AGH UNIVERSITY OF SCIENCE AND TECHNOLOGY

Code:	UBPJO-102	Module name:	Thermodynamics		
Academic year:	2013/2014	Semester:	Fall	ECTS credits:	5
Programme:	University Base of Courses in English				
Course homepage:	https://intcourses.agh.edu.pl	Lecture language:	English		
Responsible teacher:	prof. dr hab. Janik Jerzy (janikj@agh.edu.pl)				
Academic teachers:	prof. dr hab. Janik Jerzy (janikj@agh.edu.pl)				

Description of learning outcomes for module

MLO code	Student after module completion has the knowledge/ knows how to/is able to	Method of learning outcomes verification (form of completion)
Social competence		
M_K001	Student understands the need for continuous learning/stydying various aspects of thermodynamics as of science that reflects the fundamental laws of Nature.	Participation in a discussion, Examination, Activity during classes
Skills		
M_U001	Student will be able to perform all essential calculations in the area of the laws of thermodynamics as applied in various practical applications.	Test results, Execution of exercises, Examination, Activity during classes
Knowledge		
M_W001	Student will acquire a general knowledge of thermodynamics, including the laws of thermodynamics, definitions of state functions, and chemical and phase equilibria.	Execution of exercises, Examination, Activity during classes
M_W002	Student will gain fundamental knowledge about work, heat, internal energy, ethalpy, entropy, Gibbs and Helmholtz energies as well as chemical and phase equilibria stressing their application potentials.	Test results, Execution of exercises, Examination, Activity during classes

FLO matrix in relation to forms of classes

MLO code	Student after module completion has the knowledge/ knows how to/is able to	Form of classes										
		Lectures	Auditorium classes	Laboratory classes	Project classes	Conversation seminar	Seminar classes	Practical classes	Others	Fieldwork classes	Workshops	E-learning
Social competence												
M_K001	Student understands the need for continuous learning/stydying various aspects of thermodynamics as of science that reflects the fundamental laws of Nature.	+	+	-	-	-	-	-	-	-	-	-
Skills												
M_U001	Student will be able to perform all essential calculations in the area of the laws of thermodynamics as applied in various practical applications.	-	+	-	-	-	-	-	-	-	-	-
Knowledge												
M_W001	Student will acquire a general knowledge of thermodynamics, including the laws of thermodynamics, definitions of state functions, and chemical and phase equilibria.	+	+	-	-	-	-	-	-	-	-	-
M_W002	Student will gain fundamental knowledge about work, heat, internal energy, ethalpy, entropy, Gibbs and Helmholtz energies as well as chemical and phase equilibria stressing their application potentials.	+	+	-	-	-	-	-	-	-	-	-

Module content

Lectures

The thermodynamic concept of temperature or the zeroth law of thermodynamics

State of thermal equilibrium. Equations of state. Ideal gas laws and the ideal gas temperature scale. Dalton’s law for ideal gas mixtures. Real gases and the virial equation. P-V-T
relationships for a one-component system. Triple point and critical point. The Van der Waals equation and the compressibility factor for gases.

Second law of thermodynamics - spontaneity and reversibility of a process

Spontaneous and non-spontaneous changes. Carnot cycle. Thermodynamic temperature. Expressions of the second law. The fundamental equation for a closed system. Entropy for reversible and irreversible processes. Entropy of mixing ideal

gases. Entropy and statistical probability. Calorimetric determination of entropies.

Chemical equilibrium
General equilibrium expression. Equilibrium constants expressions and their determination. Thermodynamics of a simple gas reaction. Effect of pressure, temperature, and initial composition on equilibrium constants. Homogeneous and heterogeneous chemical reactions.

Phase equilibria
One-component systems. First- and second-order phase transitions. The Clapeyron equation. The Clausius-Clapeyron equation. Phase rule. Multi-component systems. Thermodynamic
properties of ideal liquid mixtures. Vapor pressure of nonideal mixtures. Raoult’s law. Henry’s law. Activity coefficients. Examples of phase diagrams.

Introduction - basic properties and definitions
SI and non-SI base units. Thermodynamics vs. kinetics. Definition of a thermodynamic system. Open and isolated, homogeneous and heterogeneous systems. Extensive and intensive properties of a system. Standard states and state variables. Equilibrium as a definite state.

First law of thermodynamics or the law of conservation of energy
Definitions and interrelations of work, internal energy, and heat. Joule’s experiments. The first law of thermodynamics and internal energy. Various kinds of work. Joule-Thomson expansion. Heat capacities Cp and Cv. Adiabatic processes with gases. Thermochemistry: exothermic and endothermic reactions. Enthalpy of formation. Temperature dependence of enthalpy.

The third law of thermodynamics or the value of entropy at absolute zero
Standard reaction entropies. Expressions of the third law. Entropy changes for phase changes and chemical reactions – examples.

Helmholtz energy, A, and Gibbs energy, G
Legendre transforms. Definitions of the Gibbs energy and Helmholtz energy. Thermodynamic functions for a closed systems. Thermodynamic equations of state. Effect of temperature and pressure on the Gibbs energy. Fundamental
equations for open systems. The additivity relation for the Gibbs energy. Partial molar quantities. The activity.

Auditorium classes

The thermodynamic concept of temperature or the zeroth law of thermodynamics
Pressure and molar volume for ideal and real gases; comparison of the ideal gas law, virial equation, and the van der Waals equation.

The first law of thermodynamics or the law of conservation of energy
Work of compression/expansion of a gas. Changes in internal energy and enthalpy on heating. Work and internal energy changes in adiabatic processes. Standard enthalpy changes for
reactions. Enthalpy of reactions at different temperatures. Calculations of bond energies.

The second law of thermodynamics; spontaneity and reversibility of a process; the third law of thermodynamics or the value of entropy at absolute zero
Changes in entropy of a gas in various processes (e.g. vaporization, heating at constant and variable pressures). Examples of entropy changes in irreversible processes via a reversible path from the initial state to the final state. Calculations of

entropy of mixing. Determination of the entropy of a substance relative to its entropy at 0 K.

Helmholtz energy, A and Gibbs energy, G
Derivation of Maxwell relations. Calculations of molar thermodynamic quantities ΔU, ΔH, ΔG, ΔA, and ΔS for ideal gas expansion and gas mixing. Molar entropy and internal energy of
isothermal expansion of a van der Waals gas. Activity of a substance at different pressures.

Introduction; basic properties and definitions
Interconversion of SI and non-SI base units. Values of the gas constant R. Mole fractions and partial pressures.

Method of calculating the final grade
Written examination.

Prerequisites and additional requirements
Prior course in mathematics (especially,concepts/calculations of integrals and differentials.

Recommended literature and teaching resources
1. Robert A. Alberty, Robert J. Silbey Physical Chemistry, Second Edition; John Wiley & Sons, Inc.,New York 1996.
2. Robert A. Alberty, Robert J. Silbey Solutions Manual to Accompany Physical Chemistry, Second Edition; John Wiley & Sons, Inc., New York 1996.

Scientific publications of module course instructors related to the topic of the module
Additional scientific publications not specified

Additional information
None

Student workload (ECTS credits balance)

Student activity form	Student workload
Participation in lectures	28 h
Participation in auditorium classes	14 h
Realization of independently performed tasks	45 h
Preparation for classes	43 h
Summary student workload	130 h
Module ECTS credits	5 ECTS