

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.

"01" September 2025

EDUCATIONAL AND METHODICAL COMPLEX OF THE DISCIPLINE

MHPRR5302 «Macrokinetics of chemical processes and reactor design»

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
Fall 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)		
MHPRR5302 Macrokinetics of chemical processes and reactor design	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			
Lecturer	Supiyeva Zhazira Asilbekovna, PhD., acting associate professor					
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Phone:	8 701 391 91 56					
ACADEMIC COURSE PRESENTATION						
Purpose of the course	Expected Learning Outcomes (LO) *				Indicators of LO achievement (ID)	
The purpose of this course is to provide graduate-level chemical engineering students with an in-depth understanding of the macrokinetic principles that govern chemical processes and their application to the design and optimization of chemical reactors.	1. Analyze macrokinetic models for homogeneous and heterogeneous chemical reactions, including rate laws and reaction mechanisms;				1.1. Correctly identifies and formulates rate laws based on experimental or literature data;	
					1.2. Distinguishes between elementary and complex reaction mechanisms;	
					1.3. Applies macrokinetic models to interpret reaction rate behavior under various conditions;	
	2. Design and evaluate chemical reactors (batch, CSTR, PFR, and catalytic reactors) based on kinetic data and performance requirements;				2.1. Selects appropriate reactor type based on reaction kinetics and process goals;	
					2.2. Performs reactor sizing and conversion calculations using design equations;	
					2.3. Compares reactor performance in terms of conversion, yield, and selectivity;	
	3. Apply principles of transport phenomena (mass, heat, and momentum transfer) to reactor design and operation;				3.1. Identifies limiting transport processes affecting reaction performance;	
					3.2. Calculates heat and mass transfer rates within different reactor systems;	
					3.3. Integrates transport limitations into reactor design and optimization;	
	4. Develop mathematical models for reactor systems and perform simulations to predict reactor behavior under various operating conditions;				4.1. Constructs differential equations representing mass and energy balances in reactors;	
					4.2. Uses numerical methods/software (e.g., MATLAB) to simulate reactor behavior;	
					4.3. Interprets simulation results to optimize reactor performance and troubleshoot design issues;	
	5. Assess scale-up strategies and safety considerations in industrial reactor design and operation.				5.1. Identifies key parameters influencing scale-up from lab to pilot or full-scale reactor;	

		5.2. Evaluates risks related to heat release, runaway reactions, and pressure build-up; 5.3. Proposes safety measures and control strategies in scaled-up reactor systems;
Prerequisites	Physics, mathematics, general chemistry and physical chemistry.	
Postrequisites	Chemical Thermodynamics.	
Learning Resources	Main literature: 1. Luyben, W.L. (2007). Frontmatter. In Chemical Reactor Design and Control, W.L. Luyben (Ed.). https://doi.org/10.1002/9780470134917.fmatter. 2. Rawlings, J. B., & Ekerdt, J. G. Chemical Reactor Analysis and Design Fundamentals, Nob Hill Publishing, 2002 – 607 p. 3. Nauman, E. Bruce Chemical Reactor Design, Optimization, and Scaleup (2nd Edition) Wiley, 2008. 4. Fogler, H. Scott Elements of Chemical Reaction Engineering (5th Edition) Pearson Education, 2016. 5. Introduction to Chemical Engineering Kinetics & Reactor Design - Hill & Root. Additional literature: 1. Levenspiel, O. Chemical Reaction Engineering (3rd Edition) Wiley, 1999. 2. Aris, R. Elementary Chemical Reactor Analysis Dover Publications, 2005 (reprint). Research infrastructure 1. Lecture classes – 517 room. 2. Practical classes – 517 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 <u>the Academic Policy and the Policy of Academic Integrity</u> 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 <u>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"</u>. 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=tAtGLMXa2k6InURHGnrvBmPaouoQYg.1. 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.
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INFORMATION ABOUT TEACHING, LEARNING AND ASSESSMENT

Score-rating letter system of assessment of accounting for educational achievements				Assessment Methods	
Grade	Digital equivalent points	points, % content	Assessment according to the traditional system	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.	
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	Formative and summative assessment	Points % content
C-	1.67	60-64		Activity in classes	5
D+	1.33	55-59		Work in practical classes	20
D	1.0	50-54		Independent work	20
FX	0,5	25-49	Unsatisfactory	Colloquium	15
F	0	0-24		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. Fundamentals of Macrokinetics and Reactor Types			
1	L 1. Introduction to the Macrokinetics of Chemical Processes	1	
	PC 1. Introduction to Macrokinetics and Reactor Classification	2	
2	L 2. Fundamentals of Conversion, Product Yield, and Calculation of Key Reactor Parameters	1	
	PC 2. Conversion, Yield, and Selectivity	2	
	IWS 1. Consultation on the Implementation of IWS №1: "Analysis of Kinetic Data and Determination of Reaction Order"		
3	L 3. Kinetic Equations: Reaction Order and the Law of Mass Action	1	
	PC 3. Reaction Order and the Law of Mass Action	2	
4	L 4. Stoichiometric Analysis, Influence of Concentrations, Pressure, and Phase State	1	
	PC 4. Stoichiometry, Pressure Effects, and Phase State	2	10
	Colloquium: Based on Lectures 1-3 (written and oral)		
	IWS 2. Submission of IWS №1		5
5	L 5. Isothermal Design of Chemical Reactors (Batch, CSTR, PFR)	1	
	PC 5. Isothermal Reactor Models: Batch, CSTR, PFR	2	10
	IWS 3. Consultation on the Implementation of IWS №2: "Calculation of Ideal Reactor Volumes for a Given Conversion"		
Module 2. Reactor Design and Performance under Ideal Conditions			
6	L 6. Modelling Molar Flows and Volumes in Continuous Reactors	1	
	PC 6. Molar Flows and Reactor Performance	2	10
	IWS 4. Submission of IWS №2		15
7	L 7. Collection and Analysis of Experimental Data: Methods for Evaluating Kinetics	1	
	PC 7. Experimental Kinetics: Graphical Methods and Data Fitting	2	10
8	L 8. Kinetics of Multiple Reactions: Parallel, Sequential, and Reversible Schemes	1	
	PC 8. Reactor Behavior for Multiple Reactions	2	40
	Colloquium: Based on Lectures 4-7 (written and oral)		
Midterm control 1			100
Module 3. Advanced Reactor Modelling and Experimental Kinetics			
9	L 9. Reaction Mechanisms, Chain Processes, and Biocatalysis	1	
	PC 9. Mechanisms and Catalytic Systems	2	5
10	L 10. Fundamentals of Catalysis and Heterogeneous Kinetics	1	
	PC 10. Reaction Heat Effects and Heat Balance	2	5
	IWS 5. Consultation on the Implementation of IWS №3: "Selection and Modeling of a Reactor for Parallel Reactions"		
11	L 11. Energy Analysis of Reactors: Thermal Effects and Heat Balance	1	

	PC 11. Heat Transfer in Reactors and Operating Modes Colloquium: Based on Lectures 9-10 (written and oral).	2	5
12	L 12. Heat Exchange in Reactors and Its Effect on Reaction Processes	1	
	PC 12. Experimental Methods for Kinetic Evaluation	2	5
13	L 13. Transient Processes in Chemical Reactors	1	
	PC 13. Dynamics of Complex Reaction Kinetics	2	5
	IWST 6. Submission of IWS №3		30
14	L 14. Modelling of Non-Ideal Reactors: Residence Time Distribution (RTD)	1	
	PC 14. RTD and Transient Behavior in Reactors	2	5
15	L 15. Non-Ideal Reactors and RTD Models	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. Dyusebaeva

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

