constant.
14. Transport and Flows
Stimulus and flow. Transfer of mass, heat, load and momentum. Effusion. Knudsen equation. Diffusion, Fick's first law of diffusion. Diffusion equation. Diffusion coefficient. Thermodiffusion. Thermal conductivity, heat conductions. Electric charge flow. Viscosity, viscosity coefficient. Non-Newtonian liquids. Ohm's law. Conductivity.
15. Colloidal systems.
Dispersion, the definition of colloidal systems. Classifications of colloidal systems. Lyophilic and lyophobic colloids. Phase, molecular and micellar systems. Formation of colloidal systems: dispersion and condensation methods. Formation of an emulsion. The structure of the micelles. Protective charge. Zeta potential. Electrophoresis. Tyndall effect. The viscosity of colloidal systems. Destruction of colloidal systems. Coagulation.
Laboratory:
PHASE EQUILIBRIUM
Liquid - Vapour transition. Temperature dependence of vapour pressure, Clausius-Clapeyron equation. Raoult's law and Henry's law. Phase diagrams: liquid - vapour. Distillation, fractional distillation. Aseotropes. Gibbs phase rule. Phase diagrams: liquid - solid for the two component systems. Two and multi component systems. Thermal analysis. Cooling curves. Chemical potential of a component in ideal

and real solution. Activity coefficients. Nernst's distribution law. Three component system. Phase diagrams: liquid - liquid. Extraction. Application of extraction process.
CHEMICAL EQULIBRIUM
Chemical equilibrium and thermodynamics functions. Thermal dependency of chemical equilibrium. Heat reaction and temperature dependence. Solubility equilibrium. Conductometry. Conductivity measurements of the electrolytes. Measurement cell construction. Heat reaction and determination. General principles of thermodynamics. Laws of thermodynamics. Internal energy and enthalpy. Molar enthalpy of formation, combustion, dissolution dilution. Calorimetry. Construction and types of calorimeters. Cells and cell types. Methods for measuring the electromotive force of a cell.

Teaching methods

Lecture: multimedia presentation
Laboratory- practical method - laboratory exercises. Planning, execution and analysis of the results of physicochemical experiment.

Bibliography

Basic:
1. K. Pigoń, Z. Ruziewicz, Chemia Fizyczna, PWN Warszawa 2013
2. P. Atkins, Chemia Fizyczna, PWN Warszawa 2019
3. L. Sobczyk , Eksperymentalna Chemia Fizyczna, PWN Warszawa 1982
4. P.W. Atkins, C.A Trapp, M.P.Cady, C.Giunta Chemia fizyczna. Zbiór zadań z rozwiązaniami
5. J. Demichowicz-Pigoniowa Obliczenia fizykochemiczne, Wydawnictwo Politechniki Wrocławskiej Wrocław 1997
6. W. Ufnalski, Obliczenia fizykochemiczne, Wydawnictwo Politechniki Warszawskiej 1995
7. Instrukcje do ćwiczeń laboratoryjnych z chemii fizycznej

Additional:
1. P. Atkins, Podstawy Chemii Fizycznej, PWN Warszawa 1999
2. L. Sobczyk, A. Kisza, Chemia fizyczna dla przyrodników, PWN Warszawa 1977
3. J. Minczewski, Chemia analityczna, PWN Warszawa 2005
4. H. Buchnowski, W. Ufnalski Wykłady z chemii fizycznej, WNT Warszawa 1998

Breakdown of average student's workload

	Hours	ECTS
Total workload	150	6,00
Classes requiring direct contact with the teacher	76	3,00
Student's own work (literature studies, preparation for laboratory classes/ tutorials, preparation for tests/exam, project preparation)	74	3,00