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Processes and equipment of chemical technology - 4. Mass transfer processes

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	*Normative*
Form of education	*full-time (face-to-face/distance)*
Year of training, semester	*3rd year, spring semester*
Scope of the discipline	*210 hours (36 hours of lectures; 36 hours – practical; 18 hours – laboratory; 120 hours – SRS)*
Semester control/ control measures	*Examination*
Lessons schedule	*https://rozklad.kpi.ua/* *https://ecampus.kpi.ua/*
Language of teaching	*Ukrainian*
Information about the course leader / teachers	*Lecturer: doctor of science, professor Yaroslav Mykytovych Kornienko*YNK@kpi.ua *Practical: Ph.D., senior teacher Serhii Serhiyovych Gaidai ssgaidai@gmail.com* *Laboratory: Ph.D., senior teacher Gaidai Serhiy Serhiyovych ssgaidai@gmail.com*
Placement of the course	*https://ecampus.kpi.ua/*

Program of educational discipline

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

The study of this discipline will allow students to learn the fundamental concepts of the theory of momentum transfer of single-phase and multiphase dispersed systems. It will allow you to formulate an idea about the ways of separating gas and liquid systems in the field of gravitational forces, centrifugal forces, and in the electric field. It will contribute to the understanding of the dependence of the efficiency of separation of dispersed systems and energy consumption on the implementation of this process. Understanding the essence of the efficiency of extraction from dispersions of particles smaller than 10 μm. Expand the understanding of mixing processes in liquid and bulk systems and master the methods of determining the main criteria for evaluating quality - efficiency and energy consumption - intensity.

Familiarize yourself with the basics of grinding theory and the conditions for the implementation of such processes, provided that the "Golden rule of grinding" is followed.

The subject of the academic discipline

A systematic approach to the study of momentum transfer processes in dispersed systems with different phase composition. calculations of energy consumption during the separation and mixing of heterogeneous systems, as well as mastering the basic principles of grinding materials.

Interdisciplinary connections

The discipline "Processes and equipment of chemical technology - 4. Mass transfer processes" is based on the following disciplines: processes and equipment of chemical technology - 1, 2; theoretical mechanics; theory of machines and mechanisms; machine parts; physical chemistry; mechanics of materials and structures.

The purpose of this educational discipline*there is a thorough familiarization of students with the theoretical principles of mass exchange, determination of the conditions for effective implementation of the process, assimilation of practical skills of calculations of mass exchange devices using computer technologies.*

The main tasks of the academic discipline

After mastering the discipline, students should acquire the following knowledge:

- modern approaches, methods and techniques, solving problems in the design, maintenance, modernization and waste disposal of chemical and oil refining industries, taking into account the basic principles of the theory of heat and mass transfer;

- modern approaches, methods and techniques, solving problems in the selection and preparation of raw materials, obtaining products and waste disposal of chemical and oil refining industries, taking into account the basic principles of the theory of heat and mass transfer.

In accordance with the goal, the training of bachelors requires deepening of the competences formed by students:

- using scientific and technical information, regulatory documents, and professional knowledge to solve problems in the design, maintenance, modernization and disposal of equipment of chemical and oil refining industries, taking into account the basic principles of the theory of heat and mass transfer;

- using scientific and technical information, regulatory documents, professional knowledge to independently solve problems in the design and modernization of equipment of chemical and oil refining industries, taking into account the basic principles of the theory of heat and mass transfer;

- using scientific and technical information, regulatory documents, and professional knowledge to solve problems in the selection and preparation of raw materials, obtaining products and disposal of waste from chemical and oil refining industries, taking into account the basic principles of the theory of heat and mass transfer;

- apply computer engineering methods using special software, perform computer design of chemical and oil refinery equipment, taking into account the basic principles of the theory of heat and mass transfer.

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

Prerequisites:*the ability to apply knowledge in practice when evaluating methods for calculating mass transfer processes, skills in the use of information and computer technologies, the ability to search, process and analyze from various sources, the ability to apply knowledge about the basic physico-chemical principles of technological processes of chemical engineering.*

Post-requisites:*the ability to apply knowledge for the practical solution of problems related to the provision of innovative technical solutions for the implementation of mass transfer processes and the choice of an algorithm for its implementation, the ability to use computerized calculation systems to substantiate technical decisions regarding the improvement of existing equipment to increase its energy efficiency, the ability to evaluate technical economic efficiency of systems and their components based on the application of analytical methods and analysis of analogues, the ability to make decisions regarding the choice of structural materials for the creation of innovative equipment.*

After mastering the academic discipline, students will be able to use knowledge of fundamental disciplines and mathematical apparatus to implement professionally-profiled knowledge and practical skills to solve system engineering tasks of creating effective processes and innovative equipment for their implementation.

3. Content of the academic discipline

Lecture classes

Chapter 1. Basic theories of mass transfer

Chapter 2. Mass exchange processes

Practical training

1. Calculation of the number of degrees of concentration change and methods of determining the average driving force of the mass transfer process. Calculation of the equilibrium line.

2. Calculation of mass transfer and mass transfer coefficients

3. Calculation of the number of transfer units and the height of the transfer units.

4. Calculation of the nozzle absorber.

5. Calculation of a plate absorber. Compare the energy efficiency of devices.

6. Calculation of the number of valid plates according to the kinetic curve.

7. Calculation of the minimum and valid phlegm number.

8. Calculation of a plate-shaped rectification column with cap and mesh plates. Compare their energy efficiency.

9. Calculation of liquid extractor.

10. Calculation of the extractor for the solid phase.

Laboratory classes

1. Determination of the hydraulic resistance of the nozzle absorber in different modes of movement of the liquid and gas phases.

2. Study of the desorption process.

3. Study of the rectification process.

4. Educational materials and resources

Basic literature

1.Kornienko Y. M. Processes and equipment of chemical technology 1: textbook / Y. M. Kornienko, Yu. Yu. Lukach, I. O. Mikulonok, V. L, Rakytskyi, G. L. Ryabtsev // K.: NTUU "KPI". – 2011. – Part 1. - 300 C.

2. Y. M. Kornienko Processes and equipment of chemical technology 2: Textbook / Y. M. Kornienko, Y. Yu. Lukach, I. O. Mikulonok, V. L. Rakytskyi, G. L. Ryabtsev // K.: NTUU "KPI". - 2011. - Part 2. - 416 p.

3. Tovazhnyansky L. L. Processes and devices of chemical technology / L. Tovazhnyanskyi, A. L. Gotlinska, V. O. Nechyporenko. I. S. Chernyshov // Kharkiv, NTU. – 2006. – Part 1. - 540 S.

4. Tovazhnyanskyi, L.L. Processes and devices of chemical technology / L.L. Tovazhnyanskyi, A.L. Gotlinska, V.O. Nechyporenko, I.S. Chernyshov. - Kharkiv, National Technical University. – 2006. – Part 2. - 540 S.

5. Kornienko Y. M. Increasing the efficiency of the process of obtaining granular humic-mineral fertilizers / Y. M. Kornienko, S. S. Gaidai, O. V. Martyniuk // NTUU "KPI". – 2014. – 349 p.

6. Y. M. Kornienko, The process of dehydration of composite liquid systems in a fluidized bed with the use of a mechanical dispersant / Y. M. Kornienko, D. S. Semenenko, O. V. Martyniuk. S. S. Gaidai // NTUU "KPI". - Kyiv. – 2015. – 167 p.

7. Kornienko, Y.M. The process of obtaining modified granulated humic-mineral fertilizers / Y.M. Kornienko, A.M. Lyubeka, S.S. Gaidai // KPI named after Igor Sikorsky. – Kyiv: KPI named after Igor Sikorsky. – 2017. – 210 p.

8. Kornienko Y. M. Granulation processes of mineral-humic fertilizers / Y. M. Kornienko, R. V. Sachok // Electronic edition. - 2014 - 158 p.

Additional literature

9. Nagursky O. A. Regularitiesencapsulationsubstances in a state of fluidization and their diffusion release: a monograph / O. A. Nagurskyi // Ministry of Education and Science, Youth and Sports of Ukraine, Nat. Lviv Polytechnic University. - L.: Vid-vo Lviv. polytechnics – 2012. – 188 p.

10. Nikytenko N.N. Molecular radiation theory and methods of calculating heat and mass transfer. Monograph / N.N. Nikytenko, Yu.F. Snezhkin, N.N. Sorokovaya, Yu.N. Kolchyk // NVP "Naukova Dumka Publishing House". - National Academy of Sciences of Ukraine. – 2014. – 567 p.

Information resources on the Internet

11. Ministry of Strategic Industries of Ukraine [Electronic resource]. – 2021. – Access mode:https://mspu.gov.ua.

12. Union of Chemists of Ukraine [Electronic resource]. – 2021. – Access mode: http://chemunion.org.ua/uk.

13. International congress of chemical process [Electronic resource]. – 2021. – Access mode: https://2020.chisa.cz.

14. Digital management of the construction process – developed by entrepreneurs for entrepreneurs [Electronic resource]. – 2021. – Access mode: https://www.chisa.dk.

Educational content

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

Lecture classes

Lectures are aimed at:

- *provision of modern, comprehensive in-depth knowledge of the discipline, the level of which is determined by the target attitude to each specific topic;*
- *provision of critical creative work together with the teacher in the process of work;*
- *education of students' professional qualities and development of their independent creative thinking;*
- *awareness of world trends in the development of science in the field of intensification of heat and mass exchange processes in industrial equipment;*
- *awareness of the methods of processing information resources and determining the main directions for solving specific scientific and technical problems.*

No s/p	***The name of the topic of the lecture and a list of the main questions (a list of didactic tools, references to the literature and tasks on the SRS)***	***Number hours***
1	*2*	*3*
Section 1.Basics of mass transfer theory		
1	***Topic 1.1 Introduction. Basic definitions. A state of equilibrium*** *The physical essence of mass transfer processes and basic definitions are presented. The equilibrium state of the processes is considered. The general solution of the main mass transfer equation and ways of expressing concentrations are substantiated.* *Literature [1,2,3].* *Tasks on SRS: Methods of expressing concentration for binary systems. Ternary diagrams for liquid systems. Mechanism of convective diffusion.*	***2***
2	***Topic 1.2 Diffusion mass transfer in moving media*** *The mechanism of mass transfer is considered. Fick's first law. Differential equation of molecular diffusion. Physical model of convective diffusion. Differential equation of convective diffusion. Thermodiffusion. Models of diffusion processes.* *The basic law of convective diffusion is Shchukarev's law. Generalized mathematical model of mass transfer processes. Determination of mass transfer*	***8***

	coefficient. Obtaining similarity criteria for mass transfer processes. Transformation of the basic equation of mass transfer for attachment devices. *Literature [1,2,3].* *Task on SRS: Explain how the hydrodynamic regime affects the efficiency of mass transfer. List the factors that most significantly determine the diffusion resistance of mass transfer.*	
3	***Topic 1.3 Fundamentals of calculating mass transfer devices*** *The basics of calculating the basic designs of mass transfer devices are given. Calculation of the diameter of mass exchange drugs of plate and nozzle types. Interaction of gas and liquid devices and determination of the working speed of the gas phase.* *Literature [1,2,3].* *Task on SRS: To list the criteria according to which it is most expedient to choose the constructive design of the mass transfer surface.*	***6***
4	***Topic 1.4****Mass transfer in systems with a solid phase* *Considered mass transfer in systems with a solid phase. Physical model of the process. Mathematical description of the process. The main criterion dependencies used for engineering calculations.* *Literature [1,2,3].* *Task for SRS: Explain which factors most significantly affect the intensity of mass transfer in systems with a solid phase.*	***2***
	Chapter 2. Mass exchange processes	
5	***Topic 2.1****Mass transfer during absorption* *A physical model of the absorption process is presented. Types of absorption. Kinetics of the absorption process. Material balance of the absorption process. Process workflow. Calculation of the minimum, working and optimal costs of the absorber.* *Absorption process schemes are considered. Features of absorber designs. Basics of calculating different types of absorption. Desorption. Physical model. Desorption methods.* *Literature [1,2,3].* *The task at the SRS: To substantiate the absorption schemes in cases of extraction of the target component from the gaseous medium or saturation of the liquid phase. Based on the materials of the patent review, provide modern effective absorption designs with various methods of organizing the surface of interphase contact. To justify the design features of desorption devices. To explain the principles of construction of technological sem absorption combined with desorption.*	***4***
6	***Topic 2.2****Mass transfer during adsorption* *A physical model is given. Statics and kinetics of adsorption. The Shilov equation.* *Adsorption schemes are considered. Basics of adsorber calculation. Designs of adsorbers. Schemes of the process. Chromatography. Ion exchange. Desorption.* *Literature [1,2,3,4].*	***3***

	The task at the SRS: Based on the materials of the patent review, present modern designs of adsorbers of periodic and continuous action, as well as devices using ion exchange resins.	
7	***Topic 2.3****Mass transfer during distillation and rectification* *Representation of the rectification process on tx, y and yx diagrams. Derivation of the equation for the working lines of the process and their graphical interpretation. Analysis of the operation of the rectification column. Determination of minimum and working phlegm numbers. Basic designs of rectification columns.* *Literature [1,2,3,4].* *Task on SRS: Explain the expediency of using periodic and continuous rectification. Indicate advantages and disadvantages. According to the review of patents, present modern designs of rectification columns with various types of mass transfer devices.*	***7***
8	***Topic 2.4****Mass transfer during extraction* *A physical model of the extraction process from a solid body is given. Ways of carrying out the process. Field of application. Basics of calculating extractors. Grapho-analytic determination of the number of extractors. Constructions of extractors.* *The definition of liquid extraction is given. Equilibrium in ternary systems. Methods of liquid extraction. Grapho-analytic determination of the number of extractors. Basics of calculation of liquid extractors.* *Literature [1,2,3,4].* *The task at the SRS: Based on the results of the patent review, provide modern designs of devices for liquid extraction. To present the basic modern designs of liquid extractors based on the results of a review of patents of advanced foreign countries.*	***4***
	In total	***36***

Practical training

Students should be helped to acquire the ability to apply theoretical knowledge when calculating equipment for carrying out mass transfer processes.

The main tasks of the cycle of practical classes:

–to help students systematize and deepen knowledge of a theoretical nature in the field of heat and mass transfer in dynamic dispersed systems;

–to help students learn the methodology of determining the limiting factors of mass transfer processes in dynamic systems in the presence of a phase transition;

–form criteria for evaluating the efficiency of transfer processes and be able to determine the level of specific energy consumption.

No s/p	***The name of the subject of the practical session and a list of the main questions (list of didactic support, references to the literature and tasks on the SRS)***	***Number hours***
1	*2*	*3*
1	***Practical lesson No. 1.***	***2***

	Calculation of the number of degrees of concentration change and methods of determining the average driving force of the mass transfer process. Calculation of the equilibrium line. *To master the method of determining the concentrations of the component in mass, mole fractions, relative mole and relative mass fractions, as well as the expression of concentration through partial pressure. Based on Henry's law, construct equilibrium curves for different values of temperature and pressure during absorption. To find out the concept of the working line of the absorption process and to acquire the skills of building the working line of the absorption process. Master the technique of determining the driving force of the process during absorption in the liquid and gas phases. To master the method of determining the average driving force of the process for the case when the equilibrium line is straight and when the equilibrium line is curved.* *Literature [1,2,3,11].*	
2	***Practical lesson No. 2.*** ***Calculation of mass transfer and mass transfer coefficients.*** *Consider a model of the transfer process in one phase. The physical essence of molecular and convective diffusion. The physical essence of the mass transfer coefficient. The equation at the interface of phases. Use of methods for calculating mass transfer coefficients in gas and liquid phases. Calculation of mass transfer coefficients in the presence of a chemical reaction. Conditions for calculating the mass transfer coefficient. Calculation of the mass transfer coefficient for the case when the driving force of the process is expressed through the difference in concentrations in the liquid or gas phases during absorption. Calculation of the mass transfer coefficient when the driving force of the process is expressed through the difference in partial pressures.* *Literature [1,2,3,11].*	**4**
3	***Practical lesson No. 3.*** ***Calculation of the number of transfer units and the height of the transfer units.*** *For the process of water absorption of HCl, NH3 and CO2 from a mixture with air, determine the number of transfer units using analytical and graphical methods for attachment devices. To analyze the results of analytical and graphical calculation, as well as to formulate proposals for the reduction of CHOP and VOP and confirm it with calculations.* *Literature [1,2,3,11].*	**4**
4	***Practical lesson No. 4.*** ***Calculation of the attachment absorber.*** *For the specific conditions of the absorption process during absorption for the three gases HCl, NH3 and CO2, justify the choice of nozzle and calculate the upstream absorber. Carry out the calculation for the case of absorption with partial recirculation in the liquid phase. Calculate the power consumption for passing the gas phase through the absorber and pumping the liquid phase. Calculate the cost of the nozzle and the cost of electricity to implement the process.* *Literature [1,2,3,11].*	**4**

5	***Practical lesson No. 5.*** ***Calculation of a plate absorber. Compare the energy efficiency of devices.*** *For the conditions of practical exercise No. 4, calculate the absorber with cap and mesh plates. Determine the conditions under which the mass transfer coefficients acquire maximum values in the gas and liquid phases. Determine energy costs in hryvnia equivalent and compare with similar costs for a plug-in absorber. Separately compare the cost of nozzles and plates. Estimate the approximate costs per 1 kg of absorbed substance.* *Literature [1,2,3,11].*	*5*
6	***Practical lesson No. 6.*** ***Calculation of the number of valid plates according to the kinetic curve.*** *To find out the methods of constructing the equilibrium lines and the working line of the continuous rectification process in the U-X diagram. Understand the essence of the kinetic curve of the mass transfer process. For the case of separation of the binary ethanol-water mixture, calculate and plot the kinetic curve on the U-X diagram. Calculate the number of valid plates and compare with the values obtained when calculating the theoretical plates.* *Literature [1,2,3,11].*	*5*
7	***Practical lesson No. 7.*** ***Calculation of the minimum and valid phlegm number.*** *To understand the expediency of returning part of the distillate to the irrigation of the upper part of the rectification column (phlegm). Carry out a calculation for a specific rectification process and determine how the value of the phlegm number affects the number of theoretical plates for continuous and periodic rectification. Calculate the minimum and theoretical reflux number for the ethanol-water or methanol-water process. Determine the influence of the phlegm number on the energy efficiency of the process.* *Literature [1,2,3,11].*	*2*
8	***Practical lesson No. 8.*** ***Calculation of a plate-type rectification column with cap and mesh plates. Compare their energy efficiency.*** *Make a selection of cap and mesh plates. Compare energy costs and propose technical solutions to increase process efficiency.* *Literature [1,2,3,11].*	*5*
9	***Practical lesson No. 9.*** ***Calculation of liquid extractor.*** *Determination of the selective ability of the solvent and construction of the equilibrium line in the ternary diagram. Calculation of the number of extractors by grapho-analytical method. Calculate the nozzle extractor. Determine energy consumption.* *Literature [1,2,3,11].*	*3*
10	***Practical lesson No. 10.*** ***Calculation of the extractor for the solid phase.***	*2*

	Determination of the solid extraction zone in the ternary diagram. Calculation of the number of extractors by the grapho-analytical method during counterflow. Calculation of a fixed bed extractor. *Literature [1,2,3,11].*	
	Together	***36***

Laboratory classes

Students should be helped to acquire the ability to apply theoretical knowledge in the study of equipment for carrying out mass transfer processes.

The main tasks of the cycle of laboratory work consist in a thorough study of the features and mechanism of mass transfer processes.

No s/p	*The name of the topic of the laboratory session and the list of main questions (list of didactic support, references to the literature and tasks on the SRS)*	*Number hours*
1	2	3
1	***Laboratory session No. 1.*** ***Determination of the hydraulic resistance of the attachment absorber in different modes of movement of the liquid and gas phase.*** *Get an idea of the implementation of mass transfer processes during absorption. Determine the hydraulic resistance of the dry column. Determine the hydraulic resistance at a constant flow of liquid, as well as at an increase in flow of the gas phase and achieve the phase inversion mode.* *Literature [1,2,3,11]. 3*	**6**
2	***Laboratory session No. 2.*** ***Study of the desorption process.*** *Investigate the process of desorption of carbon dioxide in an air stream at different flow rates of the liquid phase and constant flow rates of the gas phase. Repeat the study at the minimum irrigation density of the nozzle surface, but at different flow rates of the liquid phase.* *Literature [1,2,3,11].*	**6**
3	***Laboratory session No. 3.*** ***Study of the rectification process.*** *Determine the quantitative and qualitative parameters of the distillate at different values of the phlegm number.* *Literature [1,2,3,11].*	**6**
	Together	**1**

6. Independent work of the student

The purpose of independent work consists in the in-depth study of methods, methods and designs of equipment for carrying out mass transfer processes by familiarization with domestic and foreign patents on the specified topics. The results of SRS are entered into the design album (SRS report).

No s/p	*The name of the topic submitted for independent processing*	*Number hours*
1	2	3
	Chapter 1. Fundamentals of mass transfer theory	
1	***Topic 1.1 Introduction. Basic definitions. A state of equilibrium*** *Determine the most significant parameters that affect the state of equilibrium.* *Literature: [Literature [1,2,3].*	**4**
2	***Topic 1.2 Diffusion mass transfer in moving media*** *Familiarize yourself with methods of reducing diffusion resistance during molecular diffusion.* *Literature: [Literature [1,2,3].*	**8**

3	***Topic 1.3 Fundamentals of calculating mass transfer devices.*** *Familiarize yourself with the method of calculating plate-type rectification devices using the "plate-to-plate" method* *Literature: [Literature [1,2,3].*	***14***
	Chapter 2. Mass exchange processes	
4	***Topic 2.1. Mass transfer during absorption.*** *According to the results of the patent review, indicate one design of absorbers depending on the form of formation of interphase contact: surface, spraying, film, nozzle and plate.* *Literature: [6, 7, 8].*	***16***
5	***Topic 2.2 Mass transfer during adsorption*** *According to the materials of the patent review, provide the most effective designs of adsorbers with a fixed and a moving sorbent layer.* *Literature: [6, 7, 8].*	***14***
6	***Topic 2.3. Mass transfer during distillation and rectification.*** *According to the materials of the patent review, the most effective designs of rectification columns are given: packed, plate-type (three types of plates) and rotary-film apparatus.* *Literature: [6, 7, 8].*	***11***
7	***Topic 2.4. Mass transfer during extraction.*** *Based on the results of the patent review, list three types of designs of liquid extractors.* *Literature: [6, 7, 8].*	***7***
8	***Preparation for modular control work***	***6***
9	***Performing calculation work***	***10***
10	***Preparation for the exam***	***30***
	Together	***120***

Policy and control

Policy of academic discipline (educational component)

The system of requirements for the student:

–attending lectures, practical and laboratory classes is a mandatory component of studying the discipline;

–at lectures, the teacher uses his own presentation material, uses Google Drive to teach the materials of the current lecture, additional resources, practical and laboratory work, etc., the teacher opens access to a certain directory for downloading methodical materials in electronic form;

–during lectures, it is not desirable to distract the teacher from teaching the material, all questions, clarifications, etc., are asked by students at the end of the lecture in the time allotted for this purpose;

–laboratory work is carried out in two stages - the first stage: students confirm their necessary preparation and conduct laboratory work; second stage: protection of laboratory work. Points for laboratory work are credited only if the report is available;

–modular control work is written in lectures without the use of aids (mobile phone, tablet, etc.). The result is sent in a file to the corresponding Google Drive directory;

–incentive points are awarded for active participation in lectures, participation in faculty and university olympiads in academic disciplines, in work competitions, preparation of reviews of scientific works; presentations on one of the topics of the SRS discipline, etc. The number of incentive points is no more than 10.

Teaching methods

When teaching an educational discipline, the use of such educational technologies as problem-based lectures, work in small groups, etc. is provided for the activation of the educational process.

Problem lectures*are aimed at the development of students' logical thinking and are characterized by the fact that the range of questions of the topic is limited to two or three key points, the students' attention is concentrated on the material that was not reflected in the textbooks, the experience of foreign educational institutions is used with the distribution of printed material to students during the lecture and the selection of the main conclusions on the issues under consideration. During lectures, students are given questions for independent reflection, but the lecturer answers them himself, without waiting for the students' answers. The system of questions during the lecture plays an activating role, forces students to concentrate and start thinking actively in search of the right answer.*

Mini-lectures*involve the presentation of educational material in a short period of time and are characterized by a significant capacity, complexity of logical constructions, images, proofs and generalizations. Mini-lectures are held, as a rule, as part of a research class.*

Case method*(method of analysis of specific situations) makes it possible to bring the learning process closer to the real practical activity of specialists and provides consideration of production, management and other situations, complex conflict cases, problem situations, incidents in the process of learning educational material.*

Tools and software*, the use of which provides for the educational discipline "Processes and equipment of chemical technology - 4. Mass transfer processes".*

2. 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	Lectur es	Practical	Lab. do	SRS	MKR	RR	Semester control
7	7	210	36	36	18	120	1	1	exam

The student's rating in the discipline consists of the points he receives for:

–performance of practical tasks (36 hours)

–performance of laboratory work (18 hours)

–execution of a modular inspection

–performance of calculation work

System of rating (weighted) points and evaluation criteria

Practical work

Performance of practical work is evaluated:

- "excellent" - a complete answer, on time, the task was completed during the lesson (at least 90% of the required information) - 2 points;

- "good" - a sufficiently complete answer, on time, the task was completed during the lesson (at least 75% of the required information) - 0.75 points;

- "satisfactory" - incomplete answer, untimely, after class, completed task (at least 60% of the required information) - 0.6 points;

- "unsatisfactory" - the answer does not meet the requirements for "satisfactory" - 0 points.

Laboratory work

- "excellent" - a complete answer, on time, the task was completed during the lesson (at least 90% of the required information) - 3 points;

- "good" - a sufficiently complete answer, on time, the task was completed during the lesson (at least 75% of the required information) - 1 point;

- "satisfactory" - incomplete answer, untimely, after class, completed task (at least 60% of the required information) - 0.5 points;

- "unsatisfactory" - the answer does not meet the requirements for "satisfactory" - 0 points.

Calculation work

- creative work - 8 points;

- the work was completed with minor defects - 7-6 points;

- the work was completed with certain errors - 5-4 points;

- the work is not credited (the task is not completed or there are gross errors) - 0 points.

For each week of delay in submitting the calculation work for verification, a penalty of 1 point is charged (no more than -5 points in total).

Modular control work

- "excellent" - complete answer (at least 90% of the required information) - 6 points;

- "good" - a sufficiently complete answer (at least 75% of the required information), or a complete answer with minor inaccuracies - 5-4 points;

- "satisfactory" - an incomplete answer (at least 60% of the required information) and minor errors - 3 points;

- "unsatisfactory" - the answer does not meet the requirements for "satisfactory" - 0 points.

Incentive points

- for active work at lectures - 1-3 points

Intersessional certification

According to the results of work for the first 7 weeks, the maximum possible number of points is 20 points. At the first certification (8th week), the student receives "certified" if his current rating is at least 10 points.

According to the results of 13 weeks of training, the maximum possible number of points is 32 points. At the second certification (week 14), the student receives "certified" if his current rating is not less than 16 points.

Thus, the rating semester scale from the credit module is:

R = 2 rpractical + 5 rlaboratory + 1 rPP + 2 rMKR = 2 10 + 5 3 + 1 9 + 2 8 = 60 points

Examination

A condition for a student's admission to the exam is the enrollment of all practical and laboratory work, calculation work and a starting rating of at least 26 points.

At the exam, students perform written work (40 points).

The exam ticket contains four questions. The first, second and third are theoretical, the fourth is the construction of equipment based on the materials of the student's patent examination, therefore the maximum number of points is distributed as follows: question 1 - 14 points, question 2 - 8 points, question 3 - 8 points, question 4 - 10 points .

The system for evaluating answers to questions

- "excellent" - complete answer, at least 90% of the required information (complete, error-free solution of the task), respectively:

And - 14-12; II – 8-6; III – 8-6; IV – 10-8.

- "good", sufficiently complete answer, at least 75% of the required information or minor inaccuracies (complete solution of tasks with minor inaccuracies), respectively: I - 11-9; II – 5-3; III – 5-3; IV – 7-5.

- "satisfactory", incomplete answer, at least 60% of the required information and some errors (the task was completed with certain shortcomings), respectively: I - 8-6; II – 2-1; III – 2-1; IV – 4-2.

- "unsatisfactory" answer does not meet the requirements for "satisfactory" - 0 points

*The sum of starting points and points for the examination control work is transferred to the examination grade in accordance with*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*

7. Additional information on the discipline (educational component)

The list of theoretical questions submitted for semester control is given in Appendix 1

Tasks for calculation work are given in Appendix 2

Working program of the academic discipline (syllabus):

Folded*prof.., Doctor of Technical Sciences, Y. M. Kornienko*

Approved*by the Department of the Academy of Medical Sciences (protocol No. 20 dated June 21, 2022)*

Agreed*Methodical commission of the faculty[1](protocol No. 10 dated 24.06.2022)*

[1]Methodical council of the university - for general university disciplines.

Appendix 1

LIST

theoretical questions that are submitted for semester control

from the discipline "Processes and equipment of chemical technology - 4. Mass transfer processes"

for the specialty

133 Industrial engineering

educational program

Computer-integrated technologies of chemical engineering equipment design

Modular control work #1 is completed after studying chapter 1.

1. *Mass transfer processes. Mass transfer mechanism.*
2. *Material balance of mass exchange. Derivation of the equation of the working line of the process in mass transfer devices.*
3. *A state of equilibrium. Phase rule.*
4. *Calculation of the average driving force of the process when the equilibrium line is straight.*
5. *Convective diffusion. Shchukarev's law.*
6. *Molecular diffusion. Derivation of the differential equation of molecular diffusion.*
7. *Determination of the average driving force of the process for the case when the equilibrium line is curved.*
8. *Derivation of similarity criteria for mass transfer processes.*
9. *The physical essence of convective diffusion. Derivation of the differential equation of convective diffusion.*
10. *Mass transfer coefficients. Derivation of the equation for determining the mass transfer coefficient.*
11. *Determination of the number of transfer units for the case when the equilibrium line is straight.*
12. *Physical model of molecular diffusion. Fick's first law.*
13. *Derivation of the differential equation of molecular diffusion.*
14. *Transformation of the basic mass transfer equation for packed columns.*
15. *Number of transfer units. The height of the transfer unit.*
16. *A state of equilibrium. Phase rule. Henry's Law.*
17. *Physical model of the mass transfer process. Derivation of the differential equation of convective diffusion.*
18. *Determination of the number of theoretical plates. Degree of concentration. Its definition.*
19. *The equation at the interface of phases.*
20. *Turbulent diffusion. Commentary on the turbulent diffusion equation.*
21. *Calculation of the number of valid plates in mass transfer devices (Calculation of mass transfer devices by kinetic curves).*
22. *General solution of the basic mass transfer equation.*
23. *Derivation of the equation of the working mass transfer line.*
24. *Transformation of the basic mass transfer equation for packed columns.*
25. *Number of transfer units. The height of the transfer units.*
26. *Equations at the interface of media.*
27. *Determination of the concentration of a binary mixture in a gas medium due to the partial pressure of the components.*
28. *Similarity in mass transfer processes. Derivation of similarity criteria.*
29. *A state of equilibrium. Phase rule. Effect of temperature and pressure on the state of equilibrium.*
30. *A physical model of the interaction of liquid and gaseous phases in a mass transfer device. The procedure for calculating such devices.*
31. *Physical model of mass transfer processes in packed and plate columns. Calculation of the number of valid plates in the mass transfer apparatus according to kinetic curves.*
32. *Material balance of mass exchange processes. Derivation of the equation of the working line of the process.*

Modular control work #2 is completed after studying chapter 2.

1. *Physical model of the absorption process. Physical and chemical absorption, material balance of the absorption process.*
2. *Physical model of the rectification process. Derivation of the working line equation for the lower part of the distillation column.*
3. *The structure of the absorber with failed plates.*
4. *Determination of the minimum costs of the absorber.*
5. *Physical model of the rectification process, phlegm number.*
6. *Derivation of the working line equation for the lower part of the distillation column.*
7. *Design of a film absorber.*
8. *Distillation. The physical essence of the process.*
9. *Fractional distillation. Calculation of simple distillation.*
10. *Physical model of the absorption process. Physical and chemical absorption.*
11. *Factors that significantly affect the absorption process. Non-isothermal absorption. Calculation of the absorber temperature.*
12. *Plate-type rectification column (two types of plates).*
13. *Determination of the minimum costs of the absorber.*
14. *The first laws of Konovalov and Vrevskyi.*
15. *Design of a film absorber.*
16. *Ideal Mixture PX Charts; YX; tX,Y.*
17. *Absorption. material balance equation. Output of the working line of the process.*
18. *The design of a plate absorber, in particular with failed plates.*
19. *The design of the rectification column of the packing type.*
20. *Konovalov's second law, Vrevskii's second law.*
21. *Azeotropic point. R-X diagrams; t – X, Y; Y is X.*
22. *Non-isothermal absorption. Determination of the temperature of the absorber. Construction of a real equilibrium line.*
23. *Physical model of the absorption process. Calculation of the minimum and actual costs of the phase (absorber) during absorption.*
24. *The design of the film-type absorber.*
25. *Physical model of the rectification process. Derivation of the equation of the working line for the upper part of the column.*
26. *Attachment absorber.*
27. *Physical model of the distillation process. Ideal liquids. Liquids that do not mix with each other. Determination of the boiling point of these liquids.*
28. *Rectification column with cap plates.*
29. *Physical model of the rectification process. Derivation of the working line equation for the lower part of the distillation column.*
30. *Physical model of the process of extraction from a solid body.*
31. *What factors most significantly affect the efficiency of the extraction process from a solid body?*
32. *Methods of extraction from a solid body.*
33. *Explain the ternary diagram to represent the extraction process in a solid. Determine the area of extraction from a solid body.*
34. *Grapho-analytical method. Determination of the number of extractors from a solid body.*
35. *Give typical designs of batch extractors for extraction from a solid body.*

36. *Give typical designs of continuous extractors for extraction from a solid body.*
37. *Give a scheme of multi-stage extraction from a solid body and explain the principle of its operation.*
38. *Explain the physical essence of liquid extraction.*
39. *Equilibrium in the ternary diagram. Determine the extraction area.*
40. *State the requirements for the solvent (extractant). How is the mixing point of the starting mixture and the solvent in the ternary diagram.*
41. *How is the selectivity of the solvent determined?*
42. *How to determine the content of initial components in the extract and raffinate.*
43. *Methods of liquid extraction.*
44. *The method of graph-analytical calculation of the number of extractors of periodic action.*
45. *Give typical designs of periodic liquid extractors.*
46. *Give typical designs of liquid extractors of continuous action.*
47. *Physical model of the adsorption process.*
48. *Basic requirements for the adsorbent.*
49. *Explain the kinetics of the adsorption process. Time of action of the adsorbent protective layer. Saturation state.*
50. *Explain the Shilov equation for adsorption.*
51. *Desorption. Methods of adsorbent regeneration.*
52. *Explain the physical model of chromatography.*
53. *Give diagrams of the adsorption process.*
54. *Explain the physical essence of ion exchange. Anions and cations.*
55. *Designs of periodic action adsorbers.*
56. *Designs of continuous action adsorbers.*

Appendix 2

Task

for calculation works in the discipline "Processes and equipment of chemical technologies - 4. Mass transfer processes"

Calculate the absorber of the continuous action nozzle type for the absorption of the target component (SO_2, NH_3, CO_2, HCl) from the air mixture with a pressure of Pa [MPa]. The volumetric flow rate of the gas mixture at the entrance to the absorber is VGp [m3/s] (under normal conditions). Water with a temperature of t [oC] is used as an absorber. The mass fraction of the target component at the entrance to the column is aA.G.n [kgA/kgA+B], at the exit – aA.G.k [kgA/kgA+B]. The initial mass fraction of the target component in the absorber is aA.L.п [kgA/kgA+C].

Version	Target component	aG_p, kgA/kgA+B	aG_{to}, kgA/kgA+B	aL_p, kgA/kgA+C	VG_p, m3/s	t atWITH	P, MPa	Nozzle type
1	SO2	0.12	0.010	0.0001	2.0	18	0.1	Rasheh ceramic rings are a regular nozzle
2	SO2	0.08	0.020	0.0010	2.5	20	0.1	Rasheh steel rings are a regular nozzle
3	SO2	0.15	0.050	0.0030	1.5	20	0.1	Berl's ceramic saddles
4	SO2	0.20	0.060	0.0050	1.8	15	0.1	Rasheh ceramic rings
5	NH3	0.15	0.035	0.0150	1.5	17	0.1	Pall ceramic rings - an irregular nozzle
6	NH3	0.16	0.025	0.0020	3.0	25	0.1	Pall steel rings - irregular nozzle
7	NH3	0.08	0.030	0.0040	2.0	15	0.1	Ceramic saddles "Intalox"
8	NH3	0.10	0.030	0.0050	1.5	20	0.1	Wooden chord nozzle
9	NH3	0.15	0.050	0.0030	1.0	18	0.1	Pall's steel rings
10	NH3	0.20	0.080	0.0100	1.8	20	0.1	Pall ceramic rings
11	CO2	0.07	0.010	0.0003	2.5	18	0.1	Berl's ceramic saddles
12	CO2	0.09	0.015	0.0001	2.2	15	0.1	Ceramic saddles "Intaloks" - irregular nozzle
thirteen	CO2	0.12	0.020	0.0010	1.8	20	0.1	Rasheh ceramic rings
14	CO2	0.15	0.030	0.0020	2.8	25	0.1	Berl's ceramic saddles
15	CO2	0.20	0.040	0.0035	2.5	18	0.1	Rasheg's steel rings
16	CO2	0.25	0.040	0.0030	1.5	20	0.1	Wooden chord nozzle
17	HCl	0.11	0.020	0.0045	2.0	17	0.1	Rasheh steel rings are a regular nozzle
18	HCl	0.19	0.016	0.0020	2.5	25	0.1	Rasheh steel rings are a regular nozzle
19	HCl	0.15	0.020	0.0040	2.5	20	0.1	Rasheh ceramic rings are a regular nozzle
20	HCl	0.20	0.040	0.0080	1.5	20	0.1	Ceramic saddles "Intalox"
21	HCl	0.25	0.040	0.010	2.0	15	0.1	Berl's ceramic saddles
22	HCl	0.08	0.010	0.0010	1.8	20	0.1	Pall's steel rings

* Note

In order to achieve better energy efficiency indicators, it is advisable to choose the geometric dimensions of the nozzle within the limits of the specified type