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

Department of machines and devices of chemical and oil refining industries

SIMULATION OF SYNTHESIS AND SEPARATION PROCESSES

Working program of the academic discipline (Syllabus)

Details of the academic discipline	
Level of higher education	***Second (master's)***
Branch of knowledge	*13 Mechanical engineering*
Specialty	*133 Industrial engineering*
Educational program	*Engineering and computer-integrated design technologies of innovative industry equipment*
Discipline status	*Selective*
Form of education	*full-time (day/distance/mixed)*
Year of training, semester	*1st year, spring semester, LN-31mp*
Scope of the discipline	*7.5 ECTS credits, 225 hours*
Semester control/ control measures	*Examination/current control*
Lessons schedule	*4 hours per week (2 hours of lectures, 2 hours of practice)*
Language of teaching	*Ukrainian*
Information about head of the course / teachers	Lecturer:*associate professor, Ph.D. Serhii Valeriyovych Gulienko, +380504488173,sergiiguliienko@gmail.com* *Ph.D. Husarova Olena Vitalyivna, +380663120701,sunflowers@i.ua* Practical / Seminar:*Ph.D. Serhii Valeriyovych Gulienko, +380504488173,sergiiguliienko@gmail.com* *Ph.D. Husarova Olena Vitalyivna, +380663120701,sunflowers@i.ua* Laboratory:not provided for in the curriculum
Placement of the course	https://classroom.google.com/c/MTQ1NjE4NTY1ODk4?cjc=qv4qt4b https://classroom.google.com/c/NTg3NDc1MDc1NDMw?cjc=mlxngss

Program of educational discipline

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

Thanks to synthesis processes, one of the main problems of modern times has been solved - a raw material base has been created for the production of polymers, resins, fertilizers, paints, varnishes, explosives, biomaterials, etc. Ensuring the reliable functioning of high-pressure equipment requires fundamental engineering knowledge and modeling methods. Since natural raw materials and synthesis products contain impurities, separation processes are important. Membrane separation processes are among the most effective and common separation processes. When designing equipment for the implementation of such technological processes, there is process modeling, which allows you to significantly reduce operational and capital costs.

The basis of the educational component "Synthesis and Separation Process Modeling" is the study of their physical foundations and the determination of conditions for their rational implementation through the creation of appropriate equipment. A decisive role is played by physical and mathematical modeling of processes, which allows determining the conditions for the transition from laboratory and theoretical research to the development of industrial equipment.

The purpose of studying the educational component "Synthesis and Separation Process Modeling" is to provide future masters with knowledge of the fundamental laws underlying the main processes of synthesis and separation related to the chemical industry, their application to the theoretical analysis of specific processes, as well as the calculation and design of equipment for their implementation.

A significant amount of the educational component is read using materials that are a summary of research and design works performed by the Department of Machines and Apparatus of Chemical and Oil Refining Industries in cooperation with leading enterprises and presented in monographs, reports, training manuals and periodicals.

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

- Perform engineering calculations to solve complex problems and practical problems in synthesis and separation equipment

- Relying on the methods of mathematical modeling and using computer technologies, CAD systems and other application programs to solve problems related to synthesis and separation

In accordance with the goal, master's training in this specialty requires strengthening the competencies formed by students:

- Ability to create, improve and apply quantitative mathematical, scientific and technical methods and computer software tools to solve engineering problems related to synthesis and separation

- Ability to perform mathematical modeling when solving problems related to synthesis and separation

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 "Synthesis and Separation Process Modeling" is an optional discipline.

The requirements for starting studies include basic knowledge acquired during the first semester of master's training, in particular, knowledge of the disciplines: "Constructive design of equipment", "Engineering of innovative technologies and equipment".

The study of the discipline will be useful when learning the material of such disciplines as "Practice", "Execution of a master's thesis", and will also contribute to better learning of the materials of optional disciplines, such as "Processes and equipment for the synthesis and processing of high molecular compounds", "Reliability, durability of equipment and the use of the latest cavitation technologies".

3. Content of the academic discipline

Chapter 1. Modeling of synthesis processes

Topic 1.1. Synthesis equipment in ammonia production.

Topic 1.2. Synthesis equipment in the production of methyl alcohol.

Topic 1.3. Synthesis equipment in the production of urea (urea).

Chapter 2. Modeling of separation processes

Topic 2.1. General characteristics of separation processes

Topic 2.2 Modeling of baromembrane processes

Topic 2.3 Modeling of diffusion membrane processes

Topic 2.4 Modeling of thermomembrane processes

Topic 2.5 Modeling of electromembrane processes

4. Educational materials and resources

Basic literature:

1. *Technology of bound nitrogen: Textbook / Tovazhnyanskyi L. L., Loboyko O. Ya. et al. Kharkiv: NTU "KhPI", 2007. - 536 p.*
2. *Modeling of membrane separation processes [Electronic resource]: study guide for students of specialty 133 "Industrial mechanical engineering", specialization "Engineering, computer modeling and equipment design of chemical and oil refining industries" / KPI named after Igor Sikorskyi; structure. S. V. Gulienko. – Electronic text data (1 file: 3.25 MB). – Kyiv: KPI named after Igor Sikorskyi, 2017. – 166 p. – Title from the screen.*
3. *Modeling of membrane separation processes. Workshop on educational discipline [Electronic resource]: study guide for students of specialty 133 "Industrial mechanical engineering", specialization "Engineering, computer modeling and equipment design of chemical and oil refining industries" / KPI named after Igor Sikorskyi; structure. S. V. Gulienko. – Electronic text data (1 file: 2.27 MB). – Kyiv: KPI named after Igor Sikorskyi, 2018. – 104 p. – Title from the screen.*
4. *Technology of bound nitrogen: technology and calculation algorithms for production of ammonia and methanol. [Electronic resource]: education. manual for students specialty 161 "Chemical technologies and engineering", specialization "Chemical technologies of inorganic substances and water treatment" / A.L. Terminal; KPI named after Igor Sikorsky. – Electronic text data (1 file: 5.55 MB). – Kyiv: KPI named after Igor Sikorskyi, 2021. – 211 p.https://ela.kpi.ua/bitstream/123456789/42796/1/Amiak_metanol.pdf*

Additional literature:

5. *Andreev I.A., Zubrii O.G. High pressure devices. - K.: IZMN, 2000. - 178 p.*
6. *https://ua.waykun.com/articles/vlastivosti-amiaku-shhilnist-teploemnist.php*
7. *Hryn S. O. Historical aspects of the creation of industrial synthesis of ammonia / S. O. Hryn, P. V. Kuznetsov // Vestnik Nats. technical "Khpy" University: Sat. science tr. Subject. issue : History of science and technology. – Kharkiv: NTU "Khpy". - 2009. - No. 29. - P. 36-42.*
8. *Ammonia technology: education. manual / M. A. Yankovskyi, I. M. Demydenko, B. I. Melnikov, O. Ya. Loboyko, H. M. Korona; UDHTU. — Dnipropetrovsk: UDHTU; Horlivka: Concern Styrol, 2004. — 293 p.*
9. *Chinchen, GC, Mansfield, K., and Spencer, MS The methanol synthesis: how does it work // CHEMTECH. United States: N. p.: - No. 20:11. - 1990. - pp. 692-699.*
10. *Calculation methods in the technology of inorganic production (part I. Bound nitrogen): Textbook / O.Ya. Loboyko, L.L. Tovazhnyansky, I.O. Slabun. etc. // Edited by O. Ya. Loboyko and L. L. Tovazhnyanskyi. – 3rd ed., add. and processing. - Kh.: NTU "KhPI", 2001. - 511 p.*
11. *Smolyankin O.O., Fedik L.Yu. Analysis of the technological process of obtaining urea as a control object //Promising technologies and devices. - No. 21. – 2022. – P. 119-124. DOI:https://doi.org/10.36910/10.36910/6775-2313-5352-2022-21-18*
12. *Catalysts in the technology of inorganic substances: a monograph / L. L. Tovazhnyanskyi, O. Ya. Loboyko, A. M. Butenko, G. I. Gryn, I. O. Slabun, M. V. Koshovets, A. S. Savenkov, V I. Toshinskyi; ed.: L. L. Tovazhnyanskyi, O. Ya. Loboyko; NTU "Khpi". — Kharkiv: Textbook of NTU "KhPI", 2013. — 220 p*
13. *Voloshyn M.D. Technology of inorganic substances. Part 3. Mineral fertilizers: study guide / M. D. Voloshyn, Y. M. Chernenko, A. V. Ivanchenko, M. A. Oliinyk. — Dniprodzerzhynsk: DDTU, 2016. — 354 p. ISBN 978-966-175-130-8*
14. *Mulder, M. (1996). Basic principles of membrane technology (2nd ed.). Springer.*
15. *Baker RW Membrane technology and applications. – 2nd ed. ¬Chichester: John Wiley & Sons, 2004. – 2004.*

16. *Porter M. Handbook of industrial membrane technology. - Westwood, New Jersey: Noyes publications. - 619 p.*
17. *Huliienko SV, Korniyenko YM, Muzyka SM, Holubka K. (2022). Simulation of reverse osmosis process: Novel approaches and development trends. Journal of Engineering Sciences, Vol. 9(2), pp. F6-F36, doi: 10.21272/jes.2022.9(2).f2*
18. *Huliienko SV, Korniienko YM, Gatilov KO (2020). Modern trends in the mathematical simulation of pressure-driven membrane processes. Journal of Engineering Sciences, Vol. 7(1), pp. F1–F21, doi: 10.21272/jes.2020.7(1).f1*
19. *https://www.sciencedirect.com/journal/chemical-engineering-and-processing-process-intensification*
20. *https://www.sciencedirect.com/journal/chemical-engineering-research-and-design*
21. *https://www.sciencedirect.com/journal/journal-of-industrial-and-engineering-chemistry*
22. *https://www.sciencedirect.com/journal/journal-of-membrane-science*
23. *https://www.sciencedirect.com/journal/separation-and-purification-technology*

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 "Synthesis and Separation Process Modeling", 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 scientific development in the field of synthesis and separation processes;*
- *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. High-pressure devices in the national economy. Physical and chemical properties of ammonia. Ammonia synthesis. Nitrogen binding methods. Technological schemes. Material balances.* *Literature [1, 4-6, 10]* *Tasks for SRS: Historical reference. Alternative methods of nitrogen fixation [9]*	*2*
2	*Lecture 2. Raw material for ammonia synthesis. Obtaining a nitrogen-hydrogen mixture. Physico-chemical basis of ammonia synthesis. Equilibrium concentration. Optimal conditions for conducting the process.* *Literature [1, 4, 5, 14]* *Task for SRS: Effect of catalysts on ammonia synthesis reaction [14].*	*2*
3	*Lecture 3. Ammonia synthesis reactors. Reactors are tubular, shelf. Temperature mode. Material balance as a whole and components. Determination of*	*2*

	concentrations at the outlet of the reactor. *Literature [1, 4, 10, 12]* *Task for SRS: Design of nozzle.*	
4	*Lecture 4. Catalysts. Determination of the volume of the catalyst and the main dimensions of the reactor. The main regularities for determining the geometric dimensions of the catalyst box.* *Literature [1, 4, 10]* *Task for SRS: Use of gas laws.*	*2*
5	*Lecture 5. Built-in and external heat exchangers. Calculation of the heat exchange process. Heat recovery boilers. Calculation of heat exchange equipment.* *Literature [1, 4, 10]* *Tasks for SRS: Starter heaters.*	*2*
6	*Lecture 6. Separation of a gas mixture. Methods of isolating ammonia from a gas mixture. Calculation of the refrigerator - condenser.* *Literature [1, 4, 10]* *Tasks for SRS: Designs of capacitors.*	*2*
7	*Lecture 7. Separation of a gas-liquid mixture. Discharge and circulation compressors. Purpose, designs and main parameters.* *Literature [1, 4, 10]* *Tasks for SRS: Designs of separators.*	*2*
8	*Lecture 8. High-pressure devices in the production of methyl alcohol. Physico-chemical bases of the synthesis of methyl alcohol. Technological schemes and reactors. Requirements for structural materials.* *Literature [1, 4, 11]* *Tasks for SRS: Tubular, shelf reactors. Temperature mode. Nozzle design.*	*2*
9	*Lecture 9. High-pressure devices in the production of urea (urea). Physico-chemical basis of urea synthesis. Technological schemes and reactors.* *Literature [1, 4, 13, 15]* *Task for SRS: Protection of equipment from corrosion.*	*2*
10	*Lecture 10. The essence of methods of separation of liquid and gaseous mixtures using semipermeable membranes. The history of the development of membrane processes. Classification and characteristics of membrane separation processes.* *Literature [2-3]* *Task for SRS: The use of membrane processes in the chemical and oil refining industry and their comparison with traditional separation methods.*	*2*
11	*Lecture 11. Baromembrane processes. Osmosis. Reverse osmosis. Models and mechanisms of reverse osmosis.* *Literature [2-3]* *Tasks for SRS: Principles of process calculation.*	*2*
12	*Lecture 12. Nanofiltration. Models and mechanisms of nanofiltration.* *Literature [2-3]* *Tasks for SRS: Principles of process calculation.*	*2*
13	*Lecture 13. Ultrafiltration and microfiltration. Process models and mechanisms.* *Literature [2-3]* *Tasks for SRS: Principles of process calculation.*	*2*
14	*Lecture 14. Gas separation. Models and mechanisms of the gas separation process.* *Literature [2-3]* *Tasks for SRS: Principles of process calculation*	*2*
15	*Lecture 15. Pervaporation. Models and mechanisms of the pervaporation process.*	*2*

	Literature [2-3] *Tasks for SRS: Principles of process calculation*	
16	*Lecture 16. Dialysis. Models and mechanisms of the dialysis process. Donnan equilibrium* *Literature [2-3]* *Tasks for SRS: Principles of process calculation*	*2*
17	*Lecture 17. Membrane distillation. Models and mechanisms of membrane distillation.* *Literature [2-3]* *Tasks for SRS: Principles of process calculation*	*2*
18	*Lecture 17. Electrodialysis. Models and mechanisms of the electrodialysis process.* *Literature [2-3]* *Tasks for SRS: Principles of process calculation*	*2*
	Together	*36*

Practical training

In the system of professional training of students in this discipline, practical classes occupy 50% 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 synthesis and separation;*
- *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.* *Determination of equilibrium constant, equilibrium concentration, working concentration of ammonia at the reactor outlet.* *Literature [1, 4, 6, 10, 12]*	*2*
2	*Practical lesson 2.* *Material balance of the reactor.* *Literature [1, 4, 10, 12]*	*2*
3	*Practical lesson 3.* *Calculation of volume flow in reactor channels and their geometric dimensions.* *Literature [1, 4]*	*2*
4	*Practical lesson 4.* *Calculation of heat flows.* *Literature [1, 4, 6]*	*2*
5	*Practical lesson 5.*	*2*

	Calculation of the amount of catalyst on the shelves and clarification of the temperature regime. *Literature [1, 4, 6]*	
6	*Practical lesson 6.* *Material and heat balance of the condenser.* *Literature [1, 6, 10]*	*2*
7	*Practical lesson 7.* *Thermal calculation. Determination of the geometric dimensions of the ammonia condenser.* *Literature [1, 10]*	*2*
8	*Practical lesson 8.* *Calculation of the methyl alcohol synthesis reactor.* *Literature [1, 4, 11]*	*2*
9	*Practical lesson 9.* *Calculation of the urea synthesis reactor.* *Literature [1,13,15]*	*2*
10	*Practical lesson 10.* *Calculation of the material balance of the membrane apparatus* *Literature [2-3]*	*2*
11	*Practical lesson 11.* *Taking into account the real conditions in the membrane apparatus* *Literature [2-3]*	*2*
12	*Practical lesson 12.* *Calculation of a cascade of membrane devices* *Literature [2-3]*	*2*
13	*Practical lesson 13.* *Approximate calculation of the membrane surface area and design calculation of the reverse osmosis apparatus.* *Literature [2-3]*	*2*
14	*Practical lesson 14.* *Refined calculation of the surface area of membranes in a reverse osmosis device* *Literature [2-3]*	*2*
15	*Practical lesson 15.* *Approximate calculation of the membrane surface area and structural calculation of the ultrafiltration apparatus* *Literature [2-3]*	*2*
16	*Practical lesson 16.* *Approximate calculation of the membrane surface area and structural calculation of the ultrafiltration apparatus* *Literature [2-3]*	*2*
17	*Practical lesson 17.* *Calculation of concentration polarization in a membrane apparatus* *Literature [2-3]*	*2*
18	*Practical lesson 18.* *Calculation of the apparatus for separation of gas mixtures*	*2*

	Literature [2-3]	
	Together	*36*

6. Independent work of student

Independent work takes up 68% of the time of studying the discipline, including preparation for the exam. 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 model modern synthesis and separation processes used in chemical engineering.

No. z/p	*The name of the topic submitted for independent processing*	*Number of hours of SRS*
1	*Chapter 1. Modeling of synthesis processes* *Operating conditions of industrial catalysts.* *Poisons for catalysts.* *Control and automation of the ammonia synthesis process.* *Ammonia storage and transportation.* *Control and automation of the methanol synthesis process.* *Storage and transportation of methanol.* *Control and automation of urea synthesis process.* *Storage and transportation of urea.* *Literature [1, 4, 7, 9-12]*	*61*
2	*Chapter 2. Modeling of separation processes.* *Traditional separation methods. Advantages, disadvantages and scope of application.* *Advantages of membrane processes. The scope of their application.* *Unconventional models of baromembrane processes. Optimization methods of baromembrane processes.* *Non-traditional models of diffusion-membrane processes. Optimization methods of diffusion-membrane processes.* *Non-traditional models of diffusion-membrane processes. Optimization methods of diffusion-membrane processes.* *Non-traditional models of thermo-membrane processes. Optimization methods of thermo-membrane processes* *Unconventional models of electro-membrane processes. Optimization methods of electro-membrane processes* *Software for modeling membrane separation processes.* *Literature [2-3]*	*62*
3	*Preparation for the exam*	*30*
	Hours in general	*153*

politics 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 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 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)

System of rating (weighted) points and evaluation criteria

The system of rating points and evaluation criteria:

Performing tasks in practical classes.

The weighted point is 2. The maximum number of points for practical classes is 2·18=36.

Testing of assimilation of lecture material.

The weighted point is 12. The maximum number of points for testing the learning of the lecture material is 2·12=24.

Answers on the exam. 40 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 condition for admission to the exam is the completion of all tasks in practical classes.

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

Chapter 1

1. *Fields of application of high pressure devices.*
2. *Methods of binding atmospheric nitrogen.*
3. *Ammonia synthesis (historical reference).*
4. *Use of ammonia.*
5. *Physico-chemical basis of ammonia synthesis.*
6. *Equilibrium reaction of ammonia synthesis. The equilibrium constant of the ammonia synthesis reaction.*
7. *Equilibrium concentration of ammonia synthesis reaction.*
8. *Thermal effect of ammonia synthesis reaction.*
9. *Influence of pressure and temperature on the equilibrium reaction of ammonia synthesis.*
10. *Raw material for the production of synthetic ammonia.*
11. *Obtaining a nitrogen-hydrogen mixture.*
12. *Schemes of medium pressure ammonia synthesis.*
13. *Low-pressure ammonia synthesis schemes.*
14. *High-pressure ammonia synthesis schemes.*
2. *Tubular ammonia synthesis reactor.*
3. *A shelf ammonia synthesis reactor.*
4. *Material balance of the ammonia synthesis reactor.*
5. *Determination of concentrations and material flows of components at the outlet of the ammonia synthesis reactor.*
6. *Calculation of the main dimensions of the ammonia synthesis reactor.*
7. *The use of gas laws when calculating the geometric dimensions of the reactor.*
8. *Designs of heat exchangers of the ammonia synthesis reactor.*
9. *Calculation of the heat exchanger of the ammonia synthesis reactor.*
10. *Kinetics of ammonia synthesis.*
11. *Determination of the volume of the catalyst.*
12. *Calculation of the volume of the catalyst and the height of the shelf of the shelf reactor.*
13. *Calculation of heat losses to the environment.*
14. *Calculation of heat flows in the ammonia synthesis reactor.*
15. *Heat exchange equipment of the ammonia synthesis unit.*
16. *Designs of heaters.*
17. *Calculation of electric heaters.*
18. *Methods of isolating ammonia from a gas mixture.*
19. *Equilibrium of the liquid-vapor system.*
20. *Designs of water coolers-condensers.*
21. *Designs of ammonia refrigerators-condensers.*
22. *Condensation column design.*
23. *Material balance of the refrigerator-condenser.*

24. *Features of the process of ammonia condensation from a gas mixture.*
25. *Calculation of the heat transfer coefficient during ammonia condensation.*
26. *Separation (separation) of a gas-liquid mixture.*
27. *Designs of separators.*
28. *Separator calculation. The rate of sedimentation of a particle in the field of gravity.*
29. *Circulating compressors.*
30. *Methyl alcohol. Use of methyl alcohol.*
31. *Synthesis of methyl alcohol (historical reference).*
32. *Raw material for the production of methyl alcohol.*
33. *Physico-chemical bases of the synthesis of methyl alcohol.*
34. *Equilibrium reaction of methyl alcohol synthesis.*
35. *Materials for devices for the synthesis of methyl alcohol.*
36. *Protection of methyl alcohol synthesis equipment from corrosion.*
37. *Methyl alcohol production scheme.*
38. *Methyl alcohol synthesis reactors.*
39. *Urea (urea). Use in the national economy.*
40. *Physico-chemical basis of urea synthesis.*
41. *Reaction parameters and their effect on urea yield.*
42. *Urea synthesis schemes.*
43. *Urea synthesis reactor.*
44. *Protection of urea synthesis equipment from corrosion.*

Section 2

1. *Evaluate the processmicrofiltration and indicate the areas of its application*
2. *Analyze the work of dynamic membranes*
3. *Analyze the main requirements for membranes*
4. *Analyze the ultrafiltration process*
5. *Analyze the mechanism of the membrane distillation process*
6. *Analyze the phenomenon of concentration polarization*
7. *Analyze the mechanism of the processpervaporation*
8. *To substantiate the methods of regeneration of membranes*
9. *Analyze usageinorganic membranes*
10. *Analyze the mechanismgas separation in homogeneous membranes*
11. *Analyze process parametersreverse osmosis*
12. *Analyze the mechanismgas separation in porous membranes*
13. *To analyze the properties of polymeric membrane materials*
14. *Describe the phenomenon of osmosis and explain the term osmotic pressure*
15. *To analyze the influence of the concentration of soluble substances in the initial solution on the characteristics of membrane processes*
16. *Analyze the process of reverse osmosis*
17. *Analyze the mechanism of electrodialysis*
18. *Analyze the effect of temperature on the characteristics of membrane processes*
19. *Analyze the process of dialysis*
20. *Analyze the basic concepts and definitions of membrane processes (names of flows of formed substances)*
21. *To justify the economic feasibility of using membrane processes*
22. *To analyze the effect on the characteristics of the membrane separation of the working pressure*
23. *Analyze the membrane balanceDonnan*
24. *Analyze the design features of cascade membrane systems*
25. *Analyze the main parameters of membrane processes*
26. *Conduct a comparative analysis of porous and non-porous membranes forgas separation*

27. *Analyze the structure of an asymmetric membrane*
28. *To justify the ecological and energy-saving aspects of membrane processes*
29. *Analyze the features of process modelingreverse osmosis*
30. *Analyze the structurerolled membrane module*

Working program of the academic discipline (syllabus):

Foldedassociate professor MAHNV, Ph.D., Serhii GULIENKO

Art. teacher of the faculty MAHNV, Ph.D., Olena HUSAROVA

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)