Національний технічний університет України
«КИЇВСЬКИЙ ПОЛІТЕХНІЧНИЙ ІНСТИТУТ
імені ІГОРЯ СІКОРСЬКОГО»

Department of machines and devices of chemical and oil refining industries

THERMODYNAMICS IN CHEMICAL ENGINEERING

Working program of the academic discipline (Syllabus)

Details of the academic discipline	
Level of higher education	***First (undergraduate)***
Branch of knowledge	*13 Mechanical engineering*
Specialty	*133 Industrial engineering*
Educational program	*Computer-integrated technologies of chemical engineering equipment design*
Discipline status	*Selective*
Form of education	*daytime*
Year of training, semester	*3rd year, autumn semester*
Scope of the discipline	*4 ECTS credits*
Semester control/ control measures	*Assessment, MKR, Abstract*
Lessons schedule	
Language of teaching	*Ukrainian*
Information about the course leader / teachers	Lecturer:*Ph.D., Serhiy Valeriyovych Gulienko,sergiiguliienko@gmail.com, +38504488173* Practical:*Ph.D., Serhiy Valeriyovych Gulienko,sergiiguliienko@gmail.com, +38504488173* Laboratory:not provided for in the curriculum
Placement of the course	

Program of educational discipline

1. Description of the educational discipline, its purpose, subject of study and learning outcomes

Thermodynamics is a fundamental science that studies the general properties of macroscopic systems and methods of energy transfer and transformation in such systems, and is the basis of many practical applications in chemical engineering. In particular, knowledge of thermodynamics makes it possible to develop the most rational methods of calculating heat balances in the course of physical and chemical processes, to reveal regularities that are observed during equilibrium, to determine the most favorable conditions for the implementation of processes, reveals the conditions under which all side processes can be minimized.

In other words, thermodynamics is a key component of many fields of science and engineering, which is based on the universal laws of nature. However, the most important applications of these laws, and the materials and processes of greatest interest, differ across industries. Hence, there is a need to present these materials from a chemical engineering perspective, focusing on thermodynamic principles for the materials and processes most likely to be considered in chemical engineering.

Thermodynamics is the study of energy, including the transformation of energy from one form to another, and the effect that energy is given to or removed from a system. Thermodynamics is an important part of chemical engineering. The principles of thermodynamics play a fundamental role in the understanding, analysis and design of processes.

In particular, thermodynamics plays a vital role in process design. A chemical engineer must consider thermodynamic properties when addressing questions such as:

- how much raw materials and energy need to be spent to obtain the required productivity;

- what methods can be used to separate products and clean raw materials;

- how much energy needs to be spent to reach the given temperature;

- how processes can be optimized.

This course introduces and illustrates the principles of thermodynamics in chemical engineering by applying these principles to engineering problems.

The subject of the study discipline "Thermodynamics in chemical engineering" is the principles and laws of thermodynamics and their application in chemical engineering.

The purpose of the academic discipline "Thermodynamics in Chemical Engineering":

The purpose of studying this discipline is the formation of a set of knowledge in students, namely:

- To know and understand the principles of thermodynamics that underlie the engineering of equipment for chemical and related technologies.

- To understand the physical essence of phenomena, mechanisms of thermodynamic processes occurring in the equipment of chemical and related technologies, to apply mathematical apparatus for quantitative calculations, on the basis of which to choose equipment parameters and modes of its operation.

According to the goal, bachelor's training in this specialty requires strengthening the competencies formed by students:

- Ability to use the basic laws of thermodynamics in calculations and thermodynamic analysis of the efficiency of energy transformations in equipment.

2. Pre-requisites and post-requisites of the discipline (place in the structural and logical scheme of training according to the relevant educational program)

The discipline "Thermodynamics in Chemical Engineering" is an elective discipline.

The requirements for starting the study include the basic knowledge obtained during the first two courses of training, in particular knowledge of the disciplines: "Fundamentals of chemical engineering", "Transfer processes in solid media".

The study of the discipline will be useful in learning the material of such disciplines as "Processes and equipment of chemical technology", "Diploma design", and will also contribute to better learning of the materials of selective disciplines, such as "Refrigeration technology", "Low-temperature separation processes", "Mass exchange during the dissolution of solids materials", "Fundamentals of membrane technology".

3. Content of the academic discipline

Chapter 1. Basic laws of thermodynamics and thermodynamic parameters.

Topic 1.1*Thermodynamic parameters*

Determination of the amount of substance. Temperature. Pressure. Work. Energy. Warmth. Relationship between physical quantities of real substances. Properties of the state and properties depending on the path of the process. Intensive and extensive properties of matter. Enthalpy. Heat capacity. An ideal gas.

Topic 1.2*Laws of thermodynamics*

The first law of thermodynamics. Energy balances for closed systems. Mass and energy balances for open systems. The second law of thermodynamics.

Chapter 2. Thermodynamics of mixtures and solutions.

Topic 2.1*Variables, definitions and dependencies*

Variables, definitions and dependencies. Determination of the composition of the mixture. Systems with constant composition

Topic 2.2*Systems of variable composition*

Systems of variable composition. Mixtures of ideal gases. Fugacity and fugacity coefficient. Fundamental relations of residual properties. The perfect solution. Fundamental dependencies for redundant properties. Summary of the fundamental dependencies of properties.

Chapter 3. Mixing

Change in properties during mixing. Thermal effects during mixing. Enthalpy-concentration diagrams. Heat of dissolution.

Chapter 4. Evaluation of Thermodynamic Properties

Formulation of residual properties. Liquid/vapor phase transition. Properties of the liquid phase. Properties from PVT correlations. Expressions for excess Gibbs energy

Chapter 5. Equilibrium

Topic 5.1*Phase equilibrium*

The nature of balance. Phase rule. Duhem's theorem. Vapor/liquid equilibrium: a qualitative assessment. Equilibrium and stability of phases. Vapor/liquid/liquid equilibrium. Analytical methods of calculating parameters of the equilibrium state

Topic 5.2*Equilibrium of chemical reactions*

Reaction coordinates. Application of the equilibrium criterion to chemical reactions. Standard Gibbs energy change and equilibrium constant. Effect of temperature on the equilibrium constant

Chapter 6. Thermodynamic analysis of processes

Calculation of ideal work. Lost work. Analysis of stationary processes and processes with a stationary flow.

4. Educational materials and resources

Basic literature:

1. *Thermodynamics in chemical engineering. Theoretical foundations. Study guide [Electronic resource]: study guide for bachelor's degree holders in the educational program "Computer-integrated technologies of chemical engineering equipment design" specialty 133 "Industrial mechanical engineering" / KPI im. Igor Sikorskyi; structure. : S. V. Gulienko, O. V. Husarova. – Electronic text data (1 file 3.51 MB). – Kyiv: KPI named after Igor Sikorskyi, 2023. – 211 p. – Title from the screen.https://ela.kpi.ua/handle/123456789/55927*
2. *Dahm KD, Visco DP (2015). Fundamentals of Chemical Engineering Thermodynamics. Stamford, Cengage Learning*
3. *Smith, JM, van Ness, HC (2018). Introduction to chemical engineering thermodynamics. New York, McGraw-Hill.*
4. *Perry's Chemical Engineers' Handbook. New York: McGraw-Hill, 1997.*
5. *Physical chemistry. Chemical thermodynamics [Electronic resource]: academic. manual for study specialty 161 "Chemical technologies and engineering" / comp.: T.A. Kamenska, G.A. Rudnytska, M.E. Ponomaryov; KPI named after Igor Sikorsky. – Electronic text data (1 file: 2.594 MB). – Kyiv: KPI named after Igor Sikorskyi, 2021. – 257 p.*

Additional literature*:*

1. *Poling, BE; Prausnitz, JM; O'Connell, JP (2001). The Properties of Gases and Liquids. 5th edition, New York. McGraw-Hill.*
2. *Winterbone DE (1997). Advanced Thermodynamics for Engineers. Oxford. Butterworth-Heinemarm*

3. *Ott JB, Boerio-Goates J. (2000). Chemical Thermodynamics: Advanced Applications. London. Academic Press*
4. *Ott JB, Boerio-Goates J. (2000). Chemical Thermodynamics: Principles and Applications. London. Elsevier Academic Press.*
5. *Tschoegl NW (2000). Fundamentals of Equilibrium and Steadv-State Thermodynamics. Amsterdam. Elsevier.*
6. *Tosun I. (2021). The Thermodynamics of Phase and Reaction Equilibria. Second edition. Amsterdam. Elsevier.*
7. *Jaubert J.-N., Privat R. (2021). Thermodynamic Models for Chemical Processes. Design, Develop, Analyze and Optimize. Oxford. Elsevier.*
8. *Sieniutycz S., Jezowski J. (2018). Energy Optimization in Process Systems and Fuel Cells. Amsterdam. Elsevier.*
9. *Viswanathan B. (2017). Energy Sources. Fundamentals of Chemical Conversion Processes and Applications. Amsterdam. Elsevier.*
10. *Haseli Y. (2020). Entropy Analysis in Thermal Engineering Systems. London. Elsevier.*
11. *Barsky E. (2020). Entropy of Complex Processes and Systems. Amsterdam. Elsevier.*
12. *Wang Sh. (2022). Low-Grade Thermal Energy Harvesting. Advances In Materials, Devices, And Emerging Applications. Kidlington. Elsevier.*
13. *Lee L. (1988). Molecular Thermodynamics of Nonideal Fluids. Boston. Butterworths.*
14. *Demirel Y., Gerbaud V. (2019). Nonequilibrium Thermodynamics Transport and Rate Processes in Physical, Chemical and Biological Systems. Amsterdam. Elsevier.*
15. *Kemp I., Lim J. Sh. (2020). Pinch Analysis for Energy and Carbon Footprint Reduction User Guide to Process Integration for the Efficient Use of Energy, Third Edition. Oxford. Elsevier.*
16. *Ross JRH (2022). Sustainable Energy. Towards a Zero-Carbon Economy using Chemistry, Electrochemistry and Catalysis. Amsterdam. Elsevier.*
17. *Attard P. (2002). Thermodynamics and Statistical Mechanics Equilibrium by Entropy Maximisation. London. Academic Press.*
18. *Applied Thermal Engineering | Journal | ScienceDirect.com by Elsevier [Electronic resource]. - : [Website]. – Electronic data. – Mode of access: https://www.sciencedirect.com/journal/applied-thermal-engineering (access date 02/27/2023) – Title from screen*
19. *Experimental Thermal and Fluid Science | Journal | ScienceDirect.com by Elsevier [Electronic resource]. - : [Website]. – Electronic data. – Access mode: https://www.sciencedirect.com/journal/experimental-thermal-and-fluid-science (access date 02/27/2023) – Title from screen*
20. *Fluid Phase Equilibria | Journal | ScienceDirect.com by Elsevier [Electronic resource]. - : [Website]. – Electronic data. – Mode of access: https://www.sciencedirect.com/journal/fluid-phase-equilibria (access date 02/27/2023) – Title from screen*
21. *International Journal of Heat and Mass Transfer | ScienceDirect.com by Elsevier [Electronic resource]. - : [Website]. – Electronic data. – Mode of access: https://www.sciencedirect.com/journal/international-journal-of-heat-and-mass-transfer (access date 02/27/2023) – Title from screen*
22. *International Journal of Thermal Sciences | ScienceDirect.com by Elsevier [Electronic resource]. - : [Website]. – Electronic data. – Access mode: https://www.sciencedirect.com/journal/international-journal-of-thermal-sciences (access date 02/27/2023) – Title from screen*
23. *Thermochimica Acta | Journal | ScienceDirect.com by Elsevier [Electronic resource]. - : [Website]. – Electronic data. – Mode of access: https://www.sciencedirect.com/journal/thermochimica-acta (date of access 27.02.2023) – Title from screen*
24. *Continuum Mechanics and Thermodynamics | Home [Electronic resource]. - : [Website]. – Electronic data. – Access mode: https://www.springer.com/journal/161 (access date 27.02.2023) – Title from the screen*

25. *Journal of Phase Equilibria and Diffusion | Home [Electronic resource]. - : [Website]. – Electronic data. – Access mode: https://www.springer.com/journal/11669 (access date 02/27/2023) – Title from the screen*
26. *Heat and Mass Transfer Home [Electronic resource]. - : [Website]. – Electronic data. – Mode of access: https://www.springer.com/journal/231 (access date 02/27/2023) – Title from the screen*
27. *Journal of Engineering Physics and Thermophysics Home [Electronic resource]. - : [Website]. – Electronic data. – Access mode: https://www.springer.com/journal/10891 (access date 02/27/2023) – Title from the screen*
28. *Journal of Engineering Thermophysics Home [Electronic resource]. - : [Website]. – Electronic data. – Mode of access: https://www.springer.com/journal/11823 (date of access 02/27/2023) – Title from the screen*
29. *Thermal Engineering | Home [Electronic resource]. - : [Website]. – Electronic data. – Mode of access: https://www.springer.com/journal/11509 (date of access 02/27/2023) – Title from the screen*
30. *Energies | An Open Access Journal from MDPI [Electronic resource]. - : [Website]. – Electronic data. – Access mode: https://www.mdpi.com/journal/energies (date of access 27.02.2023) – Title from the screen*
31. *Entropy | An Open Access Journal from MDPI [Electronic resource]. - : [Website]. – Electronic data. – Access mode: https://www.mdpi.com/journal/entropy (access date 27.02.2023) – Title from the screen*
32. *Thermo | An Open Access Journal from MDPI [Electronic resource]. - : [Website]. – Electronic data. – Access mode: https://www.mdpi.com/journal/thermo (date of access 27.02.2023) – Name from the screen*
33. *Thermodynamics: First & Second Laws [Electronic resource]. - : [Website]. – Electronic data. – Mode of access: https://www.youtube.com/watch?v=UMs9GIrY4dw&list=PL4xAk5aclnUiyy5I6QsjJ_3rdKoO0q04I (access date 02/27/2023) – Title from the screen*
34. *3 Thermodynamics: Generalized Analysis of Fluid Properties [Electronic resource]. - : [Website]. – Electronic data. – Access mode: https://www.youtube.com/playlist?list=PL4xAk5aclnUjeRz26fds2w1Mw8YvKHuSU (access date 02/27/2023) – Title from the screen*
35. *Thermodynamics: Fluid Phase Equilibria in Mixtures [Electronic resource]. - : [Website]. – Electronic data. – Access mode: https://www.youtube.com/playlist?list=PL4xAk5aclnUjMQaDPzjOWCkGQORbYDNl5 (date of access 27.02.2023) – Title from the screen*
36. *Thermodynamics: Interactive Screencasts [Electronic resource]. - : [Website]. – Electronic data. – Access mode: https://www.youtube.com/playlist?list=PL4xAk5aclnUjZ_bhvqdlGfMQohOiuE8Ul (access date 27.02.2023) – Title from the screen*
37. *Thermodynamics: Interactive Simulations [Electronic resource]. - : [Website]. – Electronic data. – Access mode: https://www.youtube.com/playlist?list=PL4xAk5aclnUj1nDv5x0UVATwpQwHC-8m9 (access date 02/27/2023) – Title from the screen*
38. *Thermodynamics Review [Electronic resource]. - : [Website]. – Electronic data. – Access mode: https://www.youtube.com/playlist?list=PL5DB67B76382FC256 (access date 02/27/2023) – Title from the screen*
39. *Introduction to Chemical Engineering Thermodynamics [Electronic resource]. - : [Website]. – Electronic data. – Access mode: https://www.youtube.com/playlist?list=PLRihodfxzBsXr9sqFZ6J6ZREfVU86NxDJ (access date 02/27/2023) – Screen name*

Educational content

5. Methods of mastering an educational discipline (educational component)

Lecture classes

Lectures are aimed at:

- *provision of modern, integral, interdependent knowledge in the discipline "Thermodynamics in chemical engineering", the level of which is determined by the target setting for each specific topic;*
- *ensuring creative work of students together with the teacher during the lecture;*
- *education of students' professional and business qualities and development of their independent creative thinking;*
- *forming the necessary interest in students and providing direction for independent work;*
- *definition at the current level of science development in the field of thermodynamics in chemical engineering;*
- *reflection of the methodical processing of the material (highlighting of the main provisions, conclusions, recommendations, their wording is clear and adequate);*

- *the use of visual materials for demonstration, combining them, if possible, with the demonstration of research results;*
- *teaching research materials in a clear and high-quality language with observance of structural and logical connections, clarification of all newly introduced terms and concepts;*
- *accessibility for perception by this audience.*
-

No. z/p	The name of the topic of the lecture and the list of main questions (list of didactic tools, references to the literature and tasks on the SRS)	Hour
1	Lecture 1. Thermodynamic parameters. Determination of the amount of substance. Temperature. Pressure. Work. Energy. Warmth. Literature [1-5]	2
2	Lecture 2. Properties of the state of matter Relationship between physical quantities of real substances. Properties of the state and properties depending on the path of the process. Intensive and extensive properties of matter. Enthalpy. Heat capacity. An ideal gas. Literature [1-5]	2
3	Lecture 3. The first law of thermodynamics Energy balances for closed systems. Mass and energy balances for open systems. Literature [1-5]	2
4	Lecture 4. The second law of thermodynamics Axiomatic formulations of the second law of thermodynamics. Fundamental thermodynamic properties. Definition of PVT system. Application of the second law of thermodynamics to simple heat exchange. Application of the second law of thermodynamics to heat engines Literature [1-5]	2
5	Lecture 5. Thermodynamics of mixtures and solutions. Variables, definitions and dependencies. Determination of the composition of the mixture. Literature [1-5]	2
6	Lecture 6. Systems with constant composition. Definition of parameters Enthalpy and entropy as a function of T and p. Internal energy and entropy as a function of T and V. Dependencies for heat capacity Literature [1-5]	2
7	Lecture 7. Systems of variable composition Partial molar properties. Gibbs-Duhem equation. Partial molar Gibbs energy. The state of an ideal gas and the compressibility factor. Residual properties Literature [1-5]	2
8	Lecture 8. Thermodynamics of solutions Mixtures of ideal gases. Fugacity and fugacity coefficient. Fundamental	2

	relations of residual properties. *Literature [1-5]*	
9	*Lecture 9. An ideal solution* *Fundamental dependencies for redundant properties. Summary of the fundamental dependencies of properties.* *Literature [1-5]*	*2*
10	*Lecture 10. Mixing* *Change in properties during mixing. Thermal effects during mixing. Enthalpy-concentration diagrams. Heat of dissolution.* *Literature [1-5]*	*2*
11-12	*Lecture 11-12. Evaluation of thermodynamic properties* *Formulation of residual properties. Liquid/vapor phase transition. Properties of the liquid phase. Properties from PVT correlations. Expressions for excess Gibbs energy* *Literature [1-5]*	*4*
13-14	*Lecture 13-14. Phase equilibrium* *The nature of balance. Phase rule. Duhem's theorem. Vapor/liquid equilibrium: a qualitative assessment. Equilibrium and stability of phases. Vapor/liquid/liquid equilibrium. Analytical methods of calculating parameters of the equilibrium state* *Literature [1-5]*	***4***
15	*Lecture 15. Equilibrium of chemical reactions* *Reaction coordinates. Application of the equilibrium criterion to chemical reactions. Standard Gibbs energy change and equilibrium constant. Effect of temperature on the equilibrium constant* *Literature [1-5]*	***4***
16	*Lecture 16. Thermodynamic analysis of processes* *Calculation of ideal work. Lost work. Analysis of stationary processes and processes with a stationary flow.* *Literature [1-5]*	***2***
17	*Protection of essays. Modular control work*	***2***
18	*Test*	***2***
	Together	***18***

Practical training

In the system of professional training of students in this discipline, practical classes occupy 67% of the classroom load. As a supplement to the lecture course, they lay and form the foundations of the bachelor's qualification. The content of these classes and the method of conducting them should ensure the development of the creative activity of the individual. They develop technical thinking and the ability to use special terminology, allow you to test knowledge, therefore this type of work is an important means of operational feedback. Practical classes should perform not only cognitive and educational functions, but also contribute to the growth of students as creative workers.

The main tasks of the cycle of practical classes:

- *help students systematize, consolidate and deepen knowledge of a theoretical nature in the field of modern methods of thermodynamics;*
- *to teachstudents in the methods of solving practical tasks, to promote the mastery of skills and abilities to perform calculations, graphic and other tasks;*
- *to teachtheir work with scientific and reference literature;*
- *to form skillsto learn independently, that is, to master the methods, methods and techniques of self-learning, self-development and self-control.*

No. z/p	Name of the subject of the practical session and list of main questions (a list of didactic support, references to the literature and tasks on the SRS)	Hour
1	Practical lesson 1. Thermodynamic parameters. Energy Literature: [4] Tasks on SRS. Solving problems in order to determine thermodynamic and energy parameters.	2
2	Practical lesson 2. Thermal characteristics. Enthalpy. Entropy. Literature: [4] Tasks on SRS. Solving problems in order to determine thermal parameters of systems.	2
3	Practical lesson 3. The first and second laws of thermodynamics. Heat balances Literature: [4] Tasks on SRS. Solving problems on the application of the first and second laws of thermodynamics to drawing up heat balances.	2
4	Practical lesson 4. Model of mixtures of ideal gases. Fugitive pressure and fugitive coefficient. Literature: [4] Tasks on SRS. Solving problems on the definition of fugacity and fugacity coefficient.	2
5	Practical lesson 5. Mix. Change in properties during mixing. Literature: [5] Tasks on SRS. Solving problems on the determination of properties during mixing	2
6	Practical lesson 6. Phase equilibrium. The nature of balance.Phase rule. Literature: [4, 5] Tasks on SRS. Solving problems on the analysis of the state of phase equilibrium	2
7	Practical lesson 7. Equilibrium in the vapor/liquid system.Equilibrium and stability of phases. Literature: [5] Tasks on SRS. Solving equilibrium problems in the vapor/liquid system	2
8	Practical lesson 8. Application of the equilibrium criterion to chemical reactions. Standard Gibbs energy. Literature: [4] Tasks on SRS. Solving problems on the equilibrium of chemical reactions	2
9	Practical lesson 9. Equilibrium in the liquid/liquid system. Equilibrium in the vapor/liquid/liquid system. Literature: [4, 5] Tasks on SRS. Solving problems on determining equilibrium in systemsliquid/liquid and vapor/liquid/liquid	2
	Together	36

6. Independent work of student

Independent work takes up 55% of the time of studying the discipline, including preparation for the assessment, modular control work and preparation of the essay. The main task of students' independent work is to acquire knowledge from the course that was not included in the list of lecture questions by personally searching for information, forming an active interest in a creative approach to educational work. In the process of independent work within the framework of the educational component, the student must learn to analyze modern thermodynamic methods used in chemical engineering.

No. z/p	The name of the topic submitted for independent processing	Number of hours of SRS
1	Chapter 4. Expressions for excess Gibbs energy	10
2	Chapter 5. Analytical methods of calculating parameters of the equilibrium state. 1 Analytical methods for vapor/liquid equilibrium. Analytical methods for liquid/liquid vapor/liquid/liquid equilibria	18
3	Preparation for lectures	8
4	To practical classes	9
5	Execution of the essay	15
6	Preparation for the test	6
	Hours in general	66

Policy and control

7. Policy of academic discipline (educational component)

Rules of attending classes and behavior in classes

Attending classes is a mandatory component of the assessment. Students are obliged to take an active part in the educational process, not to be late for classes and not to miss them without a good reason, not to interfere with the teacher conducting classes, not to be distracted by actions unrelated to the educational process. When solving problems in practical classes, students can use any sources of information and means of calculations. All tasks are performed individually.

Rules for the protection of individual tasks

The curriculum provides for an individual lesson in the form of an essay. The abstract is an analytical review of scientific articles (for example, from [7, 8]) on a specific topic. The abstract is defended in the form of a short (up to 3 minutes) oral report.

Rules for assigning incentive and penalty points

- *incentive points can be awarded by the teacher exclusively for the performance of creative works in the discipline or additional completion of online specialized courses with the receipt of the appropriate certificate:*

But their sum cannot exceed 25% of the rating scale.

- *Penalty points are not provided within the academic discipline.*

Policy of deadlines and rescheduling

In the event of arrears from the academic discipline or any force majeure circumstances, students should contact the teacher through available (provided by the teacher) communication channels to resolve problematic issues and agree on an algorithm of actions for practice.

Policy of academic integrity

Plagiarism and other forms of dishonest work are unacceptable. Plagiarism includes the absence of references for the use of printed and electronic materials, quotes, opinions of other authors. Inadmissible tips and write-offs during writing tests, conducting classes; passing the exam for another graduate student; copying materials protected by the copyright system without the permission of the author of the work.
The policy and principles of academic integrity are defined in Chapter 3 of the Code of Honor of the National Technical University of Ukraine "Ihor Sikorsky Kyiv Polytechnic Institute". More details:https://kpi.ua/code

Policy of academic behavior and ethics
Students should be tolerant, respect the opinions of others, formulate objections in the correct form, constructively support feedback during classes.
Standards of ethical behavior of students and employees are defined in Chapter 2 of the Code of Honor of the National Technical University of Ukraine "Ihor Sikorskyi Kyiv Polytechnic Institute". More details:https://kpi.ua/code

8. Types of control and rating system for evaluating learning outcomes (RSO)

Distribution of study time by types of classes and tasks in the discipline according to the working study plan:

Semester	Training time		Distribution of study hours				Control measures		
	Credits	Acad. hours	Lectures	Practical	Lab. do	SRS	MKR	Ref.	Semester control
5	4	120	36	18	–	64	1	1	test

The student's rating in the discipline consists of the points he receives for: completing 16 tasks in practical classes, defending the essay and MKR.
Semester control is credit.

System of rating (weighted) points and evaluation criteria

The system of rating points and evaluation criteria:

Performing tasks in practical classes.

The weighted score is 4. The maximum number of points for practical classes is 8·8=64.

Execution and defense of the abstract. Weight score 20.

Modular control work. Weight score 16

Credit is issued based on the results of work in the semester.

A student who received at least 60 points in the semester can take part in credit work to get a higher point. In this case, the points obtained by him on the control work with the addition of 50% of the points obtained in the semester are final.

The credit control work (if necessary) is evaluated out of 70 points. The control task consists of two theoretical tasks.

Each task is evaluated out of 35 points according to the following criteria:

- *excellent performance of the task, fluency in defense material - 32-34 points.*
- *good level of performance, correct answers to questions when defending the task - 25-30 points.*

- *a sufficient level of task performance, the presence of minorinaccuracies in answers - 20-22 points.*
- *poor quality of work, ignorance of theoretical material - 0 points.*

The condition of the first attestation is obtaining at least 20 points and completing 50% of practical work (at the time of attestation). The condition for the second attestation is to obtain at least 36 points and complete 75% of practical work (at the time of attestation).

The sum of the points received by the student is transferred to the examination grade according to the table:

Scores	***Rating***
95...100	*perfectly*
85...94	*very good*
75...84	*fine*
65...74	*satisfactorily*
60...64	*enough*
RD<60	*unsatisfactorily*
Admission conditions not met	*not allowed*

9. Additional information on the discipline (educational component)

An approximate list of questions that are submitted for semester control

1. *Analyze the means of determining the amount of a substance*
2. *Explain the physical meaning of temperature*
3. *Compare temperature measurement scales*
4. *Explain the physical meaning of pressure*
5. *Analyze the physical essence of the concept of "work"*
6. *Explain the physical essence of kinetic energy*
7. *Explain the physical essence of potential energy*
8. *Analyze the features of internal energy*
9. *Explain the concept of energy conservation*
10. *Explain the physical essence of the concept of "heat"*
11. *Analyze the relationship between the physical quantities of real substances*
12. *Analyze the diagram of phase transitions for pure components*
13. *Explain the term "state properties"*
14. *Explain the difference between intensive and extensive parameters*
15. *Analyze the physical essence of enthalpy*
16. *Explain the difference between heat capacity at constant pressure and heat capacity at constant volume*
17. *Explain the "ideal gas" model*
18. *Formulate the first law of thermodynamics*
19. *Analyze energy balances for closed systems*
20. *Explain the means of measuring costs*
21. *Analyze the mass balance for open systems*
22. *Explain the features of stationary flow processes*
23. *Analyze the overall energy balance*

24. Explain the features of the energy balance for a stationary flow process

25. Explain the physical meaning of the concept of "entropy"

26. Give axiomatic formulations of the second law of thermodynamics

27. Analyze fundamental thermodynamic properties

28. Define PVT system

29. Explain the features of the application of the second law of thermodynamics to simple heat exchange

30. Explain the features of the application of the second law of thermodynamics to heat engines

31. Explain the features of the application of the first law of thermodynamics for a single-phase closed system in which there is no chemical reaction

32. Explain the introduction of the term "chemical potential"

33. Explain the meaning of Helmholtz energy and Gibbs energy in thermodynamics

34. Explain the means of expressing the composition of a mixture

35. Explain the features of a system with a constant composition

36. Characterize the dependence of enthalpy and entropy on pressure and temperature

37. Characterize the dependence of internal energy and entropy on temperature and molar volume

38. Analyze the dependences for heat capacity

39. Explain the features of the variable composition system

40. Analyze partial molar properties

41. Analyze the Gibbs-Duhem equation

42. Characterize the partial molar Gibbs energy

43. Explain the state of an ideal gas and the compressibility factor

44. To justify the use of residual properties

45. Explain the characteristics of mixtures of ideal gases

46. Analyze fugacity and fugacity coefficient

47. To characterize the fundamental relations of residual properties

48. Explain the features of the "ideal solution" model

49. Justify the use of redundant properties

50. Analyze the Lewis/Randall rule

51. Characterize fundamental dependencies for redundant properties

52. Summarize the fundamental dependencies of properties

53. Analyze the change in properties during mixing

54. Explain the general features of the behavior of systems during mixing

55. Analyze thermal effects during mixing

56. Justify the use of the enthalpy-concentration diagram

57. Analyze the heat of dissolution

58. Explain the peculiarities of the formulation of residual properties

59. Explain the peculiarities of the analysis of properties at the liquid/vapor phase transition

60. Analyze the properties of the liquid phase

61. Analyze property expressions from PVT correlations

62. Explain the correlation of the corresponding Pitzer state

63. Explain the alternative formulation of properties

64. Analyze the virtual equations of state

65. Analyze the cubic equation of state

66. Explain the peculiarities of the expressions for the excess Gibbs energy

67. Explain the nature of equilibrium

68. Explain the rule of phases

69. Analyze Duhem's theorem

70. Analyze the qualitative assessment of vapor/liquid equilibrium

71. Explain the features of p-xy diagrams

72. Explain the features of T-xy diagrams

73. Identify the critical points of binary mixtures

74. Explain the phenomenon of "retrograde condensation"

75. Explain the peculiarities of vapor/liquid equilibrium at low pressure

76. Define the azeotrope point

77. Explain the features of evaporation of binary mixtures at a constant temperature

78. Explain the features of evaporation of binary mixtures at constant pressure

79. Characterize the relationship between equilibrium and stability of phases

80. Explain the features of liquid/liquid equilibrium

81. Explain the features of vapor/liquid/liquid equilibrium

82. Explain the peculiarities of the equilibrium of chemical reactions

83. Analyze the reaction coordinates

84. Explain the features of multi-reaction stoichiometry

85. Analyze the application of the equilibrium criterion to chemical reactions

86. Describe the standard change in Gibbs energy

87. Describe the equilibrium constant

88. Explain the effect of temperature on the equilibrium constant

89. Give a general assessment of analytical methods for vapor/liquid equilibrium

90. Explain the gamma/phi approach

91. Explain the method of reducing the volume of data

92. Explain the features of solute/solvent systems

93. Analyze the equilibrium relationship

94. Explain the equation of state approach

95. Give a general assessment of analytical methods for liquid/liquid vapor/liquid/liquid equilibrium

96. Explain the calculation of ideal work

97. Analyze lost work

98. Explain the analysis of stationary processes and processes with a stationary flow

Working program of the academic discipline (syllabus):

Foldedassociate professor MAHNV, Ph.D., Assoc. Serhii GULIENKO

Approvedby the MAHNV Department (protocol No. 19 dated 17.05.2023)

Agreedby the methodical committee of the faculty (protocol No. 10 dated 05/26/2023)