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

Department of Ecology and Technology of Plant Polymers

Basics of industrial emissions treatment processes for vapors and gases

Work program of the academic discipline (Syllabus)

Details of the discipline	
Level of higher education	***First (educational and professional)***
Field of expertise	*10 Natural sciences*
Specialty.	*101 Ecology*
Educational program	*Environmental safety*
Status of the discipline	*Selective*
Form of study	*full-time/distance/mixed*
Year of study, semester	*2nd year / fall semester*
Scope of the discipline	*4 ECTS credits (120 hours)*
Semester control / control measures	*Test*
Class schedule	*4 hours per week (1 hour of lectures and 2 hours of laboratory classes, 1 hour of practical classes)*
Language of instruction	*Ukrainian*
Information about course leader / teachers	Lecturer: https://eco-paper.kpi.ua/pro-kafedru/vykladachi/ivanenko-olena-ivanivna.html Practical: https://eco-paper.kpi.ua/pro-kafedru/vykladachi/ivanenko-olena-ivanivna.html Laboratory: https://eco-paper.kpi.ua/pro-kafedru/vykladachi/ivanenko-olena-ivanivna.html
Placement of the course	*https://do.ipo.kpi.ua/course/view.php?id=5235*

Program of the discipline

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

In order to prevent the negative effects of human activity and improve the state of the air in terms of toxic vapors and gases, it is necessary to constantly improve air protection technologies. Only with the help of knowledge of gas emissions treatment and the use of devices for assessing the state of atmospheric air from man-made vapors and gases can we protect the environment from the negative anthropogenic impact on the planet's airspace.

The subject of the discipline "Basics of industrial emissions treatment processes for vapors and gases" *is one of the main areas of implementation of environmental technologies aimed at protecting the atmosphere, and it is the purification of gaseous waste from vapors and gases before they are released into the atmosphere.*

To a large extent, the solution to this problem will be determined by the level of training of specialists working in the field of environmental protection, including institutions of state environmental safety management, scientific institutions and organizations, and enterprises.

To successfully solve the problems of protecting and preserving the atmosphere, specialists must be fluent in information and be able to solve complex problems of air protection from pollution at a high professional level.

Objective of the discipline "Basics of industrial emissions treatment processes for vapors and gases"

The purpose of this discipline is to develop students' knowledge in the field of modern methods of waste gas purification, a set of skills and abilities necessary for conducting research in this area, for creating modern gas purification technologies and for qualified management of existing technological processes. In accordance with the goal, the training of bachelors requires strengthening the competencies formed by students:

- *Ability to assess the impact of technological processes on the environment and identify environmental risks associated with production activities*
- *Ability to master international and domestic experience in solving regional and transboundary environmental problems*
- *Ability to develop design and working technical documentation in the field of environmental technologies, draw up structural diagrams with elements of equipment and industrial buildings, draw up completed design and engineering developments*
- *Ability to improve, design, implement and operate technologies and equipment for the treatment and processing of exhaust gases, wastewater and solid waste*
- *Ability to apply modern methods and means of monitoring the state of atmospheric air, natural waters, soils and biota, determine the level of contamination of natural and industrial materials with radioactive elements, master methods of assessing the impact of adverse factors on living organisms, determine the adaptive capabilities of the human body in the environment*
- *Ability to distinguish between technological processes of production, identify sources and ways of entering the environment of harmful components, assess their impact on human health and environmental quality*

*In accordance with the requirements of the program of the discipline "**Basics of industrial emissions treatment processes for vapors and gases**" , students must demonstrate the following program learning outcomes after completing it:*

- *Solve problems in the field of environmental protection using generally accepted and/or standard approaches and international and national experience*
- *Be able to search for information using appropriate sources to make informed decisions*
- *Conduct laboratory tests using modern instruments, ensure sufficient measurement accuracy and reliability of results, and process the results*
- *Apply methodologies and technologies for the design, implementation and implementation of environmental technologies and equipment, carry out design and development activities*
- *To assess the state of the environment, determine the level of impact of the enterprise (production) on the environment, identify the main environmental pollutants of the enterprise (production)*
- *To develop technologies, use processes and devices that ensure effective separation, concentration, extraction, destruction of harmful impurities in water systems and gas environments, waste treatment and utilization*

2. Prerequisites and post-requisites of the discipline (place in the structural and logical scheme of study in the relevant educational program)

*The study of the discipline "**Basics of industrial emissions treatment processes for vapors and gases**" is based on the principles of integration of various knowledge gained by students during their* *bachelor's degree in natural and engineering disciplines: "General Ecology", "Special Sections of Biogeochemistry", "Chemistry with the Basics of Biogeochemistry".*

*The discipline "Fundamentals of **Basics of industrial emissions treatment processes for vapors and gases"** is the fundamental basis for the study of the following disciplines: "Environmental Monitoring", "Modeling and Forecasting of the Environment", "Normalization of the Anthropogenic Load on the Environment", "Environmental and Natural and Technogenic Safety", "Technoecology", and provides for the implementation of a bachelor's project.*

3. *Content of the discipline "Basics of industrial emissions treatment processes for vapors and gases"*

Section 1. Absorption methods of purification from vapors and gases.

Topic 1: *Equilibrium in gas-liquid systems. Kinetic laws of the absorption process. Gas-liquid systems used in industry. Absorption equipment. Tubular film absorbers. Nozzle absorbers, characteristics of nozzles. Plate absorbers with dip and overflow plates, absorbers with a moving nozzle.*

Section 2: Purification of gases from sulfur (II) oxide.

Topic 1: *Formation of sulfur (II) oxide emissions. Scheme of contact production of sulfuric acid. Scheme of processes for the production of sulfuric acid from flue gases. Purification of gases from sulfur (II) oxide. Absorption with water. Limestone and lime methods. Magnesite, zinc, ammonia methods. Scheme of gas purification plant from sulfur (II) oxide to produce ammonium nitrate-phosphate. Sulfite-bisulfite methods using soda and sodium hydroxide.*

Chapter 3. Purification of gases from hydrogen sulfide.

Topic 1: *Generation of hydrogen sulfide emissions. Vacuum carbonate and phosphate methods. Ethanolamine and iron-soda methods. Hydrogen sulfide recovery by the Claus method.*

Section 4. Purification of gases from nitrogen oxides.

Topic 1: *Formation of nitrogen oxide emissions. Scheme of nitric acid production. Absorption by water with hydrogen peroxide additives. Absorption by alkalis and selective sorbents. Purification using urea and nitrosyl sulfuric acid. Disposal of regenerated nitrous gases by catalytic reduction.*

Chapter 5. Purification of gases from fluorine compounds.

Topic 1: *Formation of hydrogen fluoride and silicon tetrafluoride emissions. Scheme of production of simple superphosphate. Absorption by water, lime milk. Capture of fluoride gases with a solution containing ammonium salts. Utilization of fluoride gases.*

Chapter 6. Purification of gases from chlorine compounds.

Topic 1: *Formation of chlorine and hydrogen chloride emissions. Absorption by water and aqueous solutions of alkalis. Use of carbon tetrachloride and titanium. Utilization of chlorine-containing gases.*

Chapter 7. Purification of gases from carbon oxides.

Topic 1: *Formation of carbon monoxide emissions. Absorption of carbon monoxide (II) by copper-aluminum-chloride and copper-ammonia solutions. Purification from carbon (II) oxide by washing with liquid nitrogen. Hydrogenation of residual amounts of carbon monoxide. Purification of gases from carbon monoxide (IV) by water absorption. Ethanolamine purification. Purification with hot potash solution.*

Chapter 8. Adsorption methods of purification from vapors and gases.

Topic 1: *Kinetic laws of the adsorption process. Desorption of absorbed substances. Characterization of industrial adsorbents. Requirements for adsorbents in gas purification processes. Adsorption equipment with a movable and fixed adsorbent layer.*

Chapter 9. Catalytic methods of purification of vapors and gases.

Topic 1: *Catalytic purification of gases. The essence and types of catalysis. Industrial catalysts. Design of contact devices. Apparatus with a fluidized bed of catalyst. Catalytic purification of organic compounds. Scheme of installation of catalytic afterburning of waste gases.*

Training materials and resources

Basic literature

1. Beketov V.E., Yevtukhova G.P. Sources and processes of atmospheric pollution. Kharkiv: A. N. Beketov Kharkiv National University of Oil and Gas Industry, 2019. 113 c.

2. Sarapina M. V. Processes and devices of dust and gas purification: a course of lectures. Kharkiv: NUCSU, 2018. 125 c.

3. Krusir G.V., Madani M.M., Garkovich O.L. Techniques and technologies of gas emissions treatment. Odesa: ONAHT-Odesa, 2017. 207 c.

4. Methods of calculation of complex dust and gas cleaning systems. Monograph / M.I. Shilyaev, E.M. Khromova. M: DIA Publishing House, 2018. 196 c.

5. Fundamentals of industrial emissions cleaning processes from dust. Laboratory workshop: a textbook for students majoring in 101 Ecology, 161 Chemical Technology and Engineering / Igor Sikorsky Kyiv Polytechnic Institute; compiled by Ivanenko O.I., Overchenko T.A., Nosachova Y.V., Tverdokhlib M.M. - Kyiv: Igor Sikorsky Kyiv Polytechnic Institute, 2021. 34 p.

6. Fundamentals of industrial emissions purification processes from vapors and gases. Laboratory workshop: a textbook for students majoring in 101 Ecology, 161 Chemical Technology and Engineering / Igor Sikorsky Kyiv Polytechnic Institute; compiled by Ivanenko O.I., Overchenko T.A., Nosachova Y.V., Tverdokhlib M.M. - Kyiv: Igor Sikorsky Kyiv Polytechnic Institute, 2021. 34 p.

Additional literature

7. Industrial technologies and purification of technological and ventilation emissions: a textbook / Yurkevych Y. S., Voznyak O. T., Zhelykh V. M.; Ministry of MES of Ukraine, Lviv Polytechnic National University. 2012. 120 c.

8. Severin L. I., Petruk V. G., Bezvoziuk I. I., Vasylkivsky I. V. Environmental technologies (protection of the atmosphere) / Part I: Study guide. Vinnytsia: Universum-Vinnytsia, 2010.

9. Ratushniak G.S., Lyalyuk O.G. Means of gas emissions purification. Study guide. Vinnytsia: Universum-Vinnytsia, 2008. 207 c.

10. Ecology and environmental protection: a textbook. Kyiv: Znannya, 2007. 422 c.

Information resources on the Internet

11. Ministry of Environmental Protection and Natural Resources of Ukraine / [Electronic resource]. - Access mode: https://mepr.gov.ua/.

12. Industrial ecology. Community of environmentalists / [Electronic resource]. - Access mode: http://www.eco.com.ua/.

13. Professional Association of Ecologists of Ukraine / [Electronic resource] - Access mode: https://paeu.com.ua/.

14. Denysenko Scientific and Technical Library / [Electronic resource] - Access mode: https://library.kpi.ua.

15. Vernadsky National Library / [Electronic resource] - Access mode: http://www.nbuv.gov.ua/.

16. Electronic archive of scientific and educational materials of Igor Sikorsky Kyiv Polytechnic Institute / [Electronic resource] - Access mode: https://ela.kpi.ua/.

Educational content

5. Methods of mastering the discipline

Lecture classes

Lecture classes are aimed at:

- *providing modern, holistic, interdependent knowledge in the discipline "**Basics of industrial emissions treatment processes for vapors and gases**", the level of which is determined by the target setting for each specific topic;*

- *ensuring that students work together with the teacher during the lecture;*
- *fostering students' professional and business skills and developing their independent creative thinking;*
- *developing the necessary interest in students and determining the direction for independent work;*
- *determination of the current level of scientific development in the field of modern methods and processes of gas purification, forecasting development for the coming years;*
- *displaying the methodological processing of the material (highlighting the main points, conclusions, recommendations, their clear and adequate formulation);*
- *use of visual materials for demonstration, combining them, if possible, with the demonstration of results and samples;*
- *presenting the research materials in clear and high-quality language, observing structural and logical connections, explaining all newly introduced terms and concepts;*
- *accessibility for this audience.*

No. s/n	**Title of the lecture topic and a list of main issues (list of didactic tools, references to literature and assignments for IWS)**	**Hours**
1	***Absorption methods for cleaning vapors and gases.*** *Equilibrium in gas-liquid systems. Kinetic laws of the absorption process. Gas-liquid systems used in industry. Absorption equipment. Tubular film absorbers. Nozzle absorbers, characteristics of nozzles. Plate absorbers with dip and overflow plates, absorbers with a moving nozzle.* *Literature: [2, 3, 4].* *Task for IWS. Disadvantages of absorption methods of purification from vapors and gases.* *Literature: [9].*	*2*
2	***Purification of gases from sulfur (II) oxide.*** *Formation of sulfur (II) oxide emissions. Scheme of contact production of sulfuric acid. Scheme of processes for the production of sulfuric acid from flue gases. Purification of gases from sulfur (II) oxide. Absorption with water. Limestone and lime methods. Magnesite, zinc, ammonia methods. Scheme of gas purification plant from sulfur (II) oxide to produce ammonium nitrate-phosphate. Sulfite-bisulfite methods using soda and sodium hydroxide.* *Literature: [2, 3, 4].* *IWS. Purification of gas mixtures from carbon black.* *Literature: [7, 8, 9].*	*2*
3	***Purification of gases from hydrogen sulfide.*** *Generation of hydrogen sulfide emissions. Vacuum carbonate and phosphate methods. Ethanolamine and iron-soda methods. Hydrogen sulfide recovery by the Claus method.* *Literature: [2, 3, 4].* *IWS. Purification of gas mixtures from mercaptans.* *Literature: [7, 8, 9].*	*2*
4	***Purification of gases from nitrogen oxides.*** *Formation of nitrogen oxide emissions. Scheme of nitric acid production. Absorption by water with hydrogen peroxide additives. Absorption with alkalis and selective sorbents. Purification using urea and nitrosyl sulfuric acid. Disposal of regenerated nitrous gases by catalytic reduction.* *Literature: [2, 3, 4].* *IWS. Ways to reduce nitrogen oxide emissions.* *Literature: [1, 8, 10].*	*2*

5	***Purification of gases from fluorine compounds.*** *Generation of hydrogen fluoride and silicon tetrafluoride emissions. Scheme of production of simple superphosphate. Absorption by water and lime milk. Capture of fluoride gases with a solution containing ammonium salts. Utilization of fluoride gases.* *Literature: [2, 3, 4].* *IWS. Ways to use captured fluorine gases in industry.* *Literature: [1, 8, 10].*	*1*
6	***Purification of gases from chlorine compounds.*** *Formation of chlorine and hydrogen chloride emissions. Absorption by water and aqueous alkali solutions. Use of carbon tetrachloride and titanium. Utilization of chlorine-containing gases.* *Literature: [2, 3, 4].* *IWS. Ways to use captured chlorine-containing gases in industry.* *Literature: [1, 8, 10].*	*1*
7	***Purification of gases from carbon oxides.*** *Formation of carbon oxide emissions. Absorption of carbon monoxide (II) by copper-aluminum-chloride and copper-ammonia solutions. Purification from carbon (II) oxide by washing with liquid nitrogen. Hydrogenation of residual amounts of carbon monoxide. Purification of gases from carbon monoxide (IV) by water absorption. Ethanolamine purification. Purification with hot potash solution.* *Literature: [2, 3, 4].* *IWS. Ways to reduce greenhouse gas emissions.* *Literature: [1, 8].*	*2*
8	***Adsorption methods of purification from vapors and gases.*** *Kinetic laws of the adsorption process. Desorption of absorbed substances. Characterization of industrial adsorbents. Requirements for adsorbents in gas purification processes. Adsorption equipment with a movable and fixed adsorbent layer.* *Literature: [2, 3, 4].* *IWS. Ways of handling spent adsorbents.* *Literature: [7, 8, 9].*	*2*
9	***Catalytic methods for purification of vapors and gases.*** *Catalytic purification of gases. The essence and types of catalysis. Industrial catalysts. Design of contact apparatus. Apparatus with a fluidized bed of catalyst. Catalytic purification of organic compounds. Scheme of installation of catalytic afterburning of waste gases.* *Literature: [2, 3, 4].* *IWS. Ways to manage spent catalysts.* *Literature: [7, 8, 9].*	*2*
10	***MCT***	*2*
	Total	***18***

Laboratory classes

In the system of professional training of students, laboratory classes take up 50% of the classroom *load. As a supplement to the lecture course, they lay the foundation and form the basis of the bachelor's degree in ecology. The purpose of laboratory classes is to develop students' experimental skills, research approach to the* subject, and consolidate theoretical material.

No. s/n	Name of the laboratory work	Number of classroom hours
1	Introduction. Safety briefing, familiarization with the program of laboratory work, issuance of methodological literature	1
2	Determination of the concentration of toxic substances in the air using the UG-2 gas analyzer	5
3	Determination of hydrochloric acid concentration in the air	5
4	Determination of ammonia content in the ambient atmosphere	4
5	Determination of atmospheric air pollution using lichen indication	4
6	Rapid method for determining carbon dioxide in the air	5
7	Determination of cesium and potassium radionuclides in leaf litter extract by gamma radiometry	5
8	Determination of beta activity of leaf products by radiometry of their ash residues	5
9	Test	2
Total hours		36

Practical classes

In the system of professional training of bachelors in this discipline, practical classes take up 25% of the class load. Being a supplement to the lecture course, they lay down and form the basis of a bachelor's qualification in the field of ecology, namely the protection of the atmosphere from anthropogenic impact. The content of these classes and the methodology of their conduct should ensure the development of creative activity of the individual. They develop scientific thinking and the ability to use special terminology, allow you to test your knowledge, so this type of work is an important means of prompt feedback. Practical classes should perform not only cognitive and educational functions, but also contribute to the growth of bachelors as creative workers in the field of environmental protection.

The main tasks of the cycle of practical classes:

- *to help bachelors systematize, consolidate and deepen their theoretical knowledge in the field of fundamental methods and technologies of air purification;*
- *to teach bachelors methods of solving practical problems, to promote the acquisition of skills and abilities to perform calculations, graphic and other tasks;*
- *teach them how to work with scientific and reference literature and diagrams;*
- *to develop the ability to learn independently, i.e. to master the methods, ways and techniques of self-study, self-development and self-control.*

No. s/n	**Name of the topic of the practical lesson and a list of key issues (list of didactic support, references to literature and assignments for IWS)**	**Hours**
1	**Calculation of the material balance of the gas cleaning process**. Literature: [4].	**2**
2	**Calculation of a centrifugal scrubber for chlorine removal.** Literature: [4].	**2**
3	**Calculation of a centrifugal scrubber for hydrogen chloride removal.** Literature: [4].	**3**

4	***Calculation of a centrifugal scrubber for cooling a gas stream.*** *Literature: [4].*	***3***
5	***Calculation of a centrifugal scrubber as a droplet collector for a venturi scrubber.*** *Literature: [4].*	***2***
6	***Calculation of a venturi scrubber for ammonia removal.*** *Literature: [4].*	***3***
7	***Calculation of a venturi scrubber for sulfur (II) oxide removal.*** *Literature: [4].*	***3***
	Total	***18***

6. Independent work of the student

Independent work takes up 40% of the credit module study time, including preparation for the test. The main task of students' independent work is to master scientific knowledge in areas that are not included in the list of lecture topics through personal search for information, the formation of an active interest in a creative approach to academic work. In the process of independent work within the educational component, students should learn to analyze in-depth modern approaches to the development and implementation of the latest technologies for the treatment of polluted waste gases, based on the concentrations of pollutants and emission standards for the gas mixture. The student must be able to create the most effective methods for cleaning contaminated gases.

No. s/n	*Name of the topic to be studied independently*	*Number of hours of IWS*
	Absorption methods for cleaning vapors and gases.	
1	*Equilibrium in gas-liquid systems. Kinetic laws of the absorption process. Gas-liquid systems used in industry. Absorption equipment. Tubular film absorbers. Nozzle absorbers, characteristics of nozzles. Plate absorbers with dip and overflow plates, absorbers with a moving nozzle.* *IWS. Disadvantages of absorption methods of purification from vapors and gases.* *Literature: [9].*	*6*
	Purification of gases from sulfur (II) oxide.	
2	*Formation of sulfur (II) oxide emissions. Scheme of contact production of sulfuric acid. Scheme of processes for the production of sulfuric acid from flue gases. Purification of gases from sulfur (II) oxide. Absorption with water. Limestone and lime methods. Magnesite, zinc, ammonia methods. Scheme of gas purification plant from sulfur (II) oxide to produce ammonium nitrate-phosphate. Sulfite-bisulfite methods using soda and sodium hydroxide.* *IWS. Purification of gas mixtures from carbon black.* *Literature: [7, 8, 9].*	*6*
	Purification of gases from hydrogen sulfide.	
3	*Generation of hydrogen sulfide emissions. Vacuum carbonate and phosphate methods. Ethanolamine and iron-soda methods. Hydrogen sulfide recovery by the Claus method.* *IWS. Purification of gas mixtures from mercaptans.* *Literature: [7, 8, 9].*	*6*
	Purification of gases from nitrogen oxides.	

4	*Formation of nitrogen oxide emissions. Scheme of nitric acid production. Absorption by water with hydrogen peroxide additives. Absorption with alkalis and selective sorbents. Purification using urea and nitrosyl sulfuric acid. Disposal of regenerated nitrous gases by catalytic reduction.* *IWS. Ways to reduce nitrogen oxide emissions.* *Literature: [1, 8, 9].*	5
5	***Purification of gases from fluorine compounds.***	
	Generation of hydrogen fluoride and silicon tetrafluoride emissions. Scheme of production of simple superphosphate. Absorption by water and lime milk. Capture of fluoride gases with a solution containing ammonium salts. Utilization of fluoride gases. *IWS. Ways to use captured fluorine gases in industry.* *Literature: [1, 8, 10].*	5
6	***Purification of gases from chlorine compounds.***	
	Formation of chlorine and hydrogen chloride emissions. Absorption by water and aqueous alkali solutions. Use of carbon tetrachloride and titanium. Utilization of chlorine-containing gases. *IWS. Ways to use captured chlorine-containing gases in industry.* *Literature: [1, 8, 10].*	4
7	***Purification of gases from carbon oxides.***	
	Formation of carbon oxide emissions. Absorption of carbon monoxide (II) by copper-aluminum-chloride and copper-ammonia solutions. Purification from carbon (II) oxide by washing with liquid nitrogen. Hydrogenation of residual amounts of carbon monoxide. Purification of gases from carbon monoxide (IV) by water absorption. Ethanolamine purification. Purification with hot potash solution. *IWS. Ways to reduce greenhouse gas emissions.* *Literature: [1, 8].*	4
8	***Adsorption methods of purification from vapors and gases.***	
	Kinetic laws of the adsorption process. Desorption of absorbed substances. Characterization of industrial adsorbents. Requirements for adsorbents in gas purification processes. Adsorption equipment with a movable and fixed adsorbent layer. *IWS. Ways of handling spent adsorbents.* *Literature: [7, 8, 9].*	4
9	***Catalytic methods for purification of vapors and gases.***	
	Catalytic purification of gases. The essence and types of catalysis. Industrial catalysts. Design of contact apparatus. Apparatus with a fluidized bed of catalyst. Catalytic purification of organic compounds. Scheme of installation of catalytic afterburning of waste gases. *IWS. Ways to manage spent catalysts.* *Literature: [7, 8, 9].*	4
	Preparing for the MCT	2
	Preparing for the test	2
	Total hours	48

Policy and control

7. Policy of the academic discipline

Rules of attendance and behavior in the classroom

Students are obliged to actively participate in the educational process, not to be late for classes and not to miss them without a valid reason, not to interfere with the teacher's classes, and not to be distracted by activities unrelated to the educational process.

Rules for awarding reward and penalty points

- *incentive points can be awarded by the teacher only for the performance of creative works in the discipline or additional online specialized courses with the receipt of a relevant certificate:*
  https://www.coursera.org/learn/climate-change-mitigation
  https://www.coursera.org/learn/earth-climate-change
  https://www.coursera.org/learn/act-on-climate
  However, their total cannot exceed 10% of the rating scale.
- *no penalty points are provided for in the discipline.*

Policy of deadlines and retakes

In the event of debts in the 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 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, and opinions of other authors. Hints and cheating during tests and classes are unacceptable; passing a test for another student; copying materials protected by copyright without the permission of the author of the work.
The policy 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". For 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, and provide constructive 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". For more details: https://kpi.ua/code

8. Types of control and rating system for assessing learning outcomes (RSO)

Allocation of study time by type of class and assignments in the discipline according to the working curriculum:

Semester	Study time		Distribution of training hours				Control measures		
	Loans	Acad. H	Lectures	Practical	Lab.	IWS	MCT	PP	Semester control
3	4	120	18	18	36	48	1	-	Test

A student's rating in a discipline is made up of the points he or she receives for it:

A student's rating in a credit module is based on the points he or she receives for laboratory work, for writing a module test, and for the final test.

The semester control is a test.

Rating (weight) points system and evaluation criteria

Rating system and evaluation criteria:

Performing laboratory work.

The weighting score for laboratory work is 4 points. The maximum number of points for all laboratory works is equal:

4 points x 7 works = 28 points

Criteria for evaluating the performance of the laboratory task

Completeness and signs of task completion	**Points.**
The task has been completed in full	4
Minor deficiencies under item 1	3
Late completion of the task, deficiencies under clause 1	2
Poor performance of the task	1
Failure to complete the task	0

Modular control test

The weighting score is 22 points. The maximum number of points for the test is equal to:

22 points x 1 paper = 22 points

Criteria for grading tests

Completeness and signs of response	**Points.**
Full answer.	20-22
A fairly complete answer with some inaccuracies	16-19
The answer does not include secondary or dependent on the main parameters (materials)	13-15
The answer does not include half of the main parameters and several minor parameters or materials	9-12
Superficial answer without analysis of parameters, conditions, materials, facts, incomplete conclusions	5-8
The test is not credited	0-4

Test work for credit

The task of the control work consists of 50 test questions from different sections of the discipline's work program. Each question of the test is evaluated in 1 point.

A prerequisite for admission to the test is passing all laboratory work and writing a module test.

Thus, the semester rating scale in the discipline is as follows:

R = 4 x 7 + 22 + 50 = 100 points

Based on the results of the first 7 weeks, an "ideal student" should score 34 points (for 3 labs and a module test). At the first assessment (week 8), a student receives a "pass" grade if their current rating is at least 15 points.

Based on the results of 13 weeks of study, an "ideal student" should score 46 points (for 6 laboratory works and a module test). At the second assessment (week 14), a student receives a "pass" if their current rating is at least 25 points.

The sum of the points for the control measures during the semester and for the final control work is converted to a final grade according to the table.

Number of points	**Assessment.**
95...100	excellent
85...94	very well
75...84	well
65...74	satisfactorily
60...64	sufficiently

RD<60	*unsatisfactorily*
The conditions for admission are not met	*not allowed*

9. Additional information on the discipline

List of questions to be submitted for the module test

1. Calculate the material balance and draw a block diagram of gas treatment facilities with the following input parameters:

volumetric gas flow rate V_r = 27000 m^3 /hour;

concentration of H_2S in gases C_{H2S} = 0.003 kg/m^3 = 0.3 g/m^3 ;

Concentration in Ambient Air for H_2S = 0.008 mg/m^3 ;

removal efficiency in a centrifugal scrubber η_1 =79.27%=0.7927;

removal efficiency in a venturi scrubber η_2 = 99.67% = 0.9967.

2. Calculate the material balance and draw a block diagram of gas treatment facilities with the following input parameters:

volumetric gas flow rate V_r = 40000 m^3 /h;

concentration of SO_2 in gases C_{SO2} = 0.05 kg/m^3 = 50 g/m^3 ;

Concentration in Ambient Air for SO_2 = 0.5 mg/m^3 ;

removal efficiency in the first venturi scrubber η_1 =73.89%=0.7389;

removal efficiency in the second Venturi scrubber η_2 = 98% = 0.98.

3. Calculate the material balance and draw a block diagram of gas treatment facilities with the following input parameters:

volumetric gas flow rate V_r = 50,000 m^3 /h;

concentration of NO_2 in gases C_{NO2} = 0.003 kg/m^3 = 3 g/m^3 ;

Concentration in Ambient Air for NO_2 = 0.2 mg/m^3 ;

removal efficiency in a centrifugal scrubber η_1 =92.4% = 0.924;

removal efficiency in a venturi scrubber η_2 = 83.3% = 0.833.

4. Calculate the material balance and draw a block diagram of gas treatment facilities with the following input parameters:

Volumetric gas flow rate V_r = 17000 m^3 /h;

concentration of SO_2 in gases C_{SO2} = 0.01 kg/m^3 = 10 g/m^3 ;

Concentration in Ambient Air for SO_2 = 0.5 mg/m^3 ;

removal efficiency in a venturi scrubber η_1 = 99% = 0.99;

removal efficiency in a foam bubble scrubber η_2 = 63.3% = 0.633.

5. Calculate the material balance and draw a block diagram of gas treatment facilities with the following input parameters:

Volumetric gas flow rate V_r = 20,000 m^3 /h;

concentration of NO in gases C_{NO} = 0.0025 kg/m^3 = 2.5 g/m^3 ;

Concentration in Ambient Air for NO = 0.4 mg/m^3 ;

Venturi scrubber removal efficiency η_1 = 90.67%;

removal efficiency in a centrifugal scrubber η_2 = 99.799%.

6. Volumetric gas flow rate V_r = 45000 m^3 /hour;

Concentration of Cl_2 in gases C_{Cl2} = 0.005 kg/m^3 = 5 g/m^3 ;

Concentration in Ambient Air for Cl_2 = 0.1 mg/m^3 ;

removal efficiency in the first Venturi scrubber η_1 =84.135% = 0.84235;

removal efficiency in the second Venturi scrubber η_2 = 90.9% = 0.909.

7. Calculate the material balance and draw a block diagram of gas treatment facilities with the following input parameters:

Volumetric gas flow rate V_r = 17000 m^3 /h;

concentration of SO_2 in gases C_{SO2} = 0.96 g/m^3 = 960 mg/m^3 ;

Concentration in Ambient Air for SO_2= 0.5 mg/m^3 ;

removal efficiency in a centrifugal scrubber η_1 =98.48%=0.9848;

removal efficiency in a venturi scrubber η_2 = 60% = 0.6.

8. Calculate the material balance and draw a block diagram of gas treatment facilities with the following input parameters:

Volumetric gas flow rate V_r = 50,000 m^3 /h;

concentration of SO_2 in gases C_{SO2} = 120 g/m^3 ;

Concentration in Ambient Air for SO_2 = 0.5 mg/m^3 ;

removal efficiency in the first Venturi scrubber η_1 = 38.27% = 0.3827;

removal efficiency in the second Venturi scrubber η_2 = 98% = 0.98;

removal efficiency in the third Venturi scrubber η_3 =99.75%=0.9975.

9. Calculate the material balance and draw a block diagram of gas treatment facilities with the following input parameters:

Volumetric gas flow rate V_r = 13000 m^3 /h;

concentration of NH_3 in gases C_{NH3} = 4.3 g/m^3 ;

Concentration in Ambient Air for NH_3 = 0.2 mg/m^3 ;

removal efficiency in the first centrifugal scrubber η_1 =77.5%=0.775;

removal efficiency in the second centrifugal scrubber η_2 = 99.5% = 0.995.

10. Calculate the material balance and draw a block diagram of gas treatment facilities with the following input parameters:

Volumetric gas flow rate V_r = 24500 m^3 /hour;

The concentration of SO_2 in gases C_{SO2} = 7 g/m^3 ;

Concentration in Ambient Air for SO_2 = 0.5 mg/m^3 ;

removal efficiency in a venturi scrubber η_1 = 59.5% = 0.595;

removal efficiency in a foam bubble scrubber η_2 = 99.99% = 0.9999.

11. Calculate the material balance and draw a block diagram of gas treatment facilities with the following input parameters:

Volumetric gas flow rate V_r = 72000 m^3 /hour;

concentration of H_2S in gases C_{H2S} = 0.99 g/m^3 = 990 mg/m^3 ;

Concentration in Ambient Air for H_2S = 10 mg/m^3 ;

removal efficiency in a centrifugal scrubber η_1 = 76.72%;

Venturi scrubber removal efficiency η_2 = 99.99%.

12. Calculate the material balance and draw a block diagram of gas treatment facilities with the following input parameters:

Volumetric gas flow rate V_r = 22000 m^3 /h;

concentration of SO_2 in gases C_{SO2} = 2.4 g/m^3 ;

Concentration in Ambient Air for SO_2 = 0.5 mg/m^3 ;

removal efficiency in the first centrifugal scrubber η_1 = 64.08% = 0.6408;

removal efficiency in the second centrifugal scrubber η_2 = 99% = 0.99.

13. Calculate the material balance and draw a block diagram of gas treatment facilities with the following input parameters:

Volumetric gas flow rate V_r = 120000 m^3 /h;

concentration of SO_2 in gases C_{SO2} = 0.3 g/m^3 ;

Concentration in Ambient Air for SO_2 = 0.5 mg/m^3 ;

removal efficiency in the first Venturi scrubber η_1 = 45.28 % = 0.4528;

removal efficiency in the second Venturi scrubber η_2 = 99.996% = 0.99996.

14. Calculate the material balance and draw a block diagram of gas treatment facilities with the following input parameters:

Volumetric gas flow rate V_r = 270000 m^3 /hour;

concentration of HCl in gases C_{HCl} = 7 g/m^3 ;

Concentration in Ambient Air for. HCl = 0.2 mg/m^3 ;

removal efficiency in the first Venturi scrubber η_1 = 86%;

removal efficiency in the second Venturi scrubber η_2 = 98%.

15. Calculate the material balance and draw a block diagram of gas treatment facilities with the following input parameters:

Volumetric gas flow rate V_r = 20,000 m^3 /h;

concentration of H_2SO_4 in gases C_{H2SO4} = 3 g/m^3 ;

Concentration in Ambient Air for H_2SO_4 = 0.3 mg/m^3 ;

removal efficiency in the first centrifugal scrubber η_1 = 86%;

removal efficiency in the second centrifugal scrubber η_2 = 98%.

16. Calculate the material balance and draw a block diagram of gas treatment facilities with the following input parameters:

Volumetric gas flow rate V_r = 40000 m^3 /h;

concentration of HCl in gases C_{HCl} = = 70 g/m^3 ;

Concentration in Ambient Air for. HCl = 0.2 mg/m^3 ;

removal efficiency in a centrifugal scrubber η_1 = 82.9 % = 0.829;

removal efficiency in a venturi scrubber η_2 = 99.99% = 0.9999.

17. Calculate the material balance and draw a block diagram of gas treatment facilities with the following input parameters:

Volumetric gas flow rate V_r = 25000 m^3 /h;

concentration of NaF in gases C_{NaF} = 4 g/m^3 ;

Concentration in Ambient Air for NaF = 0.03 mg/m^3 ;

removal efficiency in the first Venturi scrubber η_1 = 99.75%;

removal efficiency in the second Venturi scrubber η_2 = 98%.

18. Calculate the material balance and draw a block diagram of gas treatment facilities with the following input parameters:

Volumetric gas flow rate V_r = 280000 m^3 /hour;

concentration of HF in gases C_{HF} = 0.04 g/m^3 ;

Concentration in Ambient Air for HF = 0.02 mg/m^3 ;

removal efficiency in the first Venturi scrubber η_1 = 77.32% = 0.7732;

removal efficiency in the second Venturi scrubber η_2 = 68% = 0.68;

removal efficiency in the third Venturi scrubber η_3 =59.75%=0.5975.

19. Calculate the material balance and draw a block diagram of gas treatment facilities with the following input parameters:

Volumetric gas flow rate V_r = 25000 m^3 /h;

Concentration of SiF_4 in gases C_{SiF4} = 2.75 g/m^3 ;

Concentration in Ambient Air for SiF_4 = 0.02 mg/m^3 ;

removal efficiency in the first scrubber η_1 = 86%;

removal efficiency in the second scrubber η_2 = 98%.

20. Calculate the material balance and draw a block diagram of gas treatment facilities with the following input parameters:

Volumetric gas flow rate V_r = 5000 m^3 /h;

concentration of Na_2SiF_6 in gases $C_{Na2SiF6}$ = 0.275 g/m^3 ;

Concentration in Ambient Air for Na_2SiF_6 = 0.03 mg/m^3 ;

removal efficiency in the first centrifugal scrubber η_1 = 90%;

removal efficiency in the second centrifugal scrubber η_2 = 97%.

21. Calculate the material balance and draw a block diagram of gas treatment facilities with the following input parameters:

Volumetric gas flow rate V_r = 50,000 m^3 /h;

Concentration of SO_2 in gases C_{SO2} = 0.9 kg/m^3 ;

Concentration in Ambient Air for SO_2 = 0.5 mg/m^3 ;

removal efficiency in the first Venturi scrubber η_1 = 86%;

removal efficiency in the second Venturi scrubber η_2 = 61.3%.

22. Calculate the material balance and draw a block diagram of gas treatment facilities with the following input parameters:

Volumetric gas flow rate V_r = 15000 m^3 /h;

concentration of NO in gases C_{NO} = 0.0093 g/m^3 = 9.3 mg/m^3 ;

Concentration in Ambient Air for NO = 0.4 mg/m^3 ;

Venturi scrubber removal efficiency η_1 = 90.1%;

removal efficiency in a centrifugal scrubber η_2 = 98%.

23. Calculate the material balance and draw a block diagram of gas treatment facilities with the following input parameters:

Volumetric gas flow rate V_r = 30000 m^3 /h;

concentration of NO_2 in gases C_{NO2} = 0.0014 kg/m^3 = 1.4 g/m^3 ;

Concentration in Ambient Air for NO_2 = 0.2 mg/m^3 ;

removal efficiency in a centrifugal scrubber η_1 = 98.99%;

removal efficiency in a venturi scrubber η_2 = 99%.

24. Calculate the material balance and draw a block diagram of gas treatment facilities with the following input parameters:

Volumetric gas flow rate V_r = 7000 m^3 /h;

concentration of H_2S in gases C_{H2S} = 0.0046 g/m^3 = 4.6 mg/m^3 ;

Concentration in Ambient Air for H_2S = 0.008 mg/m^3 ;

removal efficiency in the first Venturi scrubber η_1 = 89.67% = 0.8967;

removal efficiency in the second Venturi scrubber η_2 = 99.7% = 0.997.

25. Calculate the material balance and draw a block diagram of gas treatment facilities with the following input parameters:

Volumetric gas flow rate V_r = 13000 m^3 /h;

concentration of SO_2 in gases C_{SO2} = 4.3 g/m^3 ;

Concentration in Ambient Air for SO_2 = 0.5 mg/m^3 ;

removal efficiency in the first Venturi scrubber η_1 = 99.5% = 0.995;

removal efficiency in the second Venturi scrubber η_2 = 99.89% = 0.9989.

Work program of the discipline (syllabus):

Compiled by *Doctor of Technical Sciences, Associate Professor Ivanenko O. I.*

Approved by *the Department of E and TPP (protocol № 14 from 8.06.2022).*

Approved by *the ICF Methodological Commission (protocol № 10 from 24.06.2022)*