AL-FARABI KAZAKH NATIONAL UNIVERSITY
Faculty of chemistry and chemical technology
Department of physical chemistry, catalysis and petrochemistry

APPROVED
Dean of the Faculty

_____ Duysebaeva M.A.
(signature)

"01" September 2025

EDUCATIONAL AND METHODICAL COMPLEX OF THE DISCIPLINE

UKFH5208 «Advanced physical chemistry»

7M07103 – Chemical Engineering

Course – 1
Semester – 1
Number of credits – 5

Almaty, 2025

The educational and methodical complex of the discipline was compiled by PhD Supiyeva Zhazira

Based on the curriculum for the educational program
7M07103 – Chemical Engineering

Reviewed and recommended at the meeting of the Chair of physical chemistry, catalysis and petrochemistry
«01» **September** 2025, Protocol № 1

Head of the department _____ Aubakirov Ye.A.
(signature)

SYLLABUS
Full semester 2025-2026 academic year
Educational program "7M07103 - Chemical Engineering"

ID and name of course	Independent work of the student (IWS)	Number of credits			General number of credits	Independent work of the student under the guidance of a teacher (IWST)
		Lectures (L)	Practical classes (PC)	Lab. classes (LC)		
UKFH5208 Advanced physical chemistry	3	1.7	3.3	0	5	7

ACADEMIC INFORMATION ABOUT THE COURSE

Learning Format	Cycle, component	Lecture types	Types of practical classes	Form and platform final control
Offline	PD/UC	Informative, lecture-presentation, lecture-consultation	Solving problems and tests	Standard written, offline
Lecturer	Supiyeva Zhazira Asilbekovna, PhD., acting associate professor			
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ACADEMIC COURSE PRESENTATION

Purpose of the course	Expected Learning Outcomes (LO) *	Indicators of LO achievement (ID)
The purpose of this course is to provide master students with a comprehensive understanding of the fundamental principles and laws of thermodynamics and their application to real-world engineering systems.	1. Demonstrate understanding of fundamental thermodynamic concepts, including system classifications, thermodynamic properties, and energy interactions such as work and heat;	1.1. Correctly identifies types of thermodynamic systems and processes (closed, open, isolated);
		1.2. Explains and distinguishes between thermodynamic properties (e.g., pressure, temperature, internal energy);
		1.3. Calculates work and heat transfer in simple thermodynamic processes (e.g., isobaric, isochoric, adiabatic);
	2. Apply the First and Second Laws of Thermodynamics to analyze closed and open systems, including physical and chemical processes in engineering contexts;	2.1. Solves energy balance problems for closed and open systems using the First Law;
		2.2. Evaluates thermal efficiency of heat engines using the Second Law and Carnot principles;
		2.3. Identifies irreversibility in thermodynamic cycles and explains its effect on efficiency;
	3. Analyze and interpret thermodynamic properties of substances, using tables, equations of state, and property diagrams for ideal and real gases;	3.1. Uses thermodynamic tables and software to determine properties of pure substances;
		3.2. Applies the ideal gas law and real gas models (e.g., van der Waals) for property estimation;
		3.3. Interprets P-v, T-s, and h-s diagrams for process analysis;
	4. Perform energy and exergy analyses of thermodynamic cycles, such as Rankine, Otto, Diesel, Brayton, and refrigeration cycles, evaluating their efficiency and losses;	4.1. Calculates thermal and exergetic efficiencies of power and refrigeration cycles;
		4.2. Identifies major components of engineering thermodynamic cycles and their functions;
		4.3. Performs exergy loss analysis and suggests methods for improving system performance;

	Integration MOOC (massive open online course). In the case of integrating MOOC into the course, all students need to register for MOOC. The deadlines for passing MOOC modules must be strictly observed in accordance with the course study schedule. **ATTENTION!** The deadline for each task is indicated in the calendar (schedule) for the implementation of the content of the course, as well as in the MOOC. Failure to meet deadlines results in loss of points.

INFORMATION ABOUT TEACHING, LEARNING AND ASSESSMENT

Score-rating letter system of assessment of accounting for educational achievements

Grade	Digital equivalent points	points, % content	Assessment according to the traditional system
A	4.0	95-100	Great
A-	3.67	90-94	
B+	3.33	85-89	Fine
B	3.0	80-84	
B-	2.67	75-79	
C+	2.33	70-74	
C	2.0	65-69	Satisfactorily
C-	1.67	60-64	
D+	1.33	55-59	
D	1.0	50-54	
FX	0,5	25-49	Unsatisfactory
F	0	0-24	

Assessment Methods

Criteria-based assessment is the process of correlating actual learning outcomes with expected learning outcomes based on clearly defined criteria. Based on formative and summative assessment.

Formative assessment is a type of assessment that is carried out in the course of daily learning activities. It is the current measure of progress. Provides an operational relationship between the student and the teacher. It allows you to determine the capabilities of the student, identify difficulties, help achieve the best results, timely correct the educational process for the teacher. The performance of tasks, the activity of work in the classroom during lectures, seminars, practical exercises (discussions, quizzes, debates, round tables, laboratory work, etc.) are evaluated. Acquired knowledge and competencies are assessed.

Summative assessment - type of assessment, which is carried out upon completion of the study of the section in accordance with the program of the course. Conducted 3-4 times per semester when performing IWS. This is the assessment of mastering the expected learning outcomes in relation to the descriptors. Allows you to determine and fix the level of mastering the course for a certain period. Learning outcomes are evaluated.

Formative and summative assessment	Points % content
Activity in classes	5
Work in practical classes	20
Independent work	20
Colloquium	15
Final control (exam)	40
TOTAL	100

Calendar (schedule) for the implementation of the content of the course. Methods of teaching and learning.

A week	Topic name	Number of hours	Max. ball
	Module 1. Thermodynamic principles of closed system analysis		
1	**L 1.** Basic concepts and classification of thermodynamic systems, parameters and properties	1	
	PC 1. Energy interactions in thermodynamic processes: work, heat and internal energy	2	
2	**L 2.** Application of the first law of thermodynamics to the analysis of closed physicochemical systems	1	
	PC 2. Thermodynamic properties of substances: tabular data, diagrams and models	2	
	IWST 1. Consultation on the Implementation of **IWS №1:** **Watch following lecture notes:** Chemical Engineering Thermodynamics https://www.coursera.org/learn/chemtherm1? **Coursera open Course:** Module 1 The Nature of Thermodynamics		
3	**L 3.** Evaluation of properties of pure substances: ideal and real gases, calculation methods	1	
	PC 3. Energy Analysis of Open Thermodynamic Systems and Devices (Control Volume)	2	
4	**L 4.** Applied Analysis: Pumps, Compressors, and Heat Exchangers	1	
	PC4. Colloquium: Based on Lectures 1-3 (written and oral)	2	10
	IWST 2. Submission of IWS №1		5
5	**L 5.** The Second Law of Thermodynamics: Postulates, Consequences, and Heat Engines	1	
	PC 5. Reversible and irreversible physicochemical processes. The Carnot cycle and marginal efficiency.	2	10
	IWST 3. Consultation on the Implementation of **IWS №2:** **Watch following lecture notes:** Chemical Engineering Thermodynamics https://www.coursera.org/learn/chemtherm1? **Coursera open Course:** Module 2 Basic Concepts		
	Module 2. Flow Systems, the Second Law of Thermodynamics, and Entropy Analysis		
6	**L 6.** Entropy as a thermodynamic function of state. The entropy balance equation	1	
	PC 6. Isentropic processes in engineering devices: application and calculations	2	10
	IWST 4. Submission of IWS №2		15
7	**L 7.** Introduction to Exergy Analysis: Loss Theory and Marginal Process Efficiency	1	
	PC 7. Exergy calculation and exergy analysis of engineering thermodynamic systems	2	10
8	**L 8.** Steam cycles in thermal plants: Rankine cycle and its modifications	1	

	5. Calculate entropy changes and evaluate thermodynamic equilibrium in phase and chemically reactive systems, including combustion and mixture behavior.	5.1. Calculates entropy changes in closed and open systems for various processes;
		5.2. Analyzes combustion processes: flame temperature, composition of products, heat release;
		5.3. Evaluates phase and chemical equilibrium using thermodynamic criteria and equations;
Prerequisites	Physical Chemistry, Quantum Chemistry, Thermodynamics and Kinetics, Theory and Problems of physical chemistry	
Postrequisites	Mathematical Methods in Chemistry, Scientific Research Methodology	
Learning Resources	***Main literature:*** 1. Atkins, P., de Paula, J. Atkins' Physical Chemistry, 11th Edition, Oxford University Press, 2018. 2. Michael J. Moran Fundamentals of Engineering Thermodynamics. 9th Edition, Wiley P.156. 3. House, J.E. Fundamentals of Quantum Chemistry, 2nd Edition, Academic Press, 2004. 4. Hammes-Schiffer, S., et al. Physical Chemistry for the Biological Sciences, University Science Books, 2009. 5. Zhdanov, V.P. Elementary Physicochemical Processes on Solid Surfaces, Springer, 1991. ***Additional literature:*** 1. Journals: Journal of Physical Chemistry A/B/C, Physical Chemistry Chemical Physics (PCCP), Chemical Physics Letters, Accounts of Chemical Research. 2. McQuarrie, D.A., Simon, J.D. Physical Chemistry: A Molecular Approach, University Science Books, 1997. **Research infrastructure** 1. Lecture classes – 319 room. 2. Practical classes – 319 room. **Professional scientific databases** 1. https://en.wikipedia.org/wiki/ 2. «WEB OF SCIENCE» [site]. – URL: http://www.webofscience.com/ **Internet resources** 1. http://elibrary.kaznu.kz/en 2. open.kaznu.kz	

Academic course policy	**The academic policy of the course** is determined by the Academic Policy and the Policy of Academic Integrity of Al-Farabi Kazakh National University. Documents are available on the main page of IS Univer. **Integration of science and education.** The research work of students, undergraduates and doctoral students is a deepening of the educational process. It is organized directly at the departments, laboratories, scientific and design departments of the university, in student scientific and technical associations. Independent work of students at all levels of education is aimed at developing research skills and competencies based on obtaining new knowledge using modern research and information technologies. A research university teacher integrates the results of scientific activities into the topics of lectures and seminars (practical) classes, laboratory classes and into the tasks of the IWST, IWS, which are reflected in the syllabus and are responsible for the relevance of the topics of training sessions and assignments. **Attendance.** The deadline for each task is indicated in the calendar (schedule) for the implementation of the content of the course. Failure to meet deadlines results in loss of points. **Academic honesty.** Practical/laboratory classes, IWS develop the student's independence, critical thinking, and creativity. Plagiarism, forgery, the use of cheat sheets, cheating at all stages of completing tasks are unacceptable. Compliance with academic honesty during the period of theoretical training and at exams, in addition to the main policies, is regulated by the "Rules for the final control" , "Instructions for the final control of the autumn / spring semester of the current academic year" , "Regulations on checking students' text documents for borrowings". Documents are available on the main page of IS Univer. **Basic principles of inclusive education.** The educational environment of the university is conceived as a safe place where there is always support and equal attitude from the teacher to all students and students to each other, regardless of gender, race / ethnicity, religious beliefs, socio-economic status, physical health of the student, etc. All people need the support and friendship of peers and fellow students. For all students, progress is more about what they can do than what they can't. Diversity enhances all aspects of life. All students, especially those with disabilities, can receive counseling assistance by phone / e- mail *+7-701-391-91-56/ Zhazira.Supiyeva@kaznu.edu.kz* or via video link in Zoom *https://us04web.zoom.us/j/73603766209?pwd=tAtGLMXa2k61nURHGnrvBmPaouoQYg.1.*

	PC 8. Colloquium: Based on Lectures 4-7 (written and oral)	2	40
Midterm control 1			**100**
	Module 3. Thermodynamics of Energy, Phase, and Reactive Systems		
9	**L 9.** Gas Cycle Analysis: Otto, Diesel, and Breyton Applied to Heat Engines	1	
	PC 9. Improving cycle efficiency: regeneration, intermediate cooling, re-expansion	2	5
10	**L 10.** Thermodynamics of refrigeration machines and heat pumps	1	
	PC 10. Refrigeration Cycle Calculations and Refrigerant Selection: Thermodynamic Criteria	2	5
	IWST 5. Consultation on the Implementation of **IWS №3:** **Watch following lecture notes:** Chemical Engineering Thermodynamics https://www.coursera.org/learn/chemtherm1? **Coursera open Course:** Module 3 Phase Behavior of Pure Substances		
11	**L 11.** Chemical thermodynamics of reaction systems: mixtures, combustion, thermal effects	1	
	PC11. Colloquium: Based on Lectures 9-10 (written and oral).	2	5
12	**L 12.** Calculation of flame temperature and combustion product composition	1	
	PC 12. Practice Problems and Assessments	2	5
13	**L 13.** Thermodynamics of Phase and Chemical Equilibrium	1	
	PC 13. Practice Problems and Assessments	2	5
	IWST 6. Submission of IWS №3		30
14	**L 14.** Thermodynamics of Phase Transitions and Multi-Component Systems	1	
	PC 14. Practice Problems and Assessments	2	5
15	**L 15.** Thermodynamics of Electrochemical Systems	1	
	PC 15. Colloquium Based on Lectures 11-15 (written and oral)	2	40
	IWST 7. Consultation on Final Exam Questions		
Midterm control 2			**100**
Final control (exam)			**100**
TOTAL for course			**100**

Policy of assessment of master student's independent work. The number of IWS is 3. The assignment is uploaded to the Univer system one week before the due date. The assignments are practical tasks, the solution of which consists of several stages, each of which is evaluated. Each task is accompanied by methodical recommendations.

RUBRICATOR OF THE SUMMATIVE ASSESSMENT OF IWS №1-3

Independent work of the student №1-3 (20% of 100% MC)

Criterion	"Excellent" 15-20%	"Good" 10-15%	"Satisfactory" 5-10%	"Unsatisfactory" 0-5%
Application of the information provided in the methodological recommendations	A thorough understanding theory, equations and formulas from lecture material and recommended textbooks. The presented course of problem solving is correct.	Understanding of theory, equations and formulas from lecture material and recommended textbooks. The solution algorithm is correct, but there are inaccuracies.	Limited understanding of theory, equations and formulas from lecture material and recommended textbooks. The progress of problem solving is not presented.	Superficial understanding/lack of understanding of theory, equations and formulas from lecture material and recommended textbooks. The progress of problem solving is not presented.
Quantitative results of the task	Good at linking key concepts of lecture material. Excellent grounding of arguments with evidence from empirical research in finding references and calculating intermediate values.	Relates key concepts of the lecture material. Supports arguments with evidence from empirical research.	Limited connection of key concepts of lecture material. Limited use of empirical research evidence.	Little or no connection of key concepts of the lecture material. Little or no use of empirical research.
Completeness and literacy of the assignment	Offers competent practical recommendations, suggestions on the possible algorithm of calculation problems tasks.	Offers some competent practical recommendations, suggestions on the on the possible algorithm of calculation problems tasks.	The proposed recommendations are insubstantial, not based on careful analysis, and shallow.	Little or no practical guidance or very poor quality guidance.

Dean _____ **M.A. Duysebaeva**

Chair of the Academic Committee
on the Quality of Teaching and Learning _____ **A.U. Bektemisova**

Head of Chair _____ **E.A. Aubakirov**

Lecturer _____ **Zh.A. Supiyeva**