COURSE DESCRIPTION CARD - SYLLABUS

Course name

Thermodynamics

Course

Field of study	Year/Semester
Circular System Technologies	2/3
Area of study (specialization)	Profile of study
-	general academic
Level of study	Course offered in
First-cycle studies	polish
Form of study	Requirements
full-time	compulsory

Number of hours

Lecture	Laboratory classes	Other (e.g. online)
30	0	0
Tutorials	Projects/seminars	
0	0	

Number of credit points

3

Lecturers

Responsible for the course/lecturer:

dr hab. Maciej Galiński, prof. PP

email: maciej.galinski@put.poznan.pl

tel + 48 61 66 52 310

Faculty of Chemical Technology

ul. M.Skłodowskiej-Curie 5, 60-965 Poznan

Responsible for the course/lecturer:

Prerequisites

Students have knowledge in general chemistry (writing chemical reactions, converting concentrations, knowledge of laboratory glassware and basic laboratory equipment).

Students have knowledge in mathematics and physics enabling the introduction of problems in physical chemistry (basic laws of physics, differential calculus).

Students are able to prepare solutions of specific concentrations.

Students are aware of further development of their competences.

Course objective

To familiarize students with issues of thermodynamics at the academic level in the field of:

thermodynamic principles and functions (thermodynamic potentials as a driving force of processes, thermochemistry, standardization of thermodynamic functions and mathematical thermodynamic relations), phase equilibria for single and multi-component systems, physicochemistry of solutions, chemical equilibria, Thermodynamic description of heat machines, thermodynamic cycles: Carnot cycle, Stirling cycle, heat pump.

Course-related learning outcomes

Knowledge

The student has knowledge of physics and chemistry allowing to understand the phenomena and changes occurring in technological and environmental processes (K_W02).

The student has an ordered, theoretically founded knowledge covering key problems in the field of technical thermodynamics (K_W17).

Skills

The student is able to obtain information from literature, databases and other sources related to circular system technologies, also in a foreign language, to integrate them, interpret and draw conclusions and formulate opinions (K_U01).

The student has the ability to self-study, is able to use source information in Polish and a foreign language in accordance with the principles of ethics, reads with understanding, conducts analyzes, syntheses, summaries, critical assessments and correct conclusions (K_U04).

The student correctly uses in the discussion and correctly uses the nomenclature and terminology in the field of circular system technology, chemistry, technology and chemical engineering, environmental protection and related disciplines, also in a foreign language (K_U05).

Social competences

The student independently determines and implements the action plan entrusted to him, defining the priorities for its implementation, critically assesses the level of advancement in the implementation of the assigned task (K_K03).

The student objectively assesses the level of their knowledge and skills, understands the importance of improving professional and personal competences adequately to the changing social conditions and the progress of science (K_K05).

The student participates in discussions and is able to conduct discussions, is open to different opinions and ready to assertively express feelings and critical comments (K_K08).

Methods for verifying learning outcomes and assessment criteria

Learning outcomes presented above are verified as follows:

Lecture: exam.

Programme content

1. 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. Thermal energy. Average thermal energy of particles. Maxwell-Boltzman distribution. Temperature, its various scales. Thermodynamic temperature scale.

2. Second law of thermodynamics.

The concept of entropy as a measure of chaos. Total entropy may increase but cannot decrease. Total entropy change as the sum of entropy system and environment changes. Zero (third) law of thermodynamics.

3. 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 enthalpy. Heat transferred at constant pressure. Heat transferred at constant volume. Definition of Gibbs energy. Definition of Helmholtz energy. When to use which function (p=const or v=const).

4. Thermochemistry.

Heat capacity. Calorimeter is a device for measuring energy transferred as heat. Dependence of heat capacity on temperature. The difference between Cp and Cv and qp and qv. Thermochemical equations. Substance heat and reaction heat. Temperature dependence of isobaric and isochoric processes.

5. Standardization of thermodynamic functions.

Standard enthalpies of formation. Specification of reference state. Standard entropy. Entropy of substances near Kelvin zero. Calorimetric measurement of entropy of a substance.

6. Thermodynamic equation of state.

The variation of Helmholtz energy with T and V. The variation of Gibbs energy with T and p. Variation of enthalpy with p. Variation of pressure with T and p. Variation of internal enthalpy with volume. Maxwell relations.

7. Properties of gases.

Ideal gas. Real gas. Definition of compression factor. Real gas description using a polynomial (virial equation). Virial coefficient - Boyle temperature. Determination of the virial coefficient. Van der Waals molecular interactions. Real gas description using a van der Waals equation. Van der Waals isotherm, perfect gas isotherm. Critical isotherm. Reduced variables.

8. 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. Heat of evaporation, 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 vapor pressure over a solid on temperature.

9. Phase equilibrium – one component system, phase diagrams.

Temperature dependence of vapour pressure for liquid-gas, liquid-solid and solid-gas equilibria. Phase diagram of a one component system. Different solid phases. Examples of phase diagrams. Glassy condition. Glass transition temperature. Glass structure. Supercritical fluid. Supercritical CO_2 - phase diagram, applications.

10. Phase equilibrium – multi component systems.

Thermal analysis. Phase diagram. Liquid-gas phase equilibria for multi component systems. Distillation, fractional distillation. Aseotropes. 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. Meritectic mixture. Peritectic mixture. Structure of eutectic alloys. Metal alloys, examples.

11. Chemical equlibrium.

The equilibrium constant for reaction K. Dependence of the equilibrium constant for reaction K on temperature - van't Hoff's isotherm. Dependence of equilibrium position on temperature, isobar and isochor van’t Hoff. Pressure dependence of the equilibrium position. Examples.

12. Thermodynamic description of mixtures.

Mixture and solution. Volume changes when mixing liquids - no additivity. Partial molar volume. In general: partial molar quantities. General lack of additivity of partial molar quantities. Gibbs-Duhem equation. Chemical potential, its dependence on the amount of substance and temperature. Thermodynamics of mixing. Ideal solutions. Real solutions. Excess functions.

13. Solution physics and chemistry.

Activity coefficients. Nernst’s distribution law. Extraction. Osmosis. Reverse osmosis. Membranes. Boiling and freezing point of the non-volatile solution. Boiling-point constant of solvent. Freezing-point constant of solvent. Solubility of gases in liquids - dependence on temperature and pressure. Solubility of solids in liquids, dependence on temperature.

14. Flows.

Stimulus and flow. Transfer of mass, heat, load and momentum. Diffusion, Fick's first law of diffusion. Diffusion equation. Diffusion coefficient. Thermodiffusion. Thermal conductivity, Fourier equation. Momentum transfer, Newton's equation. Viscosity coefficient. Non-Newtonian liquids. Ohm's law. Conductivity.

16. Heat machines.

Heat engine. Working principle - heat tank, cooler. Heat engine efficiency. Carnot cycle. Steam engine. Turbine engine. Stirling's engine. Heat pumps, principle of operation. The efficiency of the cooler and heat pump.

Teaching methods

Lecture: multimedia presentation.

Bibliography

Basic

1. K. Pigoń, Z. Ruziewicz, Chemia Fizyczna, PWN, Warszawa 2013.

2. P. Atkins, Chemia Fizyczna, PWN, Warszawa 2019.

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	75	3,0
Classes requiring direct contact with the teacher	38	1,5
Student's own work (literature studies, preparation for classes and exam) [1]	37	1,5

[1] delete or add other activities as appropriate