The National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute"

Department of Ecology and Technology of Plant Polymers

Chemistry of delignification of plant raw materials

work program of the academic discipline (syllabus)

Details of the academic discipline

Level of higher education	***First (bachelor's)***
Branch of knowledge	*16 Chemical and Bioengineering*
Speciality	*161 Chemical Technology and Engineering*
Educational program	*Industrial ecology and resource efficient cleaner technologies*
Status of discipline	*Selective*
Form of training	*full-time(day)/evening(evening)/part-time/remote/mixed*
Year of preparation, semester	*2nd year, fall semester*
Volume of discipline	*4 credits (120 hours)*
Semester control	*Test*
Schedule of classes	*4 hours a week (1 hours of lectures and 1 hour of practical classes and 2 hour of laboratory work)*
Language of instruction	Ukrainian
Information about kerivnik course / teachers Lecturer:	Lecturer: PhD, professor Valerii Barbash, https://eco-paper.kpi.ua/pro-kafedru/vykladachi/barbash-valerij-anatolijovich.html; Practical classes and laboratory work: PhD, professor Valerii Barbash.
Course placement	*https://campus.kpi.ua/tutor/index.php?mode=mob&show&irid*

Program of discipline

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

The surrounding world is formed by mineral and organic polymers, which are the basis of all living things on earth. Organic polymers include such high molecular weight compounds as cellulose, lignin, and hemicelluloses. Cellulose is the most abundant renewable organic polymer produced in the biosphere each year. Lignin is the second most common organic polymer in the plant world. The annual volume of lignin production at enterprises of the pulp and paper industry is up to 50 million tons. The content of lignin in plant raw materials ranges from 5 to 30% of the mass of plant raw materials. It acts as a binder and prevents the destruction and decay of plants in natural conditions. Lignin is obtained as a result of cellulose production processes, the so-called delignification of plant raw materials. Processes of delignification of vegetable raw materials are carried out using different chemical reagents under different temperature and time conditions. Knowledge of the chemistry of the processes of delignification of plant raw materials is necessary for the creation of new and improvement of existing chemical methods of processing plant raw materials, which will make it possible to use scarce fibrous semi-finished products, water, auxiliary chemical materials, labor and energy resources more rationally and ecologically.

The subject of the study discipline *"Chemistry of delignification of plant raw materials" consists in studying the general characteristics and theoretical foundations of the processes of delignification of plant raw materials, the general characteristics of lignin, its meaning, formation and content in plants, physical and chemical properties of lignin, as well as the chemistry of the processes that occur during obtaining technical cellulose.*

The purpose of the credit module *"Chemistry of delignification of plant raw materials" is to form in students a complex of knowledge, abilities, skills necessary for qualified management of technological processes of pulp and paper production and chemical processing of plant raw materials, to train specialists in the field of chemical technologies and engineering, capable on the basis of acquired theoretical knowledge to solve professional problems in practical situations, in particular to form the following competencies in students:*

- ability to apply knowledge in practical situations (C 02)

- knowledge and understanding of the subject area and understanding of professional activity (C 03);

- the ability to use the provisions and methods of the discipline to solve professional problems, to determine directions for the processing of plant raw materials (C 09);

- the ability to determine the directions of use of plant and pulp, design and implement their processing technologies (C 19);

- the ability to use the basic provisions of the chemistry of plant polymers to predict the quality indicators of pulp, paper and cardboard, intermediate and final products of the chemical technology of processing plant raw materials.

According to the requirements of the program of the academic discipline, after learning the credit module, students must demonstrate the following ***learning outcomes****:*

- correctly use the terminology and basic concepts of chemistry, chemical technologies, processes and equipment for the production of chemical substances and materials based on them in professional activities (PO 02);

- to substantiate the choice of technological schemes of production on the basis of rational use of raw materials, energy, obtaining high-quality products, achieving high productivity with a simultaneous solution of environmental issues, calculating material and heat balances of processes, on their basis, finding costs of raw materials and energy resources (PO 15);

- determine the quality characteristics of plant raw materials, semi-finished products and finished products (PO 16).

2. Prerequisitions and requisition of disciplines (place in the structural and logical scheme of training according to the relevant educational program)

The study of the academic discipline " Chemistry of plant polymers delignification" is preceded by academic disciplines such as: "General and inorganic chemistry", "Organic chemistry", "Chemistry of high molecular compounds", it provides the disciplines "Technology of production of cellulose ethers and esters", "Technology of pulp", "Chemical methods of analysis of raw materials, products and waste water of pulp and paper production", "Paper and cardboard technology". The educational discipline belongs to the cycle of professional training (selective educational components from the departmental Catalogues).

3. Contents of the discipline

Section 1. Chemistry of lignin

Topic 1. General characteristics of lignin. The concept of lignin, its meaning, formation and content in plants. Physical properties of lignin. Elementary composition of lignin. Structural chains of the lignin macromolecule. Nature of connection with carbohydrates. Qualitative color reactions of lignin. Methods of extracting lignin from plant materials and methods of its quantitative determination.

Topic 2. Scheme of macromolecule fragments. Types of bonds in lignin macromolecules. Functional groups of lignins: aromatic character, methoxyl and hydroxyl groups, double bonds, carboxyl and carbonyl groups.

Topic 3. Chemical properties of lignin. Oxidation of lignin. Oxygen number and oxidation products. Hydration and recovery of lignin. Products of regenerative destruction. Fusion of lignin with alkali. Nitration of lignin.

Topic 4. Effect of halogens on lignin. Methylation and acetylation of lignin. Effect of hydrolyzing agents on lignin. The effect of diluted alkalis. Effect of alcohols. Effect of phenylhydrazine and hydroxylamine on lignin.

Section 2. Chemistry of the processes that occur during the production of technical cellulose

Topic 5. Modern ideas about the structure of lignin. Chemistry of delignification processes in an acidic environment. Chemistry of sulphite cooking. Inactivation of lignin. Chemistry of bisulfite cooking. Lignin condensation reactions in acidic and alkaline environments. Lignosulfonic acids.

Topic 6. Chemistry of delignification processes of plant raw materials in an alkaline environment. Chemistry of alkaline cooking. Peculiarities of the chemistry of sulfate cooking. The role of sodium sulfide. Alkaline and sulfate lignin. Practical use of technical lignins. Utilization of lignins and environmental protection.

4. Training materials and resources

Basic literature

1. Barbash V.A., Deikun I.M. Chemistry of plant polymers. Education manual. 2nd edition, revised. and additional - Kyiv: Caravela, 2018 – 440 p.
2. Barbash V.A., Deikun I.M. Chemistry of plant polymers. Education Guide/Kyiv: Edelweiss, 2014. 437p.
3. Hetmanchuk Y.P., Bratychak M.M. Chemistry and technology of polymers. Lviv: "Beskid Bit" Publishing House, 2006. — 496 p.
4. Maslennikova L., Fabulyak F., Grushak Z., Ivanov S. Physico-chemistry of polymers. L.: NAU-print, 2009. — 312 p.

Additional literature

5. Primakov S.P., Barbash V.A., Cheryopkina R.I. Production of sulfated cellulose and pulp bleaching. Study guide K.. ECMO, 2011. - 290 p.
6. VV Nyzhnyk Physical chemistry of polymers: textbook / VV Nyzhnyk, T. Yu., Nyzhnyk; MES - Kyiv: Phytosocial Center, 2009. – 424 p.
7. Yu.V. Mygalina, O.P. Kozar. Basics of chemistry and physico-chemistry of polymers. Textbook. — K: Condor, 2010.— 325 p.
8. Barbash V.A., Antonenko L.P., Deikun I.M. Methodical instructions for laboratory work on the chemistry of plant raw materials, Kyiv, KFTP, 2003 - 71 p.

Information resources on the Internet

1. https://vlp.com.ua/node/4352
2. https://library.sspu.edu.ua/wp-content/uploads/2018/04/38.pdf

Educational contect

5. Methods of mastering the discipline (educational component)

Lecture classes

Lectures are aimed at forming in students a complex of knowledge necessary for qualified management of technological processes of pulp and paper production and chemical processing of plant raw materials, for which it is necessary to know: the structure, chemical composition and properties of plant raw materials and their individual components, as well as the opportunities that open up during various transformations of plant raw materials and their components to improve these processes and create new, more efficient, ecologically cleaner productions.

No s/p	*Title of the lecture topic and list of main questions (list of didactic means, references to literature and tasks on the SRS)*	*Hours*

1	***Section 1. Chemistry of lignin*** *Topic 1. General characteristics of lignin. The concept of lignin, its meaning, formation and content in plants. Structural chains of the lignin macromolecule. Nature of connection with carbohydrates. Qualitative color reactions of lignin. Methods of extracting lignin from plant materials and methods of its quantitative determination.* *Literature: [1, pp. 227-231; 2, p. 206-220]* *Task on SRS: Physical properties of lignin. Elementary composition of lignin*	4
2	*Topic 2. Scheme of macromolecule fragments. Types of bonds in lignin macromolecules. Functional groups of lignins: aromatic character, methoxyl and hydroxyl groups, double bonds, carboxyl and carbonyl groups* *Literature: [1, p. 154-174, 2, p. 221-237]* *Tasks on the SRS. Basic dimeric structures of lignin*	*2*
3	*Topic 3. Chemical properties of lignin. Oxidation of lignin. Oxygen number and oxidation products. Hydration and recovery of lignin. Products of regenerative destruction. Fusion of lignin with alkali. Nitration of lignin.* *Literature: [1, p. 245-255; 2, p. 273-311]* *Tasks on SRS: Methods of determining the oxygen number*	*4*
4	*Topic 4. Effect of halogens on lignin. Methylation and acetylation of lignin. Effect of hydrolyzing agents on lignin. The effect of diluted alkalis. Effect of alcohols. Effect of phenylhydrazine and hydroxylamine on lignin.* *Literature: [1, p. 255-263]* *Task on SRS: Effect of nitric acid on lignin*	*2*
5	***Section 2. Chemistry of the processes that occur during the production of technical cellulose*** *Topic 5. Chemistry of delignification processes in an acidic environment. Chemistry of sulphite cooking. Inactivation of lignin. Chemistry of bisulfite cooking. Lignin condensation reactions in an acidic medium. Lignosulfonic acids.* *Literature: [1, p. 263-272].* *Tasks at SRS: Branches and areas of use of lignosulfonates*	***4***
6	*Topic 6. Chemistry of delignification processes of plant raw materials in an alkaline environment. Chemistry of alkaline cooking. Peculiarities of the chemistry of sulfate cooking. The role of sodium sulfide. Alkaline and sulfate lignin. Lignin condensation reactions in an alkaline medium.* *Literature: [1, p. 273-333].* *Task on SRS: Practical use of technical lignins. Utilization of lignins and environmental protection*	2
Total		18

Practical classes

As part of the teaching of the subject "Chemistry of plant polymers", practical classes are provided, which take 18 hours and make up 25% of the classroom load. The main tasks of practical classes are:

- to help students systematize, consolidate and deepen knowledge of a theoretical nature in the field of chemistry of plant polymers;
- to help students acquire the skills and abilities to perform calculations, graphics and other types of tasks;
- teach students to work with scientific and reference literature, regulatory and technical documents in the field of chemistry of plant polymers.

Topics of practical classes:

No s/p	The name of the topic of practical training and the list of main questions (list of didactic support, references to literature and tasks to the SRS)	Hours
1	Topic 1 Methods of determining the content of the main functional groups of lignin in plant raw materials. Literature: [1, p.241-245] Tasks on SRS: Examples of calculating the content of the main functional groups of lignin	2
2	Topic 2. Chemistry of the action of bleaching reagents on lignin during pulp bleaching processes Literature: [1, p. 246 -252] Task on SRS: Comparison of the efficiency of lignin extraction by different pulp bleaching methods	4
3	Topic 3. Technological schemes of pulp bleaching. Literature: [5, p. 263 -278] Assignment on SRS: Examples of technological schemes of pulp bleaching at real enterprises of the pulp and paper industry	4
4	Topic 4. Directions of lignin use Literature: [1, p. 264 -267] Assignment on SRS: Examples of lignin application in the production of composite materials Writing a modular test	4
5	***Writing a modular test***	2
8	***Test***	2
	Total	18

Laboratory work

Laboratory works of the study discipline "Chemistry of delignification of plant raw materials" are aimed at students' assimilation of the methods of extracting lignin from plant materials and methods of its quantitative determination, as well as discussing the features of the chemistry of the processes that occur in the process of obtaining technical cellulose from various plant raw materials.

No s/p	The name of the topic of laboratory work and a list of main questions	Hours
1	*Topic 1. Determination of the content of substances that are extracted with an alcohol-benzene mixture* *Literature: [11, pp. 21-23]* *Tasks on SRS: Examples of calculating the content of the main functional groups of lignin*	6
2	*Topic 2. Determination of lignin content in vegetable raw materials* *Literature: [1, p. 8 -23]* *Task on SRS: Methods of lignin isolation.* *Literature - [11, p. 36-39].*	6
3	*Topic 3. Determining the hardness (degree of delignification) of cellulose by the Bjerkman method.* *Literature: [11, p.40-43]* *Task on SRS: Differences in the structure of lignin of different types of plants.* *Literature - [1, c. 229-243].*	6

4	*Topic 4. Determination of the hardness (degree of delignification) of cellulose by the Kappa method.* *Literature: [11, p. 44 - 47]* *Tasks at SRS: Use of lignin waste processing products in various industries.*	***6***
5	*Topic 5. Determination of cellulose viscosity in different types of cellulose* *Literature: [11, p. 48 -52]* *Task on SRS: Use of lignin in the production of boards.*	***6***
6	***Protection of laboratory works***	***2***
	Total	***36***

6. Independent work of a student/postgraduate student

Independent work of students is 48 hours of course study, includes preparation for includes preparation for laboratory and practical classes, writing a modular test and preparation for the assessment.

The main task of students' independent work is the mastery of scientific knowledge in the field of plant polymer chemistry, which was not included in the list of lecture questions, through independent study of the material based on educational literature, personal search for information, formation of active interest in a creative approach in educational work. In the process of independent work within the framework of the credit module, the student must learn to deeply analyze a problem in the pulp and paper industry and, based on the analysis, come to his own well-founded conclusions regarding the technological parameters of the technological process.

No s/p	***Name of the topic submitted for self-study***	***hours***
	Section 1. Chemistry of lignin	
1	*Topic 1. General characteristics of lignin. Physical properties of lignin. Elementary composition of lignin* *Literature: [1, c. 227-229]*	*6*
2	*Topic 2. Types of connections in lignin macromolecules. Basic dimeric structures of lignin* *Literature: [1, c. 245-267]*	*8*
3	*Topic 3. Chemical properties of lignin. Methods of determining the oxygen number* *Literature: [1, c. 245-267]*	*6*
4	*Topic 4. Chemical properties of lignin. Effect of nitric acid on lignin* *Literature: [1, c. 254-256]*	*6*
	Section 2. Chemistry of the processes that take place during the production of technical pulp	
5	*Topic 5. Chemistry of delignification processes in an acidic environment. Branches and areas of use of lignosulfonates* *Literature: [1, c. 290-310]*	*8*
6	*Topic 6. Chemistry of delignification processes of plant raw materials in an alkaline environment. Practical use of technical lignins. Utilization of lignins and environmental protection.* *Literature: [1, c. 310-336]*	*8*
7	***Preparation for modular control work on chapters 1-4***	*2*
8	***Preparation for the test***	4
	Total	*48*

Politics and contect

7. Policy of discipline (educational component)

Rules for attending classes and behavior in classes

Attending classes is a mandatory component of 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 to conduct classes, not to be distracted by actions that are not related to the educational process.

Rules for assigning incentive and penalty points

- encouraging points can be credited by the teacher only for the performance of creative works in the discipline or additional passage of online specialized courses with the receipt of the appropriate certificate. However, their amount cannot exceed 25% of the rating scale. Penalty points within the discipline are not provided.

Deadline and overlay policy

In case of debts in the discipline or any force majeure circumstances, graduate students should contact the teacher through accessible (provided by the teacher) communication channels to solve problematic issues and coordinate the algorithm of actions for working out.

Academic Integrity Policy

Plagiarism and other forms of dishonest work are unacceptable. Plagiarism includes the absence of references when using printed and electronic materials, quotes, opinions of other authors. Invalid hints and write-offs when writing tests, conducting classes; passing the credit for another graduate student; copying of materials protected by the copyright system without the permission of the author of the work. The policies and principles of academic integrity are defined in Section 3 of the Code of Honor of the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute"https://kpi.ua/code.

Policy of academic behavior and ethics

Students should be tolerant, respect the opinion of others, object to formulate in the correct form, constructively maintain feedback in the classroom.

The norms of ethical behavior of students and employees are defined in Section 2 of the Code of Honor of the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute" https://kpi.ua/code.

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

Distribution of educational time by types of classes and tasks in the discipline according to the working curriculum:

Semester	School time		Distribution of training hours				Control measures		
	credits	acad. H.	Lecture	Practical	Lab. Rob..	SRS	FDM	PP	Semester control
3	**4**	**120**	**18**	**18**	**36**	**48**	**1**	**-**	**Test**

The rating system for evaluating learning outcomes (RSO) of a student in a discipline consists of the points he receives for answers during express control at lectures; answers in practical and laboratory classes; execution of a modular control work, which can be divided into two 45-minute or three 30-minute works.

System of rating (weighted) points and evaluation criteria

1) Answers during express control at lectures:

Weight score - 3. Weight coefficient - 0.3. The maximum number of points for all lectures is equal to: 9 lectures (answers) x 3 points x 0.3 = 8 points

Answer evaluation criteria:

Points	Completeness of the answer
3	"excellent", Complete answer (at least 90% of the required information)
2	"good", incomplete disclosure of one of the questions or a complete answer with minor inaccuracies
1	"satisfactory", incomplete disclosure of the question (at least 60% of the required information) and minor errors
0	Unsatisfactory work (does not meet the requirements for 3 Unsatisfactory work (does not meet the requirements for 3 points).

2) Answers in practical classes:
Weight score - 3. Weight factor - 0.37. The maximum number of points in all laboratory classes is equal to: 9 practicals. (answers) x 3 points x 0.37 = 10 points
Answer evaluation criteria:

Points	Completeness of the answer
3	"excellent", Complete answer (at least 90% of the required information)
2	"good", incomplete disclosure of one of the questions or a complete answer with minor inaccuracies
1	"satisfactory", incomplete disclosure of the question (at least 60% of the required information) and minor errors
0	Unsatisfactory work (does not meet the requirements for 3 Unsatisfactory work (does not meet the requirements for 3 points).

3) Answers in laboratory works:

Weight score - 8. Weight factor - 0.56 The maximum number of points for all laboratory classes is equal to: 6 labs (answers) x 8 points x 0.56 = 27 points

Answer evaluation criteria

Бали	Completeness and signs of response
1	knowledge of theoretical material;
1	knowledge of analysis methods;
1	the presence of a work performance protocol in the laboratory journal;
1	when performing laboratory work, reliable results were obtained
1	correctly performed calculations in the report;
1	the availability of conclusions from laboratory work
2	clear answers to questions during the defense of laboratory work;
1	there are inaccuracies and errors in the answer during the defense of laboratory work
0	the answers do not correspond to the formulated topic; all the questions asked remained unanswered. Protection of laboratory work is not included.
8	The maximum amount of points for laboratory work

4) Completion of a modular control work, which consists of answers to 6 questions from different sections of the academic discipline and is performed in written form by one's own hand without the use of computer equipment.
Weight score - 3. Weight factor - 1.0. The maximum number of points for a modular test is: 5 questions x 3 points x 1.0 = 15 points

Answer evaluation criteria:

Points	Completeness of the answer
3	"excellent", Complete answer (at least 90% of the required information)
2	"good", incomplete disclosure of one of the questions or a complete answer with minor inaccuracies
1	"satisfactory", incomplete disclosure of the question (at least 60% of the required information) and minor errors
0	Unsatisfactory work (does not meet the requirements for 3 Unsatisfactory work (does not meet the requirements for 3 points).

Calculation of the rating scale (R).

The rating scale of the discipline (R) is 100 points and is formed as the sum of all the rating points of the starting scale (Rc), received by the student based on the results of current control measures, and the rating scale (Rч) of the rating. The size of the starting scale (Rc) of the Rc rating is 60 points: Rc = 8 + 10 + 27 + 15= 60 points, and the size of Rз = 40 points. Thus, the rating scale for the discipline is: R = RS + Rz = 60 + 40 = 100 points.

Semester control is test. Criteria: The answer to four questions, each of which has a weighting point of 10. The maximum number of points is 10 x 4 = 40 points.

According to the results of academic work in the first 7 weeks, a student can score 20 points. At the first certification (8th week), the student receives "credited" if his current rating is at least 10 points. According to the results of 13 weeks of study, the student must score 40 points. At the second certification (14th week), the student receives "passed" if his current rating is at least 20 points. Regular positive answers in lectures, practical and laboratory classes, writing a modular test, as well as a starting rating (Rc) of at least 40% of Rc, i.e. 24 points, are a necessary condition for admission to the credit. A student who scored a rating of less than 0.6 Rs during the semester completes a credit test. At the same time, all points received by him during the semester are cancelled. The task of the control work contains questions related to different sections of the program. The list of assessment questions is given in Chapter 9.

In order for a student to receive a passing grade, the sum of all rating points R earned during the semester is converted according to the table:

Number of points	**Evaluation**
95...100	excellent
85...94	very good
75...84	*good*
65...74	satisfactory
60...64	*enough*
RD <60	unsatisfactory
Unfulfilled conditions of admission	are not admitted

9. **Additional information on the discipline (educational component)**

Approximate list of questions submitted for semester control

1. Elementary chains of lignin of coniferous wood species.

2. Representatives of elementary chains of lignin of deciduous wood species

3. Elementary chains of lignin of annual plants

4. Examples of ether bond between elementary chains of lignin

5. Examples of C - C bond between elementary chains of lignin

6. Functional groups of lignin. Reactions and their definition.

7. Chemical properties of lignin

8. Lignin oxidation reactions

9. Lignin chlorination reaction

10. *Lignin condensation reaction in an alkaline environment*
11. *Lignin condensation reaction in an acidic environment*
12. *Chemical reactions of lignin during the bisulfite method of cooking cellulose*
13. *Chemical reactions of lignin in the sulfite method of cooking cellulose*
14. *Chemical reactions of lignin during the neutral-sulfite method of cooking cellulose*
15. *Chemical reactions of lignin in the alkaline method of cooking cellulose*
16. *Chemical reactions of lignin during the organosolvent method of cooking cellulose.*
17. *Types of connection between elementary chains of lignin*
18. *Lignin nitration reaction*
19. *Lignin hydrogenolysis reaction*
20. *Chemical reactions of lignin during the sulfate method of cooking cellulose*

Work program of the academic discipline (syllabus):

Compiled by professor, Ph.D. Barbash Valerii Anatoliyovych

Approved by the ___ETRP___ department *(protocol No. _14_ from _06.08.2022_)*

Agreed by the ECF Methodical Commission *(protocol No. _10_ from _24.06. 2022_)*