Course: General and Inorganic Chemistry		
Language: Croatian		
Lecturer: Dr. Svjetlana Krištafor, Assistant Professor; Dr. Ivana Steinberg, Assistant Professor; Dr. Stjepan Milardović, Associate Professor		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**2**	**30**
Seminar	**2**	**30**
		Overall: 90
		ECTS: 8

PURPOSE: To gain a basic knowledge in general chemistry and chemical calculation; to introduce students to the world of chemistry emphasizing the structure of matter; acquiring basic laboratory skills; to introduce students with the properties of chemical elements and compounds based on ionization energy, electron affinity, electronegativity, standard reduction potential, ionic radius etc.; to introduce students with periodic trends, aspects of bioinorganic chemistry, organometallic compounds, as well as theoretical structure models, industrial and analytical aspects of inorganic chemistry; to be able to apply knowledge gained in this course in more advanced courses and throughout ones career.

THE CONTENTS OF THE COURSE:

1st week: Introduction to the course; the importance of chemistry and chemical principles; definitions – chemistry today; atom – an overview of discoveries;

2nd week: The discovery of electron and nucleus; introduction to quantum mechanics; the characteristics of electromagnetic radiation – atomic spectra; quantum theory.

3rd week: Quantum theory and atomic structure; atomic orbitals and energy levels; electronic structure and periodic table.

4th week: Chemical bonds – ionic and covalent bonds; Lewis structures; Resonance.

5th week: Ionic character of covalent bond; intermolecular forces; formal charge; metallic bond; molecular structure and shape; molecular orbital theory; electron configurations and bond order of diatomic molecules

6th week: Valence bond theory and hybridization; geometry of molecule; multiple bonds; coordination compounds.

7th week: The properties of gases; the gas laws; applications of ideal gas law; the kinetic model of gases; real gases; liquids and solids – structure.

8th week: Thermochemistry; enthalpy and entropy; Gibbs free energy;

physical equilibria; phase transitions.

9th week: Chemical equilibria; acids and bases; buffers; solubility equilibria.
10th week: Electrochemistry – oxidation/reduction equations; electrochemical cells; chemical kinetics; reaction rates and mechanisms; nuclear chemistry.

11th week: The law of chemical periodicity and periodic table; periodic trends in physical and chemical properties along the periods and groups; periodicity of chemical properties (electronegativity, ionization energy, electron affinity, oxidation numbers, standard-state reduction potential); periodic trends in physical properties (melting point, boiling points, etc.); the general atomic and physical properties of molecular hydrogen, preparation in industrial and laboratory scale; ionized form of hydrogen (ionic hydrides, covalent hydrides, polymeric and intermediate hydrides); the hydrogen bond and hydrogen isotopes.

12th week: The elements of 18th group (noble gases) - atomic and physical properties of the elements, preparation, production and use; the general chemical properties of the halogen group of elements, physical and chemical trends along the group, the change of electronegativity along the group, properties of compound concerning oxidation numbers in the range :-1, 0, +1, +3, +4, +5, +7; chemical reactivity of diatomic halogens, preparation and properties of hydrogen halides; psudohalogens, preparation and properties; oxoacids and oxoacid salts (preparation and properties).

13th week: The general chemical properties of the chalcogens group of the elements, the properties of compounds concerning oxidation numbers in the range –2, –1, 0, +2, +3, +4, +6; chemical properties and preparation of dioxygen (O_2), ozone (O_3) and atomic oxygen (O); the properties of oxygen compounds concerning negative oxidation state (O^{2-}), (O_2^{2-}), (O_2^-), (O3-) and positive oxidation state (O2+); physical properties and structure of water, oxoacids of sulfur, selenium and tellurium, thioacids; redox properties along the group; The general chemical properties of the nitrogen group of the elements;the change of electronegativity along the group, properties of compounds concerning oxidation states in the range –3, -1, 0, +1, +3, +5; preparation and chemical properties of ammonia and ammonium salts, nitric acid, hydrazine, nitrogen oxides (N_2O, NO, NO_2, N_2O_3, N_2O_5) and oxoacid of nitrogen; preparation, use and chemical properties of hydrides of nitrogen, phosphorus, arsenic, antimony and bismuth;

14th week: The general chemical properties of the carbon group of the elements; preparation, physical and chemical properties of carbon (diamond, graphite, fullerene, graphene) CO and CO_2; chemical properties of the carbon (negative oxidation state) compounds (carbides) and silicon (silicide's); chemical properties, preparation and use of silicates and silicon; chemical and physical properties of germanium tin and lead compounds of positive oxidation state (+2, +4); lead battery; the general chemical properties of the boron group of the elements; properties of compounds concerning oxidation states in the range –3, -1, 0, +1, +2, +3; preparation, use and chemical properties of ortoboric acid; preparation, use and chemical properties of aluminum, aluminum trihalides, amphoteric properties of aluminum and aluminum passivity; chemical properties of indium and gallium compounds.

15th week: The 2nd group of the elements (alkaline earth metals); chemical reactivity and trends of chemical and physical properties along the group; introduction to hydrides, oxides, oxoacides, hydroxides and organometallic compounds; the 1st group of the elements (alkali metals); chemical reactivity and trends of chemical and physical properties along the group; introduction to hydrides, peroxides, superoxide's, hydroxides and organometallic compounds; preparation of NaOH, NaHCO3, NaCl and gypsum.

GENERAL AND SPECIFIC COMPETENCE:

The main objective of this course is to give students a basic foundation in chemistry, including development of skills required for problem solving and the application of basic chemical concepts. Students will learn to think at the atomic structural level of matter and to relate the electronic structure of atoms to the chemical properties of elements. The understanding of how atoms combine with one another and its importance in relation to the research in pharmaceuticals, agricultural chemicals, polymers and synthetic materials. After completion of this course, students will be able to use the periodic table and understand the symbolism and language of chemistry. After the successful completion of the laboratory part of this course, students will have acquired the skills necessary for scientific work – critical thinking and observation skills, ability to safely handle chemical reagents. The students will understand the basic of inorganic chemistry and adequate application of low of periodicity to predict the properties of elements or compounds. Using the modern theory of bonding students will be able to predict the structure, reactivity, acid-base properties and redox properties of elements and compounds. After the successful completion of laboratory part of this course student acquire skills necessary for scientific work – thinking and observation skills, ability to safely handle chemical reagents.

KNOWLEDGE TESTING AND EVALUATION:

Three written tests during the semester

Written and oral examinations

Exam related to the laboratory practice (successful completion of laboratory practice is needed for completion of the course)

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student survey

LITERATURE:

1. I. Filipović, S. Lipanović: "*Opća i anorganska kemija*", Školska knjiga, Zagreb, 1991.

2. N. N. Greenwood, A. Earnshaw: "*Chemistry of the Elements*", Pergamon Press, Oxford, 2002.

3. D. F. Shriver, P. W. Atkins: "*Inorganic Chemistry*", 3rd ed. Oxford University Press, 1999.

4. P. Atkins, L. Jones: "*Chemical Principles: The Quest for Insight*", 4th ed. New York, NY: W.H. Freeman and Company, 2007.

Course: Analytical Chemistry		
Language: English		
Lecturer: Assist. Prof. Šime Ukić, Ph. D.		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	2	30
Laboratory	1	15
Seminar	0	0
		Overall: 45
		ECTS: 5

PURPOSE: Collection, determination and interpretation of sample's information. Familiarising with classical qualitative and quantitative methods of chemical analysis.

THE CONTENTS OF THE COURSE:

1. Introduction to analytical chemistry. Basics. Sample-analyte-matrix-signal-information. Planning of the analytical work.
2. Chemical equilibrium and its role in controlling of the analytical system.
3. Acid-base reactions. Dissociation of acids and bases. Hydrolyzes of salt. Ampholites. Determination of pH value in solutions. Calculation examples.
4. Influence of pH value on composition of polyprotic acids and polyfunctional bases. Calculation examples.
5. Equilibrium of complexes. Precipitation reactions. Solubility product constant. Redox reactions. Electrode potential. Nernst equation. Constant of redox equilibrium.
6. Qualitative analysis. Dissolving of solid sample. Systematic analysis of cations. Systematic analysis of anions.
7. Gravimetry. Gravimetric methods. Weighting of analytical sample. Precipitation. Varieties and properties of precipitate.
8. Solubility of precipitate. Precipitate pollution. Avoiding the pollution and performing the purification. Drying and annealing of precipitate. Calculation examples.
9. Titrimetric methods of analysis. Indicators. Titration curve. End-point of titration. Equivalence point. Direct and back titration. Primary and secondary standards, characteristics. Standardization.
10. Acid-base titrations. Nature and applicability of acid-base indicators. Standards. Titration of strong and weak acids. Titration of strong and weak bases. Calculation examples.
11. Titration of polyprotic acids and polyfunctional bases. Acid-base titrations in non-aqueous media. Selection of solvent and indicator. Calculation examples.
12. Complexometric titration. EDTA complexes. Calculation examples.

13. Redox titrations. Regulation of electrode potential. Indicators for redox titrations. Varieties of redox titrations. Calculation examples.

14. Precipitation titrimetry. Mohr's, Volhard's and Fajans's titration methods. Calculation examples.

15. Gravimetric titrimetry. Culometric titrimetry.

GENERAL AND SPECIFIC COMPETENCE:

Student acquires basic knowledge relating analytical chemistry, prerequisite for solving analytical problems independently.

KNOWLEDGE TESTING AND EVALUATION:

Three (3) partial tests during the semester. Students can be released from exam if they collect sufficient points from the tests. If not, they need to pass written and oral exam.

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student survey.

LITERATURE:

- Z. Šoljić, Kvalitativna kemijska analiza anorganskih tvari, FKIT, Zagreb, 2003.
- Z. Šoljić, Osnove kvantitativne kemijske analize, FKIT, Zagreb, 2003.
- M. Kaštelan-Macan, Analitička kemija, I dio (Gravimetrija), Sveučilište u Zagrebu, Zagreb, 1991.
- Z. Šoljić, M. Kaštelan-Macan, Analitička kemija: Volumetrija, FKIT, Zagreb, 2002.
- D. A. Skoog, D. M. West, F. J. Holler, Osnove analitičke kemije, 1st ed., Školska knjiga, Zagreb, 1999.
- D. C. Harris: Quantitative Chemical Analysis, W. H. Freedman and Co., New York, 2001.

Course: Physical Chemistry I

Language:

Lecturer: Marica Ivanković ; Jelena Macan

TEACHING	WEEKLY	SEMESTER
Lectures	**3**	**45**
Laboratory	**2**	**30**
Seminar	**0**	**0**
		Overall: 75
		ECTS: 6

PURPOSE:

Understanding of basic laws and theories of physical chemistry as applied in practice of chemical engineering. Development of capabilities of logical problem solving and equation derivation.

THE CONTENTS OF THE COURSE:

1. week: Introduction, phase states of matter, ideal gas – equation of state
2. week: Kinetic-molecular theory of gasses, velocity and energy of gas molecules, Maxwell-Boltzmann distribution
3. week: Real gasses – equation of state, liquefaction
4. week: First partial exam
5. week: Thermodynamics: heat and work, The first law, internal energy, enthalpy, heat capacities
6. week: Thermochemistry: Hess's law, Kirchhoff's law, adiabatic processes
7. week: Spontaneous processes and equilibrium, Carnot cycle, The second law of thermodynamics, reversibility of processes
8. week: Gibbs free energy, The third law of thermodynamics, dependence of Gibbs energy on temperature and pressure, fugacity
9. week: Second partial exam
10. week: deal and non-ideal mixtures, chemical potential, Gibbs-Duhem equation
11. week: Phase equilibria, Clapeyron and Clausius-Clapeyron equation, triple point, phase rule
12. week: Raoult's law, colligative properties of mixtures, Henry's law
13. week: Distillation, vapour pressure diagrams, boiling diagrams
14. week: Basics of phase equilibria of three-component systems, distribution law, crystallization, osmotic equilibrium
15. week: Third partial exam

Laboratory work:

1. Determination of molecular mass by V. Meyer's method

2. Calorimetry – determination of heat of reaction
3. Cryoscopy
4. Boiling diagram
5. Nernst distribution law

GENERAL AND SPECIFIC COMPETENCE:

Describing the basic physical chemistry laws regarding gasses, thermodynamics and phase equilibria.
Applying knowledge of mathematics and deriving the equations (clearly describing the physical phenomena under consideration).
Preparing and performing laboratory experiments.
Analysis and interpretation of experimental results.
Preparation of laboratory reports.

KNOWLEDGE TESTING AND EVALUATION:

Exams, partial exams, entrance and final colloquium in laboratory work.

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student opinion surveys

LITERATURE:

P. Atkins, J. de Paula, Atkin's Physical Chemistry, 8th edition, Oxford University Press, Oxford 2006.

Course: Mass and Energy Balances		
Language: English		
Lecturer: Prof. Bruno Zelić, PhD		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**0**	**0**
Seminar	**3**	**45**
		Overall: 75
		ECTS: 7

PURPOSE: Application of principles of conservation of mass and energy to chemical, biological and environmental process systems. Introduction to engineering process analysis and calculations for steady and non-steady state systems.

THE CONTENTS OF THE COURSE:

1st week

Basic terms, concepts and techniques used in calculations in chemical engineering. Processes and process parameters. Mass balance (general form, differential balance, integral balance)

2nd week

Mass balance of steady-state process. Mass balance of non steady-state process. Calculation based on mass balances of steady-state processes (system of linear equations)

3rd week

Mass balances - process without chemical reaction performed in single process unit.

4th week

Mass balances – process with chemical reaction performed in single process unit.

5th week

Mass balances – combustion process.

1st partial test

6th week

Mass balances – process without chemical reaction in multiple process units.

7th week

Mass balance – process with chemical reaction in multiple process units.

8th week

Mass balances – process with recirculation, bypass flow, inlet and outlet streams without and with chemical reaction.

9th week

Energy and chemical engineering. Basic terms in energy balances. General form of the energy balance.

10th week

Energy balance for closed systems. Energy balance for open systems (steady-state processes).

2nd partial test

11th week

Calculations in chemical engineering based on energy balance. Energy balance for single component process. Energy balance for multiple component process.

12th week

Energy balance – process without chemical reaction.

13th week

Energy balance – process with chemical reaction.

14th week

Energy balance – combustion process.

15th week

Simultaneous mass and energy balance. Application of numerical methods in solving of energy balances.

3rd partial test

GENERAL AND SPECIFIC COMPETENCE:

Achieving of basic knowledge needed for solving of practical problems in process analysis using chemical engineering methodology.

KNOWLEDGE TESTING AND EVALUATION:

Continuous grading and evaluation during teaching – 100 points

a) Partial tests (3) – 75 points

b) Home work (10) – 20 points

c) Class attendance – 5 points

or

Written exam – 100 points

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Universityof Zagreb student survey

LITERATURE:

1. M. Brezinščak: “Mjerenje i računanje u tehnici i znanosti”, Tehnička knjiga, Zagreb, 1966.
2. T. Cvitaš, N. Kallay: “Fizičke veličine i jedinice međunarodnog sustava”, Školska knjiga, Zagreb, 1981.
3. Z. Dugi-I. Lovreček: “Osnove kemijskog računanja”, Školska knjiga, Zagreb, 1973.
4. D. M. Himmelblau, “Basic Principles and Calculations in Chemical Engineering”, Prentice Hall, New Jersey, 1982.
5. R. M. Felder and R. W. Rousseeau, “Elementary Principles of Chemical Processes”, J. Wiley, New York, 2000.

Course: Transport phenomena (KI)		
Language: English		
Lecturer: Jasna Prlić Kardum		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**3**	**45**
Laboratory	**2**	**30**
Seminar		
		Overall: 75
		ECTS: 7

PURPOSE: Acquiring knowledge of the transport phenomena (momentum, heat and mass) with uniform approach to the transfer processes which are the basis of all chemical processes and applied sciences.

THE CONTENTS OF THE COURSE:

Week 1

General conservation law. Steady and unsteady transport processes. Momentum, heat and mass flux. Mechanism of momentum transport. Properties of fluids; liquids and gasses. Newton's law of viscosity.

Week 2

Conservation laws: conservation of mass, momentum and energy. Types of fluid motion. Laminar, steady flow in horizontal circular tube and between two parallel plates; velocity distribution; head loses.

Week 3

Turbulent flow. The causes of turbulence. Boundary layer theory. Universal velocity distribution in horizontal tube. Principle of similarity; dimensionless numbers. Application of dimensional analysis. Dependence of the friction factor on the Reynolds number and relative roughness.

Week 4

Flow around bodies; total drag force of a body moving through a fluid; Estimate of drag force. Dependence of the drag coefficient on the Reynolds number.
Flow in the mixing tank. Dependence of power number and friction factor on the Reynolds number.

Week 5

Flow through the packed beds; geometric characteristics of bed and influence on transport mechanism. General principles of momentum transport; correlation equation Eu=f(Re, geometric characteristics of system).

Week 6
Partial exam I

Week 7
Heat transfer: conduction, convection, radiation Conduction heat transfer: steady conduction through different geometric bodies.

Week 8
Unsteady-state heat conduction: bodies with finite dimensions, semi-infinity body. Temperature distribution in the body.

Week 9
Convective heat transfer. Thermal boundary layer. Convective heat transfer coefficient. Convective heat transfer with laminar and turbulent fluid flow for different geometric system. Dimensionless correlation equations at different hydrodynamic conditions and geometric characteristics of system.

Lab assignment I: Pump power calculation

Week 10

Overall heat transfer; thermal resistance, relevant difference of temperature. Radiant heat transfer.

Lab assignment II: Fluid flow through the pipeline

Week 11
Partial exam II

Lab assignment III: Flow around bodies

Week 12
Mass transfer. Steady mass transfer with diffusion; equimolar-counter diffusion, diffusion component A throw inert component B. Unsteady diffusion.
Lab assignment IV: Unsteady conductive heat transfer

Week 13
Mass transfer with laminar and turbulent fluid flow. Convective mass transfer coefficient. Dimensionless correlation equations.
Lab assignment V: Convective heat transfer

Week 14
Analogies in momentum, heat and mass transport.

Lab assignment VI: Mass transfer, equimolar-counter diffusion

Week 15

Partial exam III
GENERAL AND SPECIFIC COMPETENCE: Acquiring knowledge of transport phenomena necessary to understand fundamental chemical engineering courses.
KNOWLEDGE TESTING AND EVALUATION: 3 partial exams. Students who do not achieve minimum points through partial exams have to complete the written and oral exam.
MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS: Student survey.
LITERATURE: R. G. Griskey, Transport Phenomena and Unit Operations A Combined Approach, John Wiley & Sons, Inc., New York, 2006. R. B. Bird, W.E. Stewart, E.N. Lightfoot, Transport Phenomena, Revised 2nd Edition, John Wiley & Sons, Inc., 2006. J. R. Welty, E.E. Wicks, R.E. Wilson, Fundamentals of Momentum, Heat and Mass Transfer, 2nd Ed., J. Wiley Sons, 1976. E.L. Cussler, Diffusion: Mass Transfer in Fluid Systems, Cambridge University Press, Cambridge, 1997.

Course: Chemical Engineering Thermodynamics		
Language: Croatian		
Lecturer: Prof. dr. sc. Marko Rogošić		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	3	45
Laboratory	1	15
Seminar	1	15
		Overall: 75
		ECTS: 7.0

PURPOSE:

Within the framework of this course the students will master the application of fundamental laws of thermodynamics as well as mathematical methods for solving the chemical engineering problems of: estimation of thermodynamic functions of pure substances, mixtures and solutions, phase equilibria calculation, chemical equilibria calculation. In addition, the student will get acquainted with the fundamentals of the non-equilibrium and irreversible thermodynamics.

THE CONTENTS OF THE COURSE:

Week 1

Introduction to thermodynamics of real systems – what is thermodynamics, what does it deal with, classification of thermodynamics, course contents, prerequisites, basic definitions: thermodynamic systems, functions, parameters, phases, states, processes, laws of thermodynamics,

Volumetric properties of real fluids – *pT*-diagram, Gibbs phase rule, ideal gas equation, deviations from ideality, compressibility coefficient, Joule-Thomson coefficient, liquefaction of real fluid

Volumetric properties of real fluids – gas particles interaction, Lennard-Jones potential, virial equation, Boyle temperature, BWR equation

Seminar: getting acquainted with the seminar numeric problems programme, laboratory programme as well as with the seminar individual problems programme (Rogošić)

Seminar – numeric problems: Volumetric properties of real fluids (Rogošić)

Week 2

Volumetric properties of real fluids – van der Waals equation, parameters, liquefaction work, equilibrium pressure, corresponding states principle, thermodynamic similarity principle, critical compressibility coefficient, Pitzer acentric coefficient, Lee-Kesler correlation

Volumetric properties of real fluids – third order polynomial equation of states, Redlich-Kwong, Soave-Redlich-Kwong, Peng-Robinson, calculation of *pvT*-properties, comparison of equations, gas mixtures

Thermodynamic properties of real fluids – steam (heat) tables and diagrams, construction of *ph* and *sT*-diagrams, departure functions, corresponding states principle, thermodynamic similarity principle, Yen-Alexander and Lee-Kesler correlation for enthalpy and entropy

Seminar – numeric problems: Volumetric properties of real fluids (Rogošić)

Seminar – numeric problems: Volumetric properties of real fluids, preparation for the seminar individual problem 1 (Rogošić)

Week 3

Thermodynamic properties of real fluids – fugacity and fugacity coefficient, fugacity as a departure function, calculating Gibbs energy using fugacity, fugacity vs. pressure and fugacity vs. temperature correlations, fugacity and the corresponding states principle, fugacity and the thermodynamic similarity principle

Thermodynamics of real solutions – ideal solution definition, volume, enthalpy and entropy of mixing, the causes of non-ideality of real solutions

Thermodynamics of real solutions – partial molar functions in two- and multicomponent real systems, Gibbs-Duhem equation, partial fugacity and partial fugacity coefficient, mixing functions, excess functions

Seminar – numeric problems: Thermodynamic properties of real fluids (Rogošić)

Seminar – individual problems: equation of states of real gases (Rogošić)

Week 4

Thermodynamics of real solutions – activity and activity coefficient, standard states of pure gas, liquid and solid as well as of gas and liquid mixture components, Poynting factor, Lewis-Randall rule, infinitely dilute solution, Henry law for real solutions

Thermodynamics of real solutions – determination of partial molar functions using the methods of intercept, tangent, apparent molar functions, as well as by the Gibbs-Duhem equation, Gibbs energy vs. activity and activity coefficient correlation

Activity coefficient models – Activity coefficient models: Margules, power series, Van Laar, Wohl, regular and athermal solutions, Scatchard-Hildebrand; Flory-Huggins interaction parameter, solubility parametar, determination of model parameters

Seminar – numeric problems: Thermodynamic properties of real fluids (Rogošić)

Seminar – individual problems: equation of states of real gases (Rogošić)

Week 5

Activity coefficient models – activity coefficient models: Wilson, Tsuboka-Katayama, Hiranuma, NRTL, UNIQUAC; structural group contribution models: ASOG, UNIFAC

Recapitulation – thermodynamics of real solutions and activity coefficient models, preparation for partial exam

Seminar – numeric problems: Thermodynamics of real solutions (Rogošić)

Seminar – individual problems: equation of states of real gases (Rogošić)

Week 6

Partial exam 1 – volumetric properties of real fluids, thermodynamic properties of real fluids, thermodynamics of real solutions, activity coefficient models

Thermodynamic equilibrium – equilibrium criteria in isolated and closed systems, system stability criteria, reacting systems, thermodynamic interpretation of Le Chatelier principle

Vapour–liquid equilibria – equilibrium criteria using chemical potentials and partial fugacities, phase non-ideality description using equation of states and activity coefficient models, equilibrium criteria for ideal vapour and liquid phase, respectively

Laboratory: partial molar volumes (Rogošić)

Laboratory: partial molar volumes (Rogošić)

Week 7

Vapour–liquid equilibria – phase diagrams, *Txy*-diagram, *pxy*-diagram, *xy*-diagram, systems of regular behaviour, azeotropic systems, consistency tests

Vapour–liquid equilibria – phase equilibrium calculations in chemical engineering: bubble point, dew point, flash, numerical methods in vapour–liquid equilibrium calculations

Vapour–liquid equilibria – high pressure range: retrograde condensation, equilibrium calculations; solubility of gases in liquids, Prausnitz and Shair procedure

Laboratory: Vapour–liquid equilibria (Rogošić)

Laboratory: Vapour–liquid equilibria (Rogošić)

Week 8

Liquid–liquid equilibria – equilibrium criteria using chemical potentials, phase diagrams, vapour pressure vs. composition, Gibbs energy of mixing vs. composition, miscibility as influenced by temperature and pressure, determination of model parameters using experimental data, ternary diagrams, lever rule, calculation of equilibrium composition in two- and three-component systems

Liquid–liquid equilibria – breaking azeotropes by changing pressure or by adding the third component, Liquid–liquid–vapour equilibria, phase diagrams, phase equilibrium calculations

Solid–liquid equilibria – equilibrium criteria using chemical potentials and partial fugacities, phase diagrams, eutectics, intermolecular compounds, peritectics, calculation of solubility of a solid in a liquid, Schroeder equations, ternary eutectics, eutectic troughs

Laboratory: Liquid–liquid equilibria (Rogošić)

Laboratory: Liquid–liquid equilibria (Rogošić)

Week 9

Solid–gas equilibria – equilibrium criteria using chemical potentials and partial fugacities, supercritical fluids as solvents, calculation of solubility of a solid in a fluid (gas)

Recapitulation – thermodynamic equilibrium, vapour–liquid equilibria, liquid–liquid equilibria, solid–liquid equilibria, solid–gas equilibria

Seminar – numeric problems: Thermodynamics of real solutions (Rogošić)

Seminar: laboratory data analysis (Rogošić)

Week 10

Partial exam 2 – thermodynamic equilibrium, vapour–liquid equilibria, liquid–liquid equilibria, solid–liquid equilibria

Chemical equilibria – chemical equilibrium criterion: minimum Gibbs energy, stoichiometric sum of chemical potentials, homogeneous chemical reactions, standard Gibbs energy of reaction, standard Gibbs energy of reaction vs. temperature correlation

Chemical equilibria – examples of solving homogeneous chemical equilibria problems, chemical equilibria at multireaction systems, determination of minimum number of reaction, Denbigh method, matrix elimination method

Seminar – numeric problems: Vapour–liquid equilibria (Rogošić)

Seminar: preparation for the seminar individual problem 2 (Rogošić)

Week 11

Chemical equilibria – determination of global minimum Gibbs energy of a systems, heterogeneous chemical equilibria

Thermodynamics of irreversible processes – external and internal entropy change, example of irreversible processes, heat and mass transfer, thermodynamic potentials and flows, entropy production, examples: thermal and mass diffusion

Thermodynamics of irreversible processes – examples: simultaneous thermal and mass diffusion, irreversible expansion of ideal gas, chemical reaction, affinity

Seminar – numeric problems: Liquid–liquid equilibria (Rogošić)

Seminar – individual problems: Vapour–liquid equilibria (Rogošić)

Week 12

Thermodynamics of irreversible processes – phenomenological equations, flow vs. potential relationship, Onsager phenomenological coefficients, examples: electric current in electrolytes and metals, Ohm law, mass diffusion, Fick law, simultaneous diffusion of two substances

Thermodynamics of irreversible processes – examples: thermal diffusion, Fourier law, thermoelectric effects, cross phenomenological coefficients, chemical reactions, simple and complex

Thermodynamics of irreversible processes – stationary and non-stationary states examples, thermal diffusion, Prigogine principle and its consequences: chemical potential gradient, sequential chemical reactions, stability of a stationary state, Lyapunov stability theory

Seminar – numeric problems: Liquid–liquid equilibria (Rogošić)

Seminar – individual problems: Vapour–liquid equilibria (Rogošić)

Week 13

Partial exam 3 – chemical equilibria, thermodynamics of irreversible processes

Recapitulation – discussion on the course content, lectures, seminars, laboratory and individual seminar problems, questions and answers, preparation of final written and oral exam

Seminar – numeric problems: Solid–liquid equilibria (Rogošić)

Seminar – individual problems: Vapour–liquid equilibria (Rogošić)

GENERAL AND SPECIFIC COMPETENCE:

General competences:

Application of fundamental laws of thermodynamics in combination with literature or own experimental data for solving the chemical engineering problems of: 1. estimation of thermodynamic functions of gases and liquids depending on the given pressure, temperature and composition, 2. characterisation of vapour–liquid and liquid–liquid equilibria and 3. characterisation of chemical equilibria

Understanding of the basic principles of irreversible thermodynamics

Special competences:

Calculation of thermodynamic functions of real fluids using equations of state: virial, vdW, RK, SRK, PR, Lee-Kesler

Calculation of thermodynamic functions of real solutions using activity coefficient models: Margules, Van Laar, Wilson, NRTL, UNIQUAC, UNIFAC, ASOG

Calculation of activity coefficient model parameters using experimental data

Calculation of equilibrium temperature, pressure and phase composition for the vapour–liquid equilibria: bubble point, dew point, flash calculations

Calculation of equilibrium phase composition for the liquid–liquid equilibria

Calculation of equilibrium composition in reacting systems as dependent on pressure and temperature: gas phase reactions, multiple gas phase reactions, heterogeneous reactions

KNOWLEDGE TESTING AND EVALUATION:

Laboratory entrance exam

Laboratory final oral exam

Written exams for two individual seminar problems

3 compulsory partial exams during the semester (if failed – final oral exam)

Final written exam for numeric seminar problems

Final oral exam

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student inquiry

LITERATURE:

Compulsory:

M. Rogošić, Internal textbook, www.fkit.unizg.hr, 2013.

S.I. Sandler, Chemical, Biochemical and Engineering Thermodynamics, 4th Ed., Wiley, New York, 2006.

D. Kondepudi, I. Prigogine, Modern Thermodynamics, Wiley, New York, 1998.

Additional:

J.M. Smith, H.C. Van Ness, M.M. Abbott, Introduction to Chemical Engineering Thermodynamics, 5th Ed., McGraw-Hill, New York, 1996.

J.M. Prausnitz, R.N. Lichtenthaler, E.G. de Azevedo, Molecular Thermodynamics of Fluid Phase Equilibria, 3rd Ed., Prentice Hall, Englewood Cliffs, 1999.

B.E. Poling, J.M. Prausnitz, J.P. O'Connell, The Properties of Gases and Liquids, 5th Ed., McGraw-Hill, New York, 2000.

Course: Physical Chemistry II		
Language:		
Lecturer: Krešimir Košutić		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**3**	**45**
Laboratory	**2**	**30**
Seminar	**Part of lecture**	
		Overall: 75
		ECTS: 7

PURPOSE:

Understanding of basic laws and theories of physical chemistry as applied in practice of chemical engineering. The course is not only a collection of facts but an introduction to ways of thinking about the world. Development of capabilities of logical problem solving and equation derivation.

THE CONTENTS OF THE COURSE:

1. week: Description of chemical equilibrium (Gibbs energy minimum), thermodynamic equilibrium constant, Response of equilibrium to temperature (van't Hoff equation)to pressure,
2. week: Response of equilibrium to pressure, NH_3 syntesis, Heterogeneous chemical equilibrium
3. week: Surface phenomena: surface tension, surface films
4. week: Surface phenomena: adsorption, adsorption isotherms (Freundlich, Langmuir, B.ET.)
5. week: First partial exam, Conductivities of electrolyte solutions, weak electrolytes (Ostwald's dilution law)
6. week: Conductivities of strong electrolyte solutions, (Debye-Huckel theory and law)
7. week: Equilibrium electrochemistry, half- reaction and electrodes, electrode potential
8. week: Galvanic cells, electromotive force, Nernst equation
10. week: Physical processes, Diffusion, Fick's first and second law of difusion
11. week:Rates of chemical reaction- definition, rate laws and rate constants, reaction order,and determination of rate law, The chemistry of stratospheric ozone-ozone decomposition
12. week: Kinetics of complex reaction (reverse,-parallel, and consecutive reactions)
13. week: Kinetics of complex reations-chain reaction, Explosion, Polymerization kinetics
14. week: Kinetic and thermodynamic control of reactions, Temperature

dependence of reaction rates 15. week: Catalysis and catalyst-homogeneous and heterogeneous catalysis; Second partial exam Laboratory work: 1. Surface tension 2. Adsorption (Freundlich isotherm) 3. Determination of transport number (Hittorf method) 4. Conductivity of electrolyte solutions 5. Electromotive force of galvanic cell 6. Determination of constant rate and reaction order of chemical reaction (decomposition of H_2O_2, inversion of sucrose)
GENERAL AND SPECIFIC COMPETENCE: Describing the basic physical chemistry laws regarding chemical equilibria, surface phenomena (surface tension and adsorption), equilibria in electrolyte solution, and chemical kinetics. Applying knowledge of mathematics and deriving the equations (clearly describing the physical phenomena under consideration). Preparing and performing laboratory experiments. Analysis and interpretation of experimental results. Preparation of laboratory reports.
KNOWLEDGE TESTING AND EVALUATION: Entrance and final colloquium in laboratory work, partial exams, oral exam
MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS: *Student opinion surveys*
LITERATURE: P. Atkins, J. de Paula, Atkin's Physical Chemistry, 8th edition, Oxford University Press, Oxford 2006.

Course: Fluid mechanics (KI)		
Language: English		
Lecturer: Gordana Matijašić, Jasna Prlić Kardum		
TEACHING	WEEKLY	SEMESTER
Lectures	2	30
Laboratory		
Seminar	1	15
		Overall: 45
		ECTS: 5

PURPOSE: Acquiring knowledge of the mechanical behaviour of fluids. Description of macroscopic phenomena due to practical applications in chemical process and related industries.

THE CONTENTS OF THE COURSE:

Week 1
Introduction to fluid mechanics. Forces in the fluid.

Week 2
Rheological characterization and fluid classification. Newtonian fluids. Newton's law of viscosity. Non-newtonian fluids.

Week 3
Mathematical description of rheological behaviour. Time dependent rheological behaviour. Rheological diagram. Calculation examples.

Week 4
Fluid statics. Euler equations. Calculation examples.

Week 5
Dynamics of incompressible fluids. Conservation laws. Calculation examples. Flow equations. Navier-Stokes equation. Calculation examples.

Week 6
Partial exam I

Week 7
Elementary fluid dynamics of non-newtonian fluids. Flow of pseudoplastic and Bigham fluids in horizontal pipes; velocity distribution; pressure drop; definition of Reynolds number and friction factor. Calculation examples.

Week 8
Flow through narrow orifices; cavitation; flow from tank with maintained constant and variable fluid level. Fluid transport. Calculation examples.

Week 9
Classification of pumps; scheme, characteristics, selection criteria and pump design. Calculation examples.

Week 10
Complex pipelines; fundamental energy principles for transport through branched pipeline, resistance coefficient of pipe fittings, evaluation of flow rate and pressure drop. Calculation examples.

Week 11
Partial exam II

Week 12
Compressible flow; definition of ideal gas. Conservation laws. Isothermal flow of an ideal gas in horizontal pipe; evaluation of pressure drop. Calculation examples.

Week 13
Two-phase flow (gas-liquid). Fundamentals, flow types in horizontal pipe, methods for prediction of flow type, evaluation of pressure drop. Calculation examples.

Week 14
Flow of heterogeneous systems (liquid-solid; gas-solid). Heterogeneous suspensions, hydraulic transport, evaluation of pressure drop. Homogeneous suspensions; factors effecting rheological behaviour. Pneumatic transport, evaluation of pressure drop. Calculation examples.

Week 15
Partial exam III

GENERAL AND SPECIFIC COMPETENCE: Acquiring knowledge of the principles of fluid behaviour necessary to understand fundamental chemical engineering courses.

KNOWLEDGE TESTING AND EVALUATION: 3 partial exams. Students who do not achieve minimum points through partial exams have to complete the written and oral exam.

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS: Student survey.

LITERATURE:

B. S. Masey, Mechanics of Fluids, 2nd Ed., Butler&Tanner, London, 1976.

D. N. Roy, Applied Fluid Mechanics, J. Wiley, New York, 1989.

J. Ferguson, Z. Kemblowski, Applied Fluid Rheology, Elsevier, London

I. H. Shames, Mechanics of Fluids, 4tf Ed., Mc Graw-Hill Companies, New York, 2003.

M. Pečornik, Tehnička mehanika fluida, Školska knjiga, Zagreb, 1985.

I. P. Granet, Fluid Mechanics for Engineering Tehnology, Simon&Schuster, New York, 1989.

B. R. Munson, D. F. Young, T. K. Okiishi, Fundamentals of Fluid Mechanics, 5th Ed.,J. Wiley&Sons. Ltd., 2005

V. Jović, Osnove hidromehanike, Element, Zagreb 2006. (Udžbenici Sveučilišta u Splitu)

Course: Process and instrumental analysis, Chemical engineering study programme, Undergraduate, 2nd year, required

Language: Croatian

Lecturer: **Dragana Mutavdžić Pavlović, PhD, associate professor**

TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**2**	**30**
Seminar	**0**	
		Overall: 60
		ECTS: 5

PURPOSE: The aim of this course is to introduce the theoretical principles, practical work and the use of instrumental equipment and procedures related to process analysis. The choice of method will depend on the knowledge of the basic principles of each method or group of methods and the understanding of their advantages and limitations.

THE CONTENTS OF THE COURSE:

<u>Lectures and the seminars:</u>

1. Introduction: Fundamentals of process analytics. Basic principles of instrumental analysis. Signal processing in the analysis. Validation. Calibration procedures (standard addition method, the method of external standard, internal standard method).
2. INSTRUMENTAL ANALYTICAL METHODS: Introduction to instrumental methods of analysis. The division of the methods. Basic concepts and the principles.
3. Introduction to spectroscopic methods. The division of the spectrometry. Atomic spectrometry (atomic emission spectrometry (AES), atomic absorption spectrometry (AAS), atomic fluorescence spectrometry (AFS)).
4. Molecular spectroscopy (IR spectroscopy, spectrophosphorimetry, spectrofluorimetry, scattering spectrometry, nuclear magnetic resonance (NMR), mass spectrometry).
5. The 1st partial test.
6. Electroanalytical methods. Basics. Division. Potentiometry, electrogravimetry, coulometry.
7. Electroanalytical methods. Polarography, voltammetry, stripping analysis, amperometry.
8. Conductometry. Instrumental separation techniques. Electrophoresis- a separation electroanalytical method.
9. Instrumental separation techniques. Chromatography. Basics. Division. Models of chromatographic resolution.
10. Chromatography. Mobile and stationary phases. Liquid chromatography. Gas chromatography.
11. The 2nd partial test

12. Thermal analysis (thermogravimetry, differential thermal analysis).
13. PROCESS ANALYSIS: Process analysis, the steps in the monitoring process, measuring in real time. Sampling. Automation of the analytical procedure. Analysis in the flow, the analysis by injecting samples into the flow. Automatic analytical systems. Coupled techniques. Process analyzers.
14. Presentation of student's seminar papers.
15. The 3rd partial test

Laboratory exercises:

1. UV/VIS spectrometric determination of chromium, iron and/or nitrates.
2. AAS determination of copper and/or zinc
3. AES determination of potassium and/or sodium.
4. Turbidimetric determination of sulfate.
5. Potentiometric titration: determination of acetylsalicylic acid, determination of the end-point of titration - first and the second derivative, Grann-method.
6. Determination of the concentration of chloride and/or fluoride by direct potentiometry.
7. Conductometry. Determination of acids mixtures by conductometry titration.
8. Chromatography. Liquid chromatography separation and the quantification of a mixture of "emerging contaminants"
9. Field work - Process analysis and the process analyzers in operation
10. Compensation of laboratory exercises.

GENERAL AND SPECIFIC COMPETENCE:

Introduction to instrumental methods, and their connection with process analysis.

KNOWLEDGE TESTING AND EVALUATION:

Written and oral examination. The possibility of release written part of the exam if you collect enough points (during the semester).

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Continuous evaluation. Student questionnaire.

LITERATURE:

Required literature:

1. D. A. Skoog, D. M. West, F. J. Holler, Osnove analitičke kemije, Školska knjiga Zagreb, 1999.
2. M. Kaštelan-Macan, Kemijska analiza u sustavu kvalitete, Školska knjiga Zagreb 2003
3. I. Piljac, Elektroanalitičke metode, RMC, Zagreb 1995.
4. skupina autora, Analitika okoliša (ur. M. Kaštelan-Macan, M. Petrović), HINUS i FKIT, Zagreb 2013.
5. Working material from lectures
6. Working material for exercises (internal script)

Optional literature:

1. D. A. Skoog, D. M West, F. J. Holler, Principles of Instrumental Analysis, Saunders College Publishing 1995.

Course: Organic chemistry		
Language: English		
Lecturer: Dr. Marijana Hranjec, assoc. prof.		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**3**	**45**
Laboratory	**2**	**30**
Seminar	**0**	**0**
		Overall: 75
		ECTS: 7

PURPOSE:

Expose the fundamental principles of modern organic chemistry and its application in industry.

THE CONTENTS OF THE COURSE:

1st week: Carbon compounds and chemical bonds, classes of organic compounds, a division of reactions in organic chemistry.

2nd week: Alkanes and cycloalkanes; Conformational and geometrical isomerism. Laboratory - the entrance exams for introductional exercises (recrystallization, distillation, thin layer chromatography, qualitative elemental analysis of unknown sample). 1st homework – additional problems related to the teaching units in the first 2 weeks which should be submitted via e-learning.

3rd week: Alkenes, dienes, polyenes, alkynes: properties, synthesis, reactions of addition. Laboratory - Recrystallization of the organic substance from the water and determination of melting point. Processing of the obtained experimental results and report writing. 2nd homework - additional problems related to the teaching unit processed in the 3rd week should be submitted via e-learning.

4th week: Stereochemistry: optical isomerism, constitutional isomers and stereoisomers, enantiomers and the chiral molecule, (R) - (S) system, diastereomers. Laboratory - Recrystallization of the organic substance from ethanol and determination of melting point. Processing of the obtained experimental results and report writing. 3rd homework - additional problems related to the teaching unit processed in the 4th week should be submitted via e-learning.

5th week: Written assessment by 1st partial exam.

6th week: Aromatic compounds: properties and reactions, polycyclic aromatic compounds. Laboratory - Determination of unknown substances by thin layer chromatography. Processing of the obtained experimental results and report writing.

7th week: Alkyl halides - Ionic reactions: nucleophilic substitution (SN_2 and SN_1) and the elimination reaction (E2, E1), the stereochemistry of the reaction.

Laboratory - A qualitative elemental analysis of an unknown sample. Processing of the obtained experimental results and report writing. 4^{th} homework - additional problems related to the teaching unit processed in the 6^{th} and 7^{th} week should be submitted via e-learning. **8^{th} week:** Alcohols, phenols, aryl halides, ethers, thiols, properties and reactions. Laboratory - the entrance exams for preparatory laboratory exercises (reactions of nucleophilic substitution SN_2 and SN_1: synthesis and isolation of compounds). **9^{th} week:** Aldehydes and ketones: nucleophilic addition to the carbonyl group. Laboratory - Nucleophilic substitution SN_1: Synthesis and isolation of *tert*-butyl chloride. Processing of the obtained experimental results and report writing. 5^{th} homework - additional problems related to the teaching unit processed in the 8^{th} and 9^{th} week should be submitted via e-learning. **10^{th} week:** Written assessment by 2^{nd} partial exam. **11^{th} week:** The carboxylic acids and their derivatives. Laboratory – reaction of esterification: synthesis and isolation of ethyl acetate. Processing of the obtained experimental results and report writing. **12^{th} week:** Amines and related compounds with nitrogen atom. Heterocyclic compounds. Laboratory - Cannizzaro reaction: synthesis and isolation of benzyl alcohol and benzoic acid. Processing of the obtained experimental results and report writing. 6^{th} homework - additional problems related to the teaching unit processed in the 10^{th} and11^{th} week should be submitted via e-learning. **13^{th} week:** Synthetic polymers. Carbohydrates and lipids. Amino acids and proteins, biochemical processes. Laboratory - Diazotation and coupling: synthesis and isolation of β-naphtholorange. Processing of the obtained experimental results and report writing. **14^{th} week:** Structure determination of organic compounds by spectroscopic methods. Laboratory - final partial exam. **15^{th} week:** Written assessment by 3^{rd} partial exam.
GENERAL AND SPECIFIC COMPETENCE: Apply the basic principles of modern organic chemistry and the literature as well as experimental data in solving of chemical engineering problems. Apply the basic reactions of organic synthesis and reactions involving alkanes, alkenes, alkynes, alcohols, aromatic compounds, carbonyl compounds, carboxylic acids and their derivatives and using of available instrumentation in the preparative purposes. Identify and use of the vocabulary of organic chemistry. Drawing of correct structural view of organic molecules. Writing acceptable transformation and mechanisms for alkanes, alkenes, alkynes, alkyl halides, alcohols, aromatic and heterocyclic carbonyl compounds. Using knowledge of stereochemistry in analyzing mechanisms in organic chemistry. Work in Organic Chemistry Laboratory: the isolation, purification and identification of organic products.
KNOWLEDGE TESTING AND EVALUATION:

Entrance exams related to laboratory practices.
The final exam related to laboratory practices.
3 partial written tests during the semester (60% of points on each of the exams brings the release of the oral examination).
Written exam (50% of the points needed for passage).
Oral examination.

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student survey.

LITERATURE:

H. Hart, L. E. Craine, D. J. Hart, Ch. M. Hadad, "Organic Chemistry-a short course", Twelfth Edition, Houghton Mifflin Company, Boston, USA, 2007.
S. H. Pine, "Organska kemija" (prijevod I. Bregovec, V. Rapić), Školska knjiga, Zagreb, 1994.
V. Rapić, "Nomenklatura organskih spojeva", Školska knjiga, III izmijenjeno i nadopunjeno izdanje, Zagreb, 2004.
T.W.G. Solomons, "Organic Chemistry", Eight Edition, John Wiley & Sons, New York, USA, 2004.
F. A. Carey, "Organic Chemistry", Fourth Edition, McGraw Hill Higher Education, New York, USA, 2000.

Course: Mechanical process engineering		
Language: English		
Lecturer: Gordana Matijašić		
TEACHING	WEEKLY	SEMESTER
Lectures	3	45
Laboratory	2	30
Seminar	1	15
		Overall: 90
		ECTS: 8

PURPOSE: The interaction between the unit operations, the equipment, the characterization methods of dispersed systems, processing path and the state of product during transformation of material systems by mechanical operation. Understanding of underlying phenomena by detailed local analysis from macroscopic to microscopic scale.

THE CONTENTS OF THE COURSE:

Week 1
Introduction. Familiarizing students with the methods of teaching and their obligations. Basics of mechanical operations from the macroscopic scale.

Week 2
Characterization of dispersed systems, classification, definition of particle shape, size and particle size distribution.

Week 3
Characterization of dispersed systems, instruments. Calculation examples.

Week 4
Basics of mechanical separation. Sedimentation. Theoretical background.

Week 5
Sedimentation. Theoretical background, equipment, equipment selection, calculation examples. Preparation for partial exam.

Lab assignment I: Characterization of dispersed systems.

Week 6
Partial exam I: Characterization, sedimentation.

Week 7
Filtration. Theoretical background.

Lab assignment II: Sedimentation test.

Week 8
Filtration. Theoretical background, equipment selection, calculation examples.

Week 9

Fluid mixing. Theoretical background.

Lab assignment III: Filtration test.

Week 10
Suspension mixing. Theoretical background, impeller types, calculation examples.

Week 11
Partial exam II: Filtration, fluid and suspension mixing.

Lab assignment IV: Suspension mixing.

Week 12
Basics of powder mixing. Theoretical background, equipment, equipment selection, calculation examples.

Week 13
Comminution. Theoretical background, equipment, equipment selection, calculation examples.

Week 14
Agglomeration. Theoretical background, equipment.

Lab assignment V: Comminution kinetics.

Week 15
Partial exam III: Powder mixing, comminution, agglomeration.

GENERAL AND SPECIFIC COMPETENCE: Acquiring knowledge necessary for equipment selection and definition of optimal process conditions.

KNOWLEDGE TESTING AND EVALUATION: 3 partial exams. Students who do not achieve minimum points through partial exams have to complete the written and oral exam.

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS: Student survey.

LITERATURE:

M. Hraste, Mehaničko procesno inženjerstvo, Hinus, Zagreb 2003.

M. Rhodes, Introduction to Particle Technology, John Wiley, London 1998.

A. Rushton, A.S. Ward, R.G. Hodlich: Solid –Liquid Filtration and Separation Technology, VCH Weinheim 1996.

R. J. Wakeman, E.S. Tarleton; Equipment Selection, Modeling and Process Simulation, Elsevier, Oxford 1999.

N. Harnby, M.F. Edwards, A.W. Nienow: Mixing in Process Industry, Butterworths, London 1992

Course: CATALYSIS AND CATALYSTS		
Language: English		
Lecturer: Prof. Vesna Tomašić		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**2**	**30**
Seminar	**0**	**0**
		Overall: 60
		ECTS: 6

PURPOSE:

The course is an introduction to important principles and methods of homogeneous and heterogeneous catalysts. The aim of the course is to teach students how to identify the key variables required to the design of an active, selective and stable catalyst.

THE CONTENTS OF THE COURSE:

Introduction. Homogeneous catalysis: acid-base catalysis, catalysis with metal ions.
Kinetics and mechanism of homogeneous catalytic reactions.
Heterogeneous catalysis.
The composition and preparation of the catalyst.
Physical adsorption and chemisorption.
Kinetics and mechanism of heterogeneous catalytic reactions: empirical and mechanistic models.
The rate of the heterogeneous catalytic reactions. Heat and mass transfer in catalytic reactors.
Effectiveness factor: interphase, intraphase. Experimental methods and diagnostic criteria in kinetic studies.
Activity, selectivity and stability of the catalyst.
Catalyst deactivation. Kinetics and mechanism of deactivation. Diffusion and deactivation.
Selectivity and deactivation.
Prevention of deactivation and reactivation of the catalyst.
Physical properties of the catalyst. Mechanical properties of the catalyst.
Experimental determination of the physical and mechanical properties of catalysts.
The role of catalysis in the development of sustainable technologies.

GENERAL AND SPECIFIC COMPETENCE:

Encouraging students to independent learning and the development of critical thinking. Specific competencies will include the application of acquired knowledge and the ability to plan research related to the catalytic reaction engineering.

KNOWLEDGE TESTING AND EVALUATION:

The course is given as a combination of lectures, exercises, home-works and periodic assessment of knowledge. Compulsatory exercises must be passed in order to get access to the exam. The examination form may change from written to oral.

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Quality and performance will be monitored through student surveys, interviews with students during the teaching process and their success in exams.

LITERATURE:

S. Zrnčević, KATALIZA I KATALIZATORI, HINUS, 2005.
R.W. Missen, C.A.Mims, B.A.Saville, Chemical Reaction Engineering and Kinetics, J.Wiley, New York, 1999.
R.A. Sheldon, I. Arends, U.Hanefeld, Green Chemistry and Catalysis, J.Wiley, New York, 2007.
C.H. Bartholomew, R.J. Faruto, Fundamentals of Industrial Catalytic Processes, John Wiley, New York, 2006.
Handbook of Heterogeneous Catalysis, Vol. I.-V., Eds. G.Ertl, H.Knozinger, J. Weitkamp, VCH, 1997.

Course: Thermal process engineering		
Language: English		
Lecturer: Full Prof. Aleksandra Sander		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**3**	**45**
Laboratory	**2**	**30**
Seminar	**1**	**15**
		Overall: 90
		ECTS: 7

PURPOSE: Provide knowledge that enables evaluation and selection of the optimal separation process and basic design procedure, with overview of energy savings methods.

THE CONTENTS OF THE COURSE:

Week 1
Definition of thermal separation process; mechanism of separation; overview of thermal separation processes; concurrent, countercurrent and cross flow; theoretical stage; discontinuous and continuous processes; mass and heat balances; phase equilibria; mass transfer fundamentals; driving force

Week 2
Definition and application of heat exchangers; HE classification; modes of heat transfer; general characteristics of shell and tube HE; HE with simple and complex geometry; plate and spiral HE; fluid stream allocation; thermal analysis of HE; kinetics equation; fouling factors; driving force; HE efficiency; number of transfer units

Numerical exercises: shell and tube HE

Week 3
Extended surface HE; basic design of HE; evaluation of heat transfer coefficients and pressure drop (shell and tube side)
Numerical exercises: evaluation of heat transfer coefficients and pressure drop (shell and tube side)

Laboratory – Floating-head HE

Week 4
Evaporation: definition and scope; solutions (properties; solubility; enthalpy; latent heat of evaporation); driving force; boiling point elevation; pressure drop; heat transfer coefficient; vacuum operation; mass and heat balances; enthalpy-

concentration diagram; kinetic equation; single stage and multistage evaporation; evaporators (equipment and working principle); energy savings methods
Numerical exercises: single stage and multistage evaporation
Laboratory – batch evaporator

Week 5
Crystallization: definition, scope and classification; solution properties (physical and thermal properties of solvent; concentration; solubility; saturation, supersaturation and metastability; experimental methods); crystals (definition, crystal systems; polymorphism; crystal shape; CSD); S-L equilibrium; crystallization (supersaturation; nucleation: definition, klasification and kinetics; crystal growth; mass and heat balances);

Numerical excersises: crystallization

Week 6
Crystallizers, design basis; precipitation (basis); melt crystallization: (basis); desublimation (basis)

Numerical exercises: solving complex examples
Laboratory – cooling batch crystallization

Week 7
Written partial exam: HE, evaporation, crystallization

Week 8
Drying: definition and features, heat transfer modes (convection, conduction, radiation, MW), basic terms; sorption isotherms; psychometric charts (Y-h i Y-T); psychometric and gravimetric methods; mass and heat balances, drying curves, drying periods, dryng rate, moisture movement mechanisms; influence of the external conditions on the drying kinetics; mathematical models; energy savings steps; dryers, equipment and basic design procedure.

Numerical exercises: drying
Laboratory - Drying (fluid-bed)

Week 9
Distillation: definition and application; ideal and real mixtures; azeotropes; phase equilibria; extractive and azeotropic distillation; distillation columns; differential distillation (Rayleigh equation-graphical method; working principle; heat and mass balance); continuously operated simple distillation (mass and heat balances, working principle); flash distillation (working principle; operating line); continuous adiabatic rectification (working principle, mass and heat balances, operating lines, energy saving steps; McCabe Thile and Ponchon Savarit methods for NTU determination; q-line and feed condition; diameter and height of the column; reflux ratio);
Numerical exercises: distillation

Week 1o
Column internals (plates, packings: random and structured), selection, optimization and control of rectification column, operating conditions; discontinuous adiabatic distillation: (working principle; mass and heat balances;

operating lines; R=const and xD=const)

Numerical exercises: solving complex problems
Laboratory – Rectification

Week 11
Written partial exam: drying, distillation

Week 12
Extraction: definition and application; solvent requirements; basic terms; distribution coefficient; L-L equilibrium: ternary and distribution graph; solvent rati; single stage and multistage discontinuous extraction: mass balance, operating lines; continuous countercurrent extraction: mass balance, operating line, driving force, NTU, HTU, kinetic approach; extractors: classification and basic design

Numerical exercises: single stage, multistage and continuous extraction
Laboratory – batc extraction

Week 13
Absorption, definition; solvent selection; mass transfer; rate of absorption; local and overall mass transfer coefficients; absorption coefficients; single, multistage and continuous absorption (mass balances, operating lines); optimum L/G; absorbers: classification and general design procedure

Numerical exercises: single stage, multistage and continuous absorption

Week 14
Selection of feasible separation process; guidelines for equipment selection

Numerical exercises: solving complex problems

Week 15
Written partial exam: extraction, absorption

GENERAL AND SPECIFIC COMPETENCE:

At the end of this course students have general knowledge needed for selection of the feasible separation process, based on characteristics and properties of components and their mixture as well as separation process characteristics.
Specific competencies:
Graphical and numerical determination of number of transfer units
Definition, formulation and solving thermal separation problems using balance and kinetic equations
Calculation of heat and mass transfer coefficients for the given separation process
Selection of separation process based on phase equilibria and physical properties
Selection of solvent for extraction and absorption

KNOWLEDGE TESTING AND EVALUATION:

3 partial exams. Students who do not achieve minimum points through partial exams have to complete the written and oral exam.

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student survey.

LITERATURE:

K.Satler, H.J.Feindt, Thermal Separation Processes – Principles and Design, VCH Verlagsgesellschaft mbH, Weinheim; 1995.
J.D.Seader, E.J. Henley, Separation Process Principles, John Wiley & Sons, Inc., 2006.
C.J.Geankoplis, Transport Processes and Unit Operations, Allyn and Bacon, Inc., Boston, 1978.
J.H.Lienhard, A Heat Transfer Textbook, Third Ed., Phlogiston Press, Cambridge, 2006.

Course: Process Measurement and Control		
Language: English language		
Lecturer: **Ph.D. Nenad Bolf, Assist. Prof.**		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**3**	**45**
Laboratory	**2**	**30**
Seminar	**1**	**15**
		Overall: 90
		ECTS: 6

PURPOSE:

To teach students on modern methods of process control, measurements and diagnostics, metrology and metrological infrastructure.

THE CONTENTS OF COURSE:

System description and systems approach. Fundamentals of control theory. Basic control principles of control. Manual and automatic control, feedback control and feedforward control.

Functional structure of control loop: process - measuring sensor/transducer - controller - actuator.

Process dynamics. Mathematical modelling of process and control loop. First and second order systems. Higher order systems Time constant. Dead time.

Measuring and testing; conception, principles and theoretical foundations. Measuring sensor, transducer and instruments characteristics.

Calibration and traceability, measuring error and uncertainty. Reliability, repeatability and reproducibility of measurements.

Legal metrology. Organisation of metrological services, accreditation, certification. Measuring and testing laboratories. Maintenance and calibration of instruments. Quality assurance in measurement and testing. Standards and referent materials.

Measurement, sensor and transducers of temperature, pressure, flow, level, concentration, force. Analytical measurements. Measurement of properties: mechanical, thermal, electrical, optical. Humidity and moisture. Density.

Intelligent measuring transducers and instruments. Software sensors.

Controllers. On-off control. Proportional, integral and derivative control. PID controller.

Tuning control systems. Tuning concept. Closed-loop tuning methods. Open loop tuning methods. Integral methods. Adaptive tuning. Stability.

Concept of cascade control. Simple applications. More complex example. Guiding principles for implementing.

Feedforward control. Steady-state and dynamic feedforward control. Combined feedforward and feedback control. Multivariable control problem. Implementing multivariable control.

Control valves. Types of control valves. Actuators and positioners. Control valve characteristics. Control valve selection and sizing. Control valve dynamic performance.

Special-purpose concepts. Computing components. Ratio control. Override control. Selective control. Split-range control.

Dead time control. Smith predictor algorithm and application. Moore analytic predictor and Dahlin algorithm for dead time compensation.

Nonlinear compensation and adaptive control. Nonlinearities. Process and valve characteristics. Adaptive control.

Modern control system architecture. System components. Direct digital control (DDC) system. Supervisory control systems. Distributed control systems (DCS). Sequential and batch control.

Process control and process management. Computer-integrated manufacturing (CIM). Statistical process control. Statistical quality control. Statistical process optimisation. Artificial intelligence and expert systems. Fuzzy and neural network-based control.

GENERAL AND SPECIFIC COMPETENCE:

Acquiring knowledge on the modern methods of process measurement and control, control systems, modelling and computer simulations. Using of process measurement and control equipment.

KNOWLEDGE TESTING AND EVALUATION:

Seminars, partial exams, written and oral exams.

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student’s survey

LITERATURE:

Course material, presentations and simulations on the course web page.

Marlin, T. E. (2005). *Process Control, Design Processes and Control System for Dynamic Performance*, McGraw-Hill

Seborg, D. E., T. F. Edgar, D. A. Mellichamp (2010). *Process Dynamics and Control*, Willey International

Ogunnaike, B. A., W. H. Ray (1994). *Process Dynamics, Modelling, and Control*, Topics in Chemical Engineering, Oxford University Press

MATLAB, *The Language of Technical Computing*, The MathWorks, Inc., 2002.

Course: Surfactants		
Language: English		
Lecturer: Prof. Sanja Papić, PhD		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**1**	**15**
Seminar		
		Overall: 45
		ECTS: 4

PURPOSE:

Gaining knowledge about surface active agents or surfactants, about specific molecular structure of surfactants and their properties. Understanding of the phase behavior of surfactants (L/G, L/L, L/S) which is essential for their application as wetting agents, stabilizers of emulsions and foams, in detergents formulations and as softeners. Introduction to chemical characteristics, methods of production and the field of application of different groups and subgroups of surfactants. Gaining knowledge about detergents and their formulation for a variety of uses.

THE CONTENTS OF THE COURSE:

1)Introduction to surface active agents or surfactants: specific molecular structure of surfactants and surface active properties exhibited by surfactants. Explanation of basic terms: surface tension, micelle. Fields of application of surfactants

2) The formation, structures and shapes of micelles in the aqueous and non-aqueous medium. CMC (critical micelle concentration); the determination and the factors of influence. Micellar solubilization.

3)Phase behavior of surfactants (L/G, L/L, L/S) which is of technological importance for the surfactant applications. Surface tension. Interfacial tension. Wetting.

4)Emulsions: types, characteristics, stability. Stabilization of emulsions using surfactants as emulsifiers.

5)Foams: classification, mechanical balance and structure, properties, foaming and defoaming, stabilising effects in foams.

6) Classification of surfactants according to ionic charge (anionic, cationic, nonionic and amphoteric) and the field of application (emulsifiers, wetting agents, foaming agents, softeners, detergents).

7,8) Chemical groups of anionic surfactants and their characteristics.

Manufacturing methods of selected types of anionic surfactants and their applications.

9, 10) Chemical groups of cationic surfactants and their characteristics. Manufacturing methods of selected types of cationic surfactants and their applications

11, 12) Chemical groups of nonionic surfactants and their characteristics. Manufacturing methods of selected types of nonionic surfactants and their applications.

13) Chemical groups of amphoteric surfactants and their characteristics. Manufacturing methods of selected surfactants and their applications

14)Detergents: types, ingredients and their functions in the washing process, the role of surfactants. Formulations of detergents for different uses.

15)Biodegradation of surfactants. Examples of some new, environmentally friendly surfactants

GENERAL AND SPECIFIC COMPETENCE:

Knowledge and understanding of the basic facts, concepts, principles and theories related to the fundamentals of chemistry and chemical engineering
1. To define the basic terms
2.To explain the properties of surfactants
3. To classify surfactants
4. To explain the effects on the surface and at the interface relevant to the application of surfactants
5. To apply mathematical expressions to describe the surface effects
6. To describe the processes of preparation of selected types of surfactants
7. To explain the role of certain compounds in the formulation of detergents

KNOWLEDGE TESTING AND EVALUATION:

Partial tests (2 times) (written) or exam (written and/or oral)

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

University of Zagreb student survey.

LITERATURE:

1. R. J. Farn, Chemistry and Technology of Surfactants, Blackwell Publishing, Oxford, 2006.
2. E. Smulders, Laundry Detergents, Wiley-VCH, Weinheim, 2002.
3. A. Davidsohn, B. M. Milwidsky, Synthetic Detergents, John Wiley& Sons, New York, 1978.
4. K. Holmberg, Novel Surfactants, Marcel Dekker, New York, 2003.

Course: Petroleum refining processes

Language: English

Lecturer: Full Prof. Katica Sertić-Bionda, PhD.

TEACHING	WEEKLY	SEMESTER
Lectures	**2**	**30**
Laboratory	**1**	**15**
Seminar		
		Overall: 45
		ECTS: 5

PURPOSE:

Study of chemical engineering fundamentals of basic petroleum refining processes, specifics of technologies, as well as properties of basic petroleum refining products, particularly regarding environmental protection requirements.

THE CONTENTS OF THE COURSE:

1. Introduction. Origin, exploration, production and consumption of petroleum.
2. Chemical composition and properties of petroleum.
3. Classification and characterization of petroleum.
4. Petroleum refining: processes and products review; separation processes, conversion processes, treatment processes, products of petroleum refining.
5. Distillation; atmospheric distillation, vacuum distillation.
6. Cracking processes. Thermal cracking; coking, visbreaking.
7. Catalytic cracking of gas oils in fluidized bed of catalyst (FCC process).
8. Hydrocracking processes: raw materials and products.
9. Catalytic reforming; semi-regenerative processes, processes with continuous regeneration of the catalyst.
10. Isomerisation processes of light naphtha (C5/C6 hydrocarbons).
11. Alkylation and polymerisation of liquefied petroleum gas (LPG) hydrocarbons.
12. Treatment processes. Hydrodesulphurisation of raw materials and products of petroleum refining.
13. Lubricating oils: the main processes, properties and additives.

14. Basic petroleum products: motor gasoline, diesel fuel.

GENERAL AND SPECIFIC COMPETENCE:

Introduce students to theoretical knowledge about the basic raw materials, products and technologies to develop their abilities for monitoring and control the processes of petroleum refining.

KNOWLEDGE TESTING AND EVALUATION:

Continuous assessment, written or oral exam.

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student survey.

LITERATURE:

K. Sertić-Bionda, Petroleum refining, lecture for students (www.fkit.hr).

K. Sertić-Bionda, Petroleum refining, instructions for laboratory practicum (www.fkit.hr).

David S. J. Jones and Peter R. Pujadó, Handbook of Petroleum Processing, Springer, 2006

P. Leprince, Petroleum Refining. Vol. 3 Conversion Processes, Edition Technip, Paris, 2001.

Course: Matlab/Simulink		
Language: English language		
Lecturer: Ph.D. Nenad Bolf, Assist. Prof.		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**0**	**0**
Seminar	**1**	**15**
		Overall: 45
		ECTS: 4

PURPOSE:

Instruct the students to use the software package MATLAB / Simulink and its advanced functions for the purpose of implementing chemical engineering calculation, display and analysis of measurement data, modelling and process optimization.

THE CONTENTS OF COURSE:

MATLAB/Simulink high-level language. Work environment and basic operations.

Working with matrices and fields. Data structure and programming.

Simulation of the processes and systems. Methods and tools for simulation.

MATLAB advanced functions. Drawing and graphic display. Two-dimensional and three-dimensional graphics. Animation.

Fundamentals of symbolic computations in MATLAB. The functions of symbolic computation. Examples of linear algebra. Solving symbolic equations. Special functions. Working in a graphical environment.

Processing of measurement data in the Curve Fitting Toolbox. Parametric and nonparametric adjustment.

Linear and nonlinear adjustment procedures. Statistical parameters of quality adjustment.

Spline Toolbox. The implementation and application of regression analysis methods.

Case-study. First partial exam.

System Identification Toolbox. The development of dynamic process models using identification methods.

Parametric and nonparametric identification. Model validation.

System Identification Toolbox graphical interface. Example of identification based on data from industrial processes.

Fundamentals of Simulink. Modelling, simulation and analysis of dynamic systems. Interaction of MATLAB and Simulink.

Simulink graphical environment. Design of the process models, graphic, work with blocks. Analysis of the results of simulations.

Examples of linear and nonlinear systems, continuous and discrete models, hybrid systems.

Solving real-life problems. Results analysis.

Second partial exam.

GENERAL AND SPECIFIC COMPETENCE:

Apply information technology and programming fundamentals. Solve engineering problems by applying available software packages. Apply mathematical methods and software in case-study solving.

Apply advanced features for analyzing and displaying data. Perform symbolic functions and calculations. Process and analyze measurement data using software tools. Develop process models in a graphical user interface using Simulink. Resolve examples of continuous, discrete and hybrid systems.

KNOWLEDGE TESTING AND EVALUATION:

homework and seminars, partial exams, written exams

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student's survey

LITERATURE:

Course material, presentations and simulations on the course web page.

Ž. Ban, J. Matuško, I. Petrović, Primjena programskog sustava MATLAB za rješavanje tehničkih problema, Graphis, Zagreb, 2010.

D. Grundler, T. Rolich, A. Hursa. MATLAB i primjena u tekstilnoj tehnologiji, Sveučilište u Zagrebu, Tekstilno-tehnološki fakultet, Zagreb, 2010.

MATLAB, The Language of Technical Computing, The MathWorks, Inc., 2012

S.T. Karris, Introduction to Simulink with Engineering Applications, Orchard Publications, 2006

Course: PLANT DESIGN I

Language: English

Lecturer: Prof.dr.sc. Ljubica Matijašević

TEACHING	WEEKLY	SEMESTER
Lectures	2	30
Laboratory	2	30
Seminar	0	
		Overall: 60
		ECTS: 5

PURPOSE: Learning basic steps of chemical plant design process. Synthesis of knowledge acquired during undergraduate study.

THE CONTENTS OF THE COURSE:

Week 1

Introductory lecture – role of chemical engineers in plant design. Project documentation.

Week 2

Standards, codes and recommendations. Engineering units. Organisation and coordination of a design project.

Week 3

Preparatory steps: data acquisition, feasibility studies. Importance of thermodynamic data and models and their impact on mass and energy balances.

Week 4

Steps in plant design. Engineering diagrams (block diagram, PFD, P&ID), and standards applying to them. Specification tables.

Week 5

Process simulation. Use of process simulators. Mass balance and its importance in equipment selection and sizing. Example: cooling tower design.

Week 6

Energy balances. Laws of thermodynamics. Utilities.

Week 7

Equipment sizing (standardized and non-standard equipment). Pipes and pumps.

Week 8

Selection of pumps. Compressors. Separation processes – overview and selection. Modelling of a continuous distillation process: short-cut and rigorous models. Column sizing.

Week 9

Column internals. Trays and packings: selection and sizing.

Week 10

Heat exchanger types and selection criteria. TEMA standards. Sizing.

Week 11

Flash drums and vessels. Selection and sizing.

Week 12

Tanks and stirrers. Calculation of required power.

Week 13

Investment estimation. Direct and indirect costs. Cost indices.

Week 14

Estimating key equipment cost (reactors, pressure vessels, towers, heat exchangers). Influence of dimensions, construction materials, pressure and equipment type on cost.

Week 15

Plant layout. Process safety and environmental impact. Dow and Mond-Dow indices (F&EI, risk assesment). HAZOP study.

GENERAL AND SPECIFIC COMPETENCE:

Knowledge of basic design project steps. Understanding the role of chemical engineers in design projects. Ability to participate in plant design projects

KNOWLEDGE TESTING AND EVALUATION:

Partial tests (2 in theory + 2 in laboratory practice). Oral and written exam.

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student poll.

LITERATURE:

1. W.D. Seider at al., PRODUCT AND PROCESS DESIGN PRINCIPLES; Synthesis, Analysis and Evaluation, 3rd

Editon, Wiley, 2010

2. R. Smith, CHEMICAL PROCESS, Design and integration, Wiley, 2005

3. Peters& Timmerhaus, PLANT DESIGN AND ECONOMICS FOR CHEMICAL ENGINEERS, Mc Graw Hill, 1991

4. R.K.Sinnot, CHEMICAL ENGINEERING, Vol.6 (Chem. Eng. Design), Jordan Hill, Oxford, 1996

5. R.Turton at al., Analysis, Synthesis, and Design of Chemical Processes, 2nd Edition, Prentice Hall, 2003

Course: CHEMICAL REACTORS		
Language: English		
Lecturer: Prof. Vesna Tomašić		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**2**	**30**
Seminar	**0**	**0**
		Overall: 60
		ECTS: 6

PURPOSE:

Introduction to the most important types of reactors. The purpose of the course is to present in a clear and concise manner the fundamentals of the reactor analysis and modeling.

THE CONTENTS OF THE COURSE:

- **Kinetics of the heterogeneous catalytic reactions.**
Introduction and required knowledge. Definition of basic concepts. The concept of catalysis. Reaction time. Physical adsorption and chemisorption. Kinetic models. Deactivation of the catalyst and reaction rate. Mass transfer and the rate of catalytic reaction.

- **Choice of reactor and reactor design, comparison of basic types of reactors.**
Features of the reaction system. Features of the process. Comparison of continuous stirred tank reactor and the plug flow (tubular) reactor. Systems of several reactors. The choice of the reactor and complex reactions. The choice of the reactor and heat effects. Design and sizing of the reactor.

- **Batch Reactors (features, reactor models).**
Basic features. Application. Introduction to the reactor models.

- **Examples of the reactor models for batch reactor under isothermal conditions.**
Batch reactor under isothermal conditions. Batch reactor under adiabatic conditions. Optimization of the batch reactor.

- **Continuous stirred tank reactors (CSTRs).**
Basic features. Application. Introduction to the reactor models. Heat balance for the heat transfer fluid (cooling or heating medium).

- **Examples of the reactor models for CSTRs.**
Isothermal operation of the CSTR. Adiabatic operation of the CSTR. Heat transfer in a stirred reactor.

- **CSTRs reactors in unsteady operation (CSTRs,n) and steady-state multiplicity in CSTRs.**
Conditions leading to unsteady operation. General model of the CSTR. Examples of models describing unsteady operation of CSTR. Stability of the CSTRs and stability criteria.

- **Plug flow (tubular) reactors (PFRs) (basic features, reactor models).**
Basic features. Application. Models of tubular reactors and classification of models.

- **One dimensional (1D) and two dimensional (2D) homogeneous models.**

Application. Mass balaces. The models based on assumption of plug flow conditions. Axial dispersion. The model of the tubular reactor with laminar flow. Heat balance. Examples of models.

- **One dimensional (1D) and two dimensional (2D) heterogeneous models.**
The basic model assumptions for 1D heterogeneous models. Mass and heat balances. Examples of models. 2 D models and equations of the model. Models and practical application. Examples of models.

- **Examples of models and numerical methods.**
Review of the numerical methods (direct method, implicit method, methods of lines, collocation method). Examples.

- **Mass and heat transfer coefficients and experimental methods.**
Heat and mass transfer through the catalyst. External mass transfer coefficients. Heat and mass transfer inside the catalyst bed. The average diffusion. The coefficients of heat transfer through the reactor walls.

- **Multiphase reactors: classification and basic features.**
The basic classification. Reactors for gas-liquid reactions. CSTR reactors with mixing of both phases. Reactor models. Column reactors. Two-phase packed column reactors. Three phase reactors.

- **Trickle bed reactors and slurry reactors: comparison of advantages and disadvantages.**
Classification of the slurry reactors. Reaction path. Example of models. Basic design of trickle bed reactor. Example of models. Comparison of the main representatives of multiphase reactors.

GENERAL AND SPECIFIC COMPETENCE:

Application of the basic methodology of chemical engineering to choose the appropriate type of chemical reactor, an understanding of reactor performances, defining process variables and process parameters, mathematical modeling of the process in different types of chemical reactors.

KNOWLEDGE TESTING AND EVALUATION:

The course is given as a combination of lectures, exercises, home-works and periodic assessment of knowledge. Compulsatory exercises must be passed in order to get access to the exam. The examination form may change from written to oral.

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Quality and performance will be monitored through student surveys, interviews with students during the teaching process and their success in exams.

LITERATURE:

H.S. Fogler, Elements of Chemical Reaction Engineering, Prentice Hall, Englewood Cliffs, New Jersey, 1986.
G.F. Froment and K.B. Bischoff, Chemical Reactor Analysis and Design, J. Wiley, N. Y. 1988.
H. F. Rase, Chemical Reactor Design for Process Plants, J. Wiley, N. Y. 1977.
M.O. Tarhan, Catalytic Reactor Design, McGraw-Hill, New York, 1983.
J.J. Carrbery, Chemical and Catalytic Reactor Engineering, McGreaw-Hill, New York, 1978.
V.V. Ranade, R.V. Chaudhari, P.R. Gunjal, Trickle Bed Reactors, Reaction Engineering & Applications, Elsevier, Amsterdam, 2011.
U. Mann, Principles of Chemical Reactor Analysis and Design, Wiley, 2nd Ed., New Jersey, 2009

Course: Plant design 2		
Language: English		
Lecturer: Prof.dr.sc. Ljubica Matijašević		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**3**	**45**
Seminar		
		Overall: 75
		ECTS: 6

PURPOSE:

Learning basic steps of process analysis and synthesis, with aim of optimal use of materials and energy.

THE CONTENTS OF THE COURSE:

Week 1

Designing a process. Strategies of process synthesis and analysis. Process design hierarchy - onion diagram. Batch vs continuous processes. Input/output structure of a process, recirculation. Separation train synthesis – basics. Introduction to heat and mass integration.

Week 2

Material tracking in a process – benzene production via toluene hydrodealkylation example. Mixer and splitter units.

Week 3

Heat exchanger network (HEN) synthesis. Basics of *pinch* technology – 1^{st} and 2^{nd} law of thermodynamics. HEN design using table method – a simple example (2 hot and 2 cold streams).

Week 4

Graphical method of HEN design – a real industrial example. Heat curves. Algebraic methods and cascade diagram for *pinch* location. Example: HEN synthesis in HNO_3 production process.

Week 5

Meaning of ΔT_{min}. Rules for HEN synthesis above and below *pinch*. Considering thermally active units in HEN synthesis. Grand composite curve (GCC). Examples.

Week 6

Placing thermally active units with regards to *pinch* – heat engines, heat pumps and separation units. GCC and energy savings in distillation.

Week 7

Mass integration. Mass exchanger network (MEN) synthesis. Mass exchange unit operations. Influence of minimal driving force on total annualized costs of MEN.

Week 8

Composite curves and pinch diagram. Examples: Benzene use in polymer production; Phenol removal from waste water.

Week 9

Algebraic method of mass integration – interval and cascade diagram.

Week 10

Water consumption minimization through process superstructure synthesis (network of processing units (PU) and treatment units (TU)). Water network synthesis. Example: waste waters in an oil refinery.

Week 11

Example: water reduction in paper production. WSD diagram by Wang and Smith.

Week 12

Optimization – formulation and classification of optimization problems (basics).

Week 13

Overview of procedures and technologies for pollution prevention and waste reduction according to EPA. *CLEANER Design* – available methods.

Week 14

Case study: sustainable water management in process industry.

Week 15

Industrial examples of process integration.

GENERAL AND SPECIFIC COMPETENCE

Design and selection of processes leading to optimal use of materials and energy in basic design and revamp projects. Selecting environmentally and economically acceptable solutions.

KNOWLEDGE TESTING AND EVALUATION:

Partial tests (2 in theory + 1 in laboratory practice). Oral and written exam.

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student poll.

LITERATURE:

1. R. Smith, CHEMICAL PROCESS, Design and integration, Wiley, 2005

2. I.C. Kemp, PINCH ANALYSIS AND PROCESS INTEGRATION, Elsevier,

2007

3. M.M. El-Halwagi, POLLUTION PREVENTION THROUGH PROCESS INTEGRATION, Academic Press, 2003

4. D.T:Allen, K.S.Rosselot, POLLUTION PREVENTION FOR CHEMICAL PROCESSES, John Wiley &Sons, 1997

5. R.Turton at al., ANALYSIS, SYNTHESIS, AND DESIGN OF CHEMICAL PROCESSES, 2nd Edi9tion, Prentice Hall,

2003

Course: Petroleum Refining and Petrochemical Processes

Language: English

Lecturer: Full Prof. Katica Sertić Bionda, PhD., Full Prof. Ante Jukić, PhD.

TEACHING	WEEKLY	SEMESTER
Lectures	**2**	**30**
Laboratory	**1**	**15**
Seminar	**0**	**0**
		Overall: 45
		ECTS: 5

PURPOSE:

Integration and implementation of previously acquired basic chemical/engineering knowledge on the most important processes in petroleum refining and petrochemical industry; interaction of science, technology, ecology and economy are considered.

THE CONTENTS OF THE COURSE:

1. Introduction to the petroleum refining. The origin, exploration, chemical composition and properties of petroleum. Raw materials, processes and products.
2. Separation processes; atmospheric and vacuum distillation, adsorption, extraction.
3. Thermal conversion processes. Cracking processes; cocking, visbreaking.
4. Catalytic conversion processes. Catalytic cracking, hydrocracking: thermodynamics, catalysts, reaction mechanisms, kinetics, processes.
5. Catalytic conversion processes. Catalytic reforming, isomerization, alkylation: thermodynamics, catalysts, reaction mechanisms, kinetics, processes.
6. Treating processes. Hydrodesulphurization and hydrodenitrification: thermodynamics, catalysts, reaction mechanisms, kinetics, processes.
7. Production and properties of mineral lubricating oils.
8. Introduction in petrochemistry: raw materials, processes, products. Status of petrochemical industry in Croatia and world.
9. Natural gas: composition, treatment processes.
10. Production of hydrogen and syngas. Fischer-Tropsch synthesis and synthetic fuels. IGCC technology.
11. Ammonia production.
12. Production of olefins by steam cracking.

13. Ethylene, propylene and its derivatives. Aromatics and its derivatives.
14. Integration of petroleum refining and petrochemical processes in modern refineries.

GENERAL AND SPECIFIC COMPETENCE:

To familiarize students with the technologies and processes of petroleum refining and petrochemical industry; understanding of social and ecological influences on technology and economy of processing units.

KNOWLEDGE TESTING AND EVALUATION:

Two written colloquiums (optional) related to lectures and colloquiums related to laboratory practices.
Written (50% of the points needed for passage) or oral exam.

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student survey.

LITERATURE:

K. Sertić-Bionda: Petroleum refining, lectures for students (www.fkit.hr).
K. Sertić-Bionda: Petroleum refining, instructions for laboratory practicum (www.fkit.hr).
Z. Janović: Petroleum and petrochemical processes and products, Croatian Society for Fuels and Lubricants, Zagreb, 2011. (Croatian)
D. S. J. Jones i R. Peter: Handbook of petroleum processing, Springer, 2006.
S. D. Raseev: Thermal and catalytic processes in petroleum refining, Marcel Dekker, New York, 2003.
A. Chauvel i G. Lefebvre: Petrochemical processes - technical and economic characteristics: Vol. I. Synthesis gas derivatives and major hydrocarbons; Vol. II. Major oxygenated, chlorinated and nitrated derivatives, Technip, Paris, 2001.

Course: CATALYTIC REACTION ENGINEERING		
Language: English		
Lecturer: Prof. Vesna Tomašić		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**1**	**15**
Seminar	**0**	**0**
		Overall: 45
		ECTS: 5

PURPOSE:

The aim of this course is synthesis of fundamental knowledge from catalysis, reaction engineering and transport phenomena as basis for design and optimization of industrial catalytic reactors and to solve complex technical problems.

THE CONTENTS OF THE COURSE:

Introduction, kinetics and mechanism of the reaction, determination of the limited step of reaction rate.
Integrated approach to design of catalysts and reactors.
Experimental methods of testing in laboratory reactors.
Classification of catalytic reactors.
Fixed bed reactor (features, classification, advantages and disadvantages, examples of the process).
Heat and mass transfer in a fixed bed reactor under isothermal and non-isothermal conditions (theoretical and experimental approach).
Adiabatic reactors (conditions for adiabatic operation, the performance of adiabatic reactor, fields of applications) and nonisothermal- nonadiabatic (NINA) reactors.
Trickle bed reactor and submerged fixed-bed reactor with gas bublling.
Modeling of the fixed bed reactor.
Moving bed reactors (features, classification, advantages and disadvantages).
Fluidized bed reactors.
Slurry reactors: features, classification and examples of process.
Heat and mass transfer in slurry reactors.
Process intensification - applying of the structured reactors.

GENERAL AND SPECIFIC COMPETENCE:

Application of the basic methodology of chemical engineering to solve the real problems, analysis and synthesis of knowledge, understanding the relationships between reactor inputs and reactor outputs, identification of the key process parameters for design and successful reactor performance.
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KNOWLEDGE TESTING AND EVALUATION:

The course is given as a combination of lectures, exercises, home-works and periodic assessment of knowledge. Compulsatory exercises must be passed in order to get access to the exam. The examination form may change from written to oral.

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Quality and performance will be monitored through student surveys, interviews with students during the teaching process and their success in exams.

LITERATURE:

S. Zrnčević, KATALIZA I KATALIZATORI, HINUS, 2005.
Z.Gomzi, KEMIJSKI REAKTORI, HINUS, Zagreb, 1998.
R.W. Missen, C.A.Mims, B.A.Saville, Chemical Reaction Engineering and Kinetics, J.Wiley, New York, 1999.
H.S. Fogler, Elements of Chemical Reaction Engineering, Prentice-Hall, New Jersey, 1999.
C.H. Bartholomew, R.J.Faruto, Fundamentals of Industrial Catalytic Processes, J.Wiley, New York, 2006.
Handbook of Heterogeneous Catalysis, Vol. I.-V., Eds. G.Ertl, H.Knozinger, J. Weitkamp, VCH, 1997.
Catalysis: An Integrated Approach, Eds. R. A. van Santen, P. W. N. M. van Leeuwen, J. A. Moulijn, B. A. Averill, Elsevier, Amsterdam, 2000.
V.V. Ranade, R.V. Chaudhari, P.R. Gunjal, Trickle Bed Reactors, Reaction Engineering & Applications, Elsevier, Amsterdam, 2011.

Course: Air Pollution Control Engineering		
Language: English		
Lecturer: Prof. Vesna Tomašić		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**1**	**15**
Seminar	**0**	**0**
		Overall: 45
		ECTS: 5

PURPOSE:

Understanding of the technical processes and equipments that are used in the air pollution control, with a special emphasis on the optimization of operating conditions, sizing/dimensions of the process equipments (process equipments design) and the development of integrated processes.

THE CONTENTS OF THE COURSE:

The composition and structure of the atmosphere and definition of the basic concepts.
Sources and sinks for the main groups of pollutants and their influence on the air pollution.
Emissions, imissions and atmospheric dispersion of air pollutant.
The history of air pollution and legislation.
Classification of pollutants and determination of the pollutants concentrations.
Mechanisms of formation for the major groups of contaminants/pollutants.
Solving of the air pollution problems (primary and secondary processes, integrated approach).
Classification of the technical processes and devices for air protection and description of the basic principles of their work.
Removal of the particulate matter using mechanical separation methods (centrifugal sedimentators, cyclones, filters, electrostatic precipitators).
Waste gas scrubbing in the washing column and wet dedusting (scrubbers).
Removal of gaseous pollutants by using physical separation methods (absorption and adsorption).
Removal of gaseous pollutants by condensation and membrane separation.
Chemical treatment of the waste- or exhaust gas: thermal treatment (incineration) and catalytic oxidation.
Biological treatment of waste gases.
Reducing pollutant emissions from mobile sources.

GENERAL AND SPECIFIC COMPETENCE:

Application of the basic methodology of chemical engineering for the selection of process and device for air pollution control, understanding of the influences of different process values and parameters, mathematical modeling and design of the air pollution equipments.

KNOWLEDGE TESTING AND EVALUATION:

The course is given as a combination of lectures, exercises, home-works and periodic assessment of knowledge. Compulsatory exercises must be passed in order to get access to the exam. The examination form may change from written to oral.

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Quality and performance will be monitored through student surveys, interviews with students during the teaching process and their success in exams.

LITERATURE:

N. de Nevers, Air Pollution Control Engineering, McGraw-Hill, N.Y., 1995.
H. Brauer, Y.B.G. Varma, Air Pollution Control Equipment, Springer-Verlag, Berlin, 1981.
R.A. Santen, P.W.N.M. van Leeuwen, J.A. Moulijn and B.A. Averil, Catalysis-An Integrated Approach, 2nd Ed., Studies in Surface Science and Catalysis, Vol. 123, Elsevier, Amsterdam, 1998.
A. Cybulski and J.A. Moulijn, Structured Catalysts and Reactors, Marcel Dekker, N.Y. , 1998.
C. D. Cooper, F.C. Alley, Air Pollution Control-A design Approach, Waveland Press, Long Grove, 2002.
R. M. Heck, R. J. Farrauto, S.T. Gulati, Catalytic Air Pollution Control: Commercial Technology, John Wiley & Sons, Int., New York, 2002.
H. de Lasa, B. Serrano, M. Salaices, Photocatalytic Reaction Engineering, Springer, New York, 2005.

Course: Environmental Engineering

Language: English

Lecturer: Dr. Ana Lončarić Božić, associate professor
Dr. Hrvoje Kušić, assistant professor

TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**0**	**0**
Seminar	**1**	**15**
		Overall:30 + 0 + 15
		ECTS: 5

PURPOSE:

Introducing the environmental engineering issues and methodology for development and application of environmentally friendly processes and products.

THE CONTENTS OF THE COURSE:

1. **week:** Basic terms and definitions from the field of environmental protection. Main guidelines and principles laid down by National Environmental Protection Law.
2. **week:** Definition and concept of sustainable development. Role of engineering disciplines in environmental protection. Sources and transportation of pollutants in environment. Application of conservation laws in monitoring the pollutants in environments.
3. **week:** Basic principles and tools in prevention strategy for environmental protection. Cleaner production methodology and waste management hierarchy.
4. **week:** Sources of waste generation in chemical industry processes. Methodology of source analysis and corresponding preventive measures. Case studies.
5. **week:** 1st partial exam.
6. **week:** Definition of terms “green chemistry” and “green engineering”. Application of basic principles of “green chemistry” and “green engineering” in development and design of processes and products.
7. **week:** Methods for quantification of environmental impacts. Application of atom economy. Calculation of E-factor.
8. **week:** Definition of term “green indicator”. Application of “green indicator” in life cycle analysis of products.
9. **week:** Importance of catalysis in development of sustainable processes.

Role of catalyst in creation of reaction path. Opportunities of reduction of raw materials and energy consumption and consequent minimization of environmental impact by catalytical processes.

10. week: 2nd partial exam.

11. week: Instruments of sustainable development and their application in environmental engineering. Methodology for analysis of correlation between activity and pollution.

12. week: Principles and elements of environmental management systems. Role of environmental engineering in environmental impact assessment procedures.

13. week: Main features of IPPC directive; transposition in national legislation. Best available technologies.

14. week: Control and minimization of emissions in environment. Noise source – transmission path – receiver concept.

15. week: 3rd partial exam

GENERAL AND SPECIFIC COMPETENCE:

Application of engineering principles in identification, analysis and solving environmental problems. Adoption of basic principles and tools for preventive approach in environmental protection.

KNOWLEDGE TESTING AND EVALUATION:

1. Partial exams
2. Written exam

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student survey

LITERATURE:

A. Rubin, E.S. Introduction to engineering and environment, McGraw Hill, , New York, 2001.

B. Lectures

Course: Technological processes of organic industry		
Language: English		
Lecturer: Prof. Sanja Papić, PhD		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**1**	**15**
Seminar		
		Overall:45
		ECTS: 5

PURPOSE:

Understanding the importance of the organic chemical industry, and numerous products essential to the modern economy, and the continued need for the development and changes. Fundamentals of chemical technological processes. Gaining knowledge about basic processes of organic chemistry industry (sulfonation, nitration, amination by reduction, oxidation, alkylation, hydrolysis, halogenation), which includes understanding of the process flow diagram and process conditions, reaction mechanisms, kinetics, thermodynamics and competitive processes, and examples of process improvement in terms of better selectivity and environmental acceptability.

THE CONTENTS OF THE COURSE:

1) Introductory lecture: characteristics and the role of the organic chemical industry. Overview of important intermediates and products. The variety of the products of organic chemical industry (organic dyes, coatings, printing inks, soaps, detergents, cosmetics, agrochemicals, pharmaceuticals, synthetic resins, rubber, plastics, explosives).

2) Briefly about the fundamentals of chemical technological processes: the supply of the reactants into the reaction zone, chemical reactions, removal of the products from the reaction zone**.**

3) The overall rate of a process; kinetically and diffusion controlled processes. The basic parameters of the technological regime. Equilibrium and product yield.

4-12) The basic industrial processes for the processing of organic materials in products essential to the modern economy. Briefly about the types of chemical reactions, the reaction agents, process parameters, kinetics, mechanism and thermodynamics (with examples of production of selected important intermediates and products) for each basic process: **sulfonation** (4, 5), **nitration** (6, 7), **amination by reduction** (8), **oxidation** (9), **alkylation**

(10), **hydrolysis** (11), **halogenation** (12).

13) Flow diagrams of selected industrial processes; from raw material to product (or intermediate) with all technological parameters. Understanding of the process flow diagrams and process conditions.

14, 15) Examples of the improvements of basic processes of organic chemical industry in terms of improved selectivity and environmental acceptability.

GENERAL AND SPECIFIC COMPETENCE:

Engineering knowledge on the basic processes of the organic chemical industry, issues and the need for the development of alternative, new environmentally friendly technologies. Knowledge of the intermediates and products relevant to the modern economy.

KNOWLEDGE TESTING AND EVALUATION:

Partial tests (2 times) (written) or exam (written and/or oral)

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

University of Zagreb student survey

LITERATURE:

1. R.C. Wittcoff, Industrial Organic Chemicals, John Wiley&Sons, New York, 1996.

2. H.G. Franck, J.W. Stadelhofer, Industrial Aromatic Chemistry, Springer-Verlag, New York, 1988.

3. J. P. Mukhlyonov, Fundamentals of Chemical Technology, Mir Publishers, Moscow, 1986.

4. F. Cavani, G. Centi, S. Perathoner, F. Trifiro, Sustainable Industrial Chemistry, Wiley-VCH, Weinheim, 2009.

5. D.T. Allen, D.R. Shonnard, Green Engineering, Prentice Hall PTR, New Jersey, 2002.

6. R. Turton, R.C. Bailie, W.B. Whiting, J.A. Shaeiwitz, Analysis, Synthesis and Design of Chemical Processes, Prentice Hall PTR , New Jersey, 2003.

Course: Petrochemical technology

Language: English

Lecturer: **Assoc. Prof. Elvira Vidović, PhD.**

TEACHING	WEEKLY	SEMESTER
Lectures	2	30
Laboratory	1	15
Seminar	0	0
		Overall: 45
		ECTS: 5

PURPOSE:

The development of processes of petrochemical production involves the synthesis of science and engineering, technology, ecology and economy. For selected examples of the process to achieve the integration of engineering and technological knowledge and to train professionals for research and development of the field.

THE CONTENTS OF THE COURSE:

1. Introduction to petrochemistry: raw materials, processes, products.
2. Natural gas: production and composition.
3. Processes of gas treatment.
4. Processes of syngas production.
5. Development of processes based on Fischer-Tropsch synthesis.
6. process of ammonia production: reaction parameters.
7. Processes of ammonia production.
8. Technological improvements; example of the application of BAT concept.
9. Pyrolysis (steam creaking): the most important process of petrochemical industry.
10. Products of pyrolysis: the importance for the chemical and the overall industry.
11. Production of aromatic hydrocarbons (BTX).
12. Production of phenol
13. Production of styrene
14. Production of polystyrene

GENERAL AND SPECIFIC COMPETENCE:

The adoption and application of theoretical knowledge on the main processes of production of the most important petrochemical products; including reaction pathways and technological schemes.

KNOWLEDGE TESTING AND EVALUATION:

Continuous assessment through the two exams, written or oral exam.

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

student survey

LITERATURE:

E. Vidović: Petrochemical technology, lecture (www.fkit.hr)

G. M. Wells: Handbook of petrochemicals and processes, Ashgate Publishing Limited, Hampshire, 1999.

Course: Polymer nanocomposites		
Language: English		
Lecturer: Prof. Sanja Lučić Blagojević		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**0**	**0**
Seminar	**1**	**15**
		Overall: 45
		ECTS: 4

PURPOSE:

To introduce students with access of design of nanocomposite polymer materials aiming to achieve specific properties. The objective can be achieved by integrating knowledge from the field of polymer materials, inorganic materials, and knowledge about the modelling of the interface polymer / filler.

THE CONTENTS OF THE COURSE:

L1 - Polymeric materials. The importance and application of polymeric materials. Classification of polymer materials by origin, by application properties, according to the type of repeating units, according to the forms of macromolecules. Mechanisms of polymerization: step, chain; homogeneous and heterogeneous processes of polymerization. The structure of polymers: configuration and conformation of macromolecules. Super-molecular structures. Physical properties of polymers. Additives to polymer materials. Fillers as modifiers of properties.

L2 - Differences between micro and nanocomposites. Polymer Composites. Interphase polymer - filler: mechanisms of adhesion, the application of adsorption theory. Thermodynamics of interfacial free energy, coefficient of wetting, thermodynamic work of adhesion. Chemisorption theory. Differences between nanocomposites and microcomposites: filler particle size, size of the interface, morphology, fraction of matrix in the interphase layer.

L3-5 The types of nanofillers. *Carbon nanotubes*: molecular and supramolekulna structure, properties (mechanical properties, electrical properties). Processing of nanotubes: laser ablation, arc discharge, chemical vapor deposition. Composition and purification of the reaction products. Surface modification (covalent and non-covalent)

The layered nanofillers: types, structure, organic modification of layered nano-filler. *Equi-axed nanofillers*: types, production, surface modification.

Quantum dots: types, structure, quantum effects, properties. Surface modification of quantum dots: with amphiphilic polymers, multidentate polymeric ligands, polymers functionalized at the ends of the chain, quantum dots encapsulated by dendrimers.

1st partial exam

L7-9 Preparation of polymer nanocomposites. The distribution and the dispersibility of fillers in the polymer matrix. *Preparation p*rocess for composites with carbon

nanotubes: preparation of the solution, stirring the mass of the polymer, the mixing in the melt, in situ polymerization.
Preparation of nanocomposites with layered nano-fillers: intercalated and exfoliated morphology, instrumental techniques for morphology investigation. Methodology and thermodynamics of individual processes: intercalation of polymer or prepolymer, in situ intercalation polymerization, melt intercalation. The impact of factors on the morphology of the melt intercalation process. The degradation of the system during the preparation of the melt intercalation.
Preparation of polymer nanocomposites with equi-axed nano-fillers. The process for preparing the melt and solution, in situ polymerization of the polymer, the in situ polymerization of the inorganic phase is formed.
Preparation of nanocomposite system quantum dot / polymer. Quantum dots in polymer colloids - a methodology for preparing nanocomposites with different methods, advantages and disadvantages of different methods of preparation. Systems of layer-by-layer quantum dot / polymer. Controlled binding of polymer layers and quantum dots. Quantum dots in polymers bulk and thin polymer films.

L10-11 Properties and application of polymer nanocomposites. Mechanical properties: the influence of types of nano-filler, filler particle size and thermodynamics of the polymer / filler morphology, failure mechanisms and features of the mechanical behavior (modulus, tensile strength, toughness). Effect of nanofiller on the permeability of gases and liquids: the concept of tortuous diffusion. Dimensional stability of nanocomposites. The thermal stability of the nanocomposites. Effect of nanofillers on flammability of polymers. Electrical properties. Optical and optoelectronic properties.

L12 2nd partial exam

L13-15 Student seminars

GENERAL AND SPECIFIC COMPETENCE:

The course develops the general students' competence of analysis and synthesis of scientific knowledge and presentation in oral form.

Specific competencies courses include connecting knowledge engineering polymer materials and surface and interfacial engineering in multiphase polymer systems, broadening and deepening the knowledge of the structure, properties, production and application of polymer nanocomposites as advanced materials, and knowledge about the selection of techniques and methods for the characterization of multiphase systems and quality control of the final products.

KNOWLEDGE TESTING AND EVALUATION:

Partial exams, writing and oral exam

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student questionnaire.

LITERATURE:

1. P. M. Ajayan, L. S. Schadler, P. V. Braun, Nanocomposite Science and Technology, Wiley – VCH, 2003.
2. T. J. Pinnavaia, G. W. Beall, Polymer-Clay Nanocomposites, John Wiley and Sons Inc., 2001.
3. A. I. Nakatani, R. P. Hjelm, M. Gerspacher, R. Krishnamoorti, Filled and Nanocomposite Polymer Materials, Vol.661, Materials Research Society, 2001.
4. R.Vaia, R. Krishnamoorti, Polymer nanocomposites: Synthesis, Characterization and Modeling, American Chemical Society, 2001.
5. Y. S. Lipatov, Polymer Reinforcement, Chem. Tec. Publishing, Ontario, 1995.

Course:	**Additives for polymer materials and products (optional)** Chemical Engineering graduation; 1st and 2nd year

Language: English

Lecturer: Mirela Leskovac

TEACHING	WEEKLY	SEMESTER
Lectures	**2**	**30**
Laboratory	**1**	**15**
Seminar	**-**	**-**
		Overall: 45
		ECTS: 4

PURPOSE:

Familiarizing students with the most important additives which are used for modification, improvement of properties and resistance of polymer materials and their products, focused on mechanisms of their action and application, as well as on economic and ecological aspects of their application.

THE CONTENTS OF THE COURSE:

L-1 An introduction to polymer additives. Classification of additives for polymer materials and products, principles of their action, properties and application; ecological and economical impacts of polymer additives.

L-2 Modifiers of physical properties of polymer materials; principles of their action, classification, properties and applications. The polymer additives efficiency.

L-3 Improvement/ Modification of mechanical properties. Impact modifiers: toughness and macromolecular modifiers. Additives for improvement of strength, processibility and stability: fillers, reinforcing agents and coupling agents.

L-4 Blowing agents; chemical and physical blowing agents; characteristics and factors acting on blowing.

L-5 Plasticizers: Solubility parameter, theory of plasticization, primary and secondary plasticizers. Classification of plasticizers. Plasticizer efficiency.

L-6 Modifiers of optical properties: dyes, pigments and optical brighteners. Classification, properties and application. Criteria for selection of pigments.

L-7 Modifiers of surface properties. Lubricants: reducing of friction, surface abrasion and adhesion. The effect of lubrication on the polymer processing.

L-8 Conductivity: antistatic and conductive additives, action mechanism, classification, properties and application.

L-9 Additives that have a protecting effect against polymer aging and degradation; action mechanism, classification, properties and application.

L-10 Effects of chemically and physically active media, effect of ionizing radiations, mechanical and thermal degradation.

L-11 Heat stabilizers; the influence of heat stabilizers. Thermo-oxidative degradation: action mechanism of antioxidants.

L-12 Photo-oxidative degradation: action mechanism of UV stabilizers, classification and application.

L-13 Flammability: burning mechanism of polymers, flame retardants; action mechanism of retardants, classification, properties and applications.

L-14 Microbiological degradation: action mechanism of biocides; properties and application.

L-15 Methods used to incorporate additives into polymer matrices. Ecological aspects of application of additives for polymer materials and their products. Technical trends and new market requests.

Laboratory exercises:

I. PROPERTIES OF POLYMER ADDITIVES

LE-1) Surface phenomena and surface tension measurement by pendant drop method.

II. OXIDATIVE STABILITY OF POLYMER MATERIALS

LE-2) Influence of additives on the oxidative stability of materials; determination of oxidation induction time, OIT

LE-3) Influence of additives on the oxidative stability of materials; determination of oxidation induction temperature, OIT*

LE-4) Influence of additives on the thermal stability of polymer materials.

LE-5) Polymer flammability **-** Limited oxygen index (LOI)

III. PRINCIPLES OF POLYMER PLASTICIZATION

LE-6) Influence of plasticizers on the polymer material properties.

LE-7) Evaluation of plasticizers efficiency.

LE-8) The influence of plasticizers on the polymer surface properties (study of plasticizers migration).

L-Lectures, **LE**-Laboratory exercises

GENERAL AND SPECIFIC COMPETENCE:

Acquiring knowledge required to obtain satisfactory properties of polymeric materials and quality. Knowledge relevant to the selection of additives and features crucial for ensuring the quality and stability of engineering polymers depending on the specific requirements of the application.
Specific competencies include training of future experts to apply the acquired knowledge in the production process and quality control.

KNOWLEDGE TESTING AND EVALUATION:

Partial exams; written / oral exam.

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student questionnaire.

LITERATURE:

1. M. Leskovac, *Dodatci za polimerne materijale i proizvode*, Interna skripta, 2008.
2. Z. Janović, Polimerizacije i polimeri, Hrvatsko društvo kemijskih inženjera i tehnologa, 1997.
3. L. H. Sperling, Introduction to Physical Polymer Science, Wiley Interscience, New Yersey, 2006.
4. Jan C.J. Bart, Additives in polymers (Industrial Analysis and Applications), John Wiley & Sons Ltd, England 2005
5. J. T. Lutz, R.F. Grossman, Polymer Modifiers and Additives, Marcel Dekker, 2001.
6. J. Štepek, H. Daoust, Additives for Plastics, Springer-Verlag, New York, 1983.

Course:	**Characterization and identification of the products (optional)** Chemical Engineering graduation; 1st and 2nd year (1st and 3rd semester)
Language: English	
Lecturer:	**Prof. Mirela Leskovac, PhD** **Prof. Emi Govorčin Bajsić, PhD** **Prof. Zlata Hrnjak-Murgić, PhD**

TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**0**	**0**
Seminar	**1**	**15**
		Overall: 45
		ECTS: 4

PURPOSE:

Familiarising with the techniques used to characterisation and identification of materials very essential in the development of new materials, the improvement of existing materials and the quality verification of materials and final products.

THE CONTENTS OF THE COURSE:

WEEK (1-4)

L (1) Introduction to the characterization and identification, relationship structure-properties of materials.

L (2-3) The chemical, physical, electrical and optical properties of polymers.

L (4-5) Techniques of characterization: GCP, FTIR, UV / VIS, NMR.

S (1-4) Practical teaching - interpretation of spectra (FTIR, NMA). Molar mass determination.

WEEK (5)

PARTIAL TEST - 1st partial test

WEEK (6-9)

L (6-7) Thermal analysis. Thermal properties of materials.Techniques of thermal analysis. Differential scanning calorimetry (DSC) technique. Characterization and identification of materials by DCS technique. The type of DSC instruments.

L (8-9) Dynamic mechanical technique (DMA). Characterization of materials by DMA. Primary viscoelastic functions. Secundary viscoelastic functions. Time-temperature superposition (TTS). The influence of the compositions and conditions of the measurements on the viscoelastic functions.

L (10) Thermogravimetry analysis (TGA). Application of TGA technique. Thermal stability determination by TGA technique. Kinetic of thermal degradation.

S (5-8) Practical teaching - thermal properties - DMA, DSC, TGA

WEEK (10)

PARTIAL TEST - 2nd partial test

WEEK (11-14)

L (11-12) Surface characterization. Surface and interfacial phenomena and processes of heterogeneous systems. Cohesion, adhesion, contact angle, Young's equation. The surface tension of the liquid and the surface free energy of solids and measurement techniques.
Surface free energy determination by contact angle measurement.
Goniometer. Models for calculating the surface free energy (Zisman, Owens-Wendt, Wu, Acid-base model).

S (8-11) Practical teaching - Surface characterization

L (13-14) The mechanical properties of materials and influential factors. The types of loading. Tensile testing. Stress-strain curve. Elastic and plastic deformation.
Time-dependent deformation, viscoelasticity, relaxation processes.
Creep and stress relaxation. Cyclic loading-unloading (hysteresis).

S (12-14) Mechanical properties of materials

L (15) Microscopic techniques for materials characterization. Terms in microscopy. The characteristics of different types of microscopes.
Selection of microscopy techniques and sample preparation.

S (15) Practical teaching - Microscopy of materials

WEEK (15)

PARTIAL TEST - 3rd partial test

L-Lectures, **S** - Seminar

GENERAL AND SPECIFIC COMPETENCE:

The students are trained to work with selected techniques of materials and products characterization.
They are going to gain the knowledge and competence on certain methods and techniques of characterization and identification of polymers. Independent performance of analysis and quality control of materials and final products.

KNOWLEDGE TESTING AND EVALUATION:

Partial tests (3 times) (written) or exam (written and/or oral)

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student questionnaire.

LITERATURE:

1. G. Kümpf, Characterization of Plastics by Physical Methods, Hanser Pub. München 1986.
2. A. A. Collyer, L. A. Utracki, Polymer Rheology and Processing, Elsevier Sc. Publ. Co., Inc., New York , 1990.
3. B. Wunderlich, Thermal Analysis, Academic Press, Inc., London, 1990.
4. A. R. West, Solid State Chemistry and its Applications, Wiley and Sons, Brisbane, 1984.
5. Ovid, Science Direct, Web of Science

Course: Molecular spectroscopy

Language: English

Lecturer: **Prof. Irena Škorić, Ph.D., Prof. Vesna Volovšek, Ph.D.**

TEACHING	WEEKLY	SEMESTER
Lectures	**2**	**30**
Laboratory	**1**	**15**
Seminar		
		Overall: 45
		ECTS: 6

PURPOSE: To inform students with physical base of molecular spectroscopy and with application of individually each method in chemistry, especially with interpretation of spectra in determination of structures of organic compounds.

THE CONTENTS OF THE COURSE:

1. Interaction of electromagnetic radiation and matter, Electromagnetic spectrum, Quantization of energy and molecular energy levels, Absorption and emission of electromagnetic radiation, Half-width and intensities of spectral transitions.
2. Molecular symmetry, Elements of symmetry, Point groups, Tables of character, Election rules and transition probability.
3. Vibrational spectroscopy, Experimental methods.
4. Molecular vibrations of diatomic molecules, Molecular vibrations of polyatomic molecules, Characteristic vibration.
5. Analysis of vibrational spectra.

COLLOQUIUM

6. NMR spectroscopy: Basic approaches, Nuclear magnetic moment. ^{1}H NMR spectra: Chemical shift and shielding, Integrals, Chemical environment and chemical shift, Magnetic anisotropy, Coupling constant.
7. NMR spectroscopy. ^{13}C NMR spectra: Chemical shifts of carbon-13, integration in ^{13}C NMR spectrum, NOE effect, Heteronuclear coupling of carbon with deuterium, Fluorine-19 and Phosphorus-31.
8. NMR spectroscopy. Spin-spin coupling: Mechanism of coupling, coupling constants of spectrum of first and second order, Long-range coupling.

9. – 11. NMR spectroscopy. Additional chapters in one-dimensional NMR: Exchange of protons in H_2O and D_2O, Tautomerism, Protons on the nitrogen atom, Effect of the solvent on chemical shift; Advanced NMR techniques: DEPT experiment, Two-dimensional spectroscopic methods: COSY, HETCOR

COLLOQUIUM

12. UV/Vis spectroscopy and fluorescence: Instrumentation, Presentation of spectra, Solvents, Chromophores, Effect of conjugation

13. UV/Vis spectroscopy and fluorescence: Woodvards rule for enons, Aromatic compounds, Visible spectrum, Color in compounds

COLLOQUIUM

14. Mass spectroscopy: Mass spectrometer, GC/MS, Mass spectrum, Determination of molecular weight and formula, Effect of isotopes

15. Mass spectroscopy: Fragmentation

COLLOQUIUM

GENERAL AND SPECIFIC COMPETENCE:

Students will be able to analyze obtained results and apply it in determination of structures of organic compounds, by combining spectroscopic methods which they studied in this course.

KNOWLEDGE TESTING AND EVALUATION:

Exam will be held through colloquiums after each major methodological units.
Students who do not pass colloquia (total 4) will take written test.

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student questionnaire

LITERATURE:

1. Banwell, C. N., McCash, E. M., *Fundamentals of Molecular Spectroscopy*, McGraw-Hill College, 1995.
2. Pavia, D. L., Lampman, G. M., Kriz, G. S., *Introduction to Spectroscopy*, Third Edition, Brooks/Cole Thomson Learning, Australia, 2001.
3. Silverstein, R. M., Webster, F. X., *Spectrometric Identification of Organic Compounds*, Sixth Edition, John Wiley & Sons, Inc., New York, USA, 1997.

Course: Environmental management systems		
Language: English		
Lecturer: Associate prof. Ana Lončarić Božić, PhD		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**0**	
Seminar	**1**	**15**
		Overall: 45
		ECTS: 4

PURPOSE: Introduction to the aims, methodology and structure of Environmental Management Systems (EMS). Overview of knowledge and skills for development and implementation if EMS as one of sustainable development tools.

THE CONTENTS OF THE COURSE:

1st week – Preventive approach in environmental protection and management. Basic principles and elements of sustainable development. Introduction to EMS based on Deming's cycle.

2nd week – Basic terms and definitions. Overview of ISO 14001 (HR EN ISO 14001:2009) standard. Purpose of standardisation. Positive features of EMS implementation.

3rd week –Basic roles and focus of EMS. Structure and main elements of EMS. Concept of continual improvement.

4th week – Requirements of ISO 140001 for EMS. Environmental policy. Objectives and targets. Examples of setting "smart" objectives.

5th week –Elements of planning process. Environmental aspects and impacts. Identification of legal requirements and significant aspects. Case studies.

6th week – Significance of defined roles, resources and responsibilities for successful implementation of EMS. Competences and communication.

7th week –Types and management of EMS documentation. Differences between documents and records. Case studies.

8th week –1st partial exam

9th week – Emergency preparedness and response. Analysis of processes and activities, aspects and potential impacts; case study.

10th week **–** Assessment of compliance of EMS with ISO 14001 standard. Identification of non-conformances and appropriate corrective and preventive actions. EMS audit and management review. Identification of significant aspects and impacts: service industry case study.

11th week – Basic elements and methodology of Life cycle assessment (LCA) methodology. LCA as sustainable development tool.

12th week – Cleaner production. Correlation of EMS with waste management strategy within Cleaner production. Identification of waste sources and corresponding preventive measures of Cleaner production. Cleaner production methodology; case study.

13th week – Differences and similarities of environmental management systems according to EMAS and ISO 14001.

14th week – Occupational health and safety; OHSAS18001. Integrated management systems.

15th week – Programme Responsible care. Principles and guidelines. Correlation of Responsible care elements with environmental management system.

GENERAL AND SPECIFIC COMPETENCE:

Adoption of proactive approach in environmental protection and management. Understanding the opportunities of continual improvement of environmental performances by adoption and implementation of EMS.

KNOWLEDGE TESTING AND EVALUATION:

1. Partial preliminary exams

2. Written exam

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student survey

LITERATURE:

1) Sheldon, C.: ISO 14000 and Beyond, Environmental management systems in real world, Greenleaf Publishing, UK,1997.
2) Lectures

Course: Adhesion and adhesive products		
Language: English		
Lecturer: Prof. Sanja Lučić Blagojević		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**0**	**0**
Seminar	**1**	**15**
		Overall: 45
		ECTS: 4

PURPOSE:

To introduce students to the functional characteristics of products which are used as adhesives and sealants in understanding their structure and properties, quality factors and their target applications in bonding technologies. The emphasis is on the effects of surface phenomena, environmental influences and stresses in the application. Within Analysis of samples - a case study in a seminar in selected experimental exercises, students develop specific knowledge and skills that enable them to assess the quality and characteristics of adhesive materials, as well as their choice for a particular purpose.

THE CONTENTS OF THE COURSE:

L-Lectures (1-15); LE-Laboratory exercises; S- Seminar (1);

L (1-3) Application of surface science. Definition and application of following terms: surface tension, surface and interfacial energy, the thermodynamic work of adhesion, wetting, spreading and debonding. Inhomogeneity of surface and measurements.

L (4-6) Practical adhesion. The application of mechanisms and theories in analyzing results of the adhesion bonding. Mechanical, diffusion, adsorption, chemical, electrostatic theory in practice. Criteria for achieving quality adhesion bonds.

LE - Determination of parameters of adhesion

L (7-9) Characterization of surfaces. Analysis of the specificity of polymer surfaces. Application of thermodynamics and solubility parameters in assessing the adhesion properties of the surface. The effects of surface modification. Application of the method for the characterization of surfaces.

L (10-15) The adhesive products. The application of scientific methodology of product engineering in the analysis pyramid of the product. Types of adhesives and sealants. The specifics of their application. Characteristics of the structure and properties of the matrix and the impact on the formulation and implementation of quality factors. Examples of adhesives and sealants given purpose.
Structural and non-structural adhesives. Epoxies, urethanes, neoprene, cyanoacrylates as base adhesives. Acrylic, Bituminous, polysulfide, silicone, polyether and polyurethane sealants. The advanced adhesive products based on nanotechnology. A new generation

of silane-terminated organic seal. Analysis of the practical implementation of Adhesion bonding. The elements for optimal selection of adhesives and sealants.
LE - testing of adhesive compound
S

GENERAL AND SPECIFIC COMPETENCE:

General competencies of students complement with application of basic knowledge of surface phenomena, which are essential for proper adhesion at the interface between two materials in the application process of bonding, as well as designing new products for the market.
Specific competencies are related to the possibility of appropriate modifications of bonding process by modification and activation of surfaces in industrial applications, as well as the selection of appropriate product for a given application.

KNOWLEDGE TESTING AND EVALUATION:

Partial exam, written exam

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student questionnaire.

LITERATURE:

1. V. Kovačević, Adhezija i adhezijski proizvodi, interna skripta, 2009.
2. A.J. Kinloch, Adhesion and Adhesives; Science and Technology, Chapman & Hall, London, UK, 1995.
3. K.L. Mittal, Adhesion Measurement of Films and Coatings, VSP, Utrecht, 1995.
4. A. Pizzi, K.L. Mittal, Handbook of Adhesive Technology, 2nd Ed., Marcel Dekker, Inc., New York, 2003.
5. K.L. Mittal, A. Pizzi, Adhesion Promotion Techniques: Technological Applications, Marcel Dekker, Inc., New York, 2004.
6. E.M. Petrie, Handbook of Adhesives and Sealants, Mc-Graw-Hill, New York, 2000.

Course: DEGRADATION AND MODIFICATION OF POLYMERS		
Language: English		
Lecturer: **Prof. Zlata Hrnjak – Murgić, PhD**		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**0**	**0**
Seminar	**1**	**15**
		Overall: 45
		ECTS: 4

PURPOSE:

The purpose of this course is to introduce the students to degradation and modification of polymers. This course elaborates mechanisms of degradation of various types of polymers. The students will learn about characterization techniques of degradation products and modification of polymers. The modification leads to new kinds of polymers with improved properties. Degradation and modification are connected to the recycling of polymers and environmental impact.

THE CONTENTS OF THE COURSE:

Lectures:

1. Introduction to degradation processes. Mechanisms of degradation.
2. Oxygen and ozone activity. Thermal and photo-oxidation.
3. Mechanical degradation.
4. Degradation of polyolefins.
5. Degradation of biopolymers. Hydrolyzable polymers.
6. 1st partial test
7. Modification of polymers: multifunctional systems - compatibility
8. Thermodynamics of multifunctional systems
9. Polymer blends,
10. Polymer composites
11. Chemical modification of polymers (graft polymerization)
12. Chemical modification of polymers (copolymerization)
13. Physical modification of polymers (homogenization in the melt, in solution)
14. Modification of fillers
15. 2nd partial test

Seminar:

- Making presentations and / or written seminar paper on a given topic

GENERAL AND SPECIFIC COMPETENCE:

To introduce the students to the degradation of polymers and how to modify polymer with polymers and additives to obtain improved and functional polymer properties.

Students will gain the basic knowledge of multifunctional systems and their compatibility; understand their thermodynamic, get to know the processes of preparing blends and composites.

KNOWLEDGE TESTING AND EVALUATION:

Partial tests (2 times) (written) or exam (written and/or oral)

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

University of Zagreb student survey

LITERATURE:

1. H. Mark, N. Bikales, C. Overberger, G. Menges, Encyclopedia of Polymer Science and Engineering, John Wiley & Sons, New York, **4**, (1985)
2. C. Chan, Polymer Surface Modification and Characterization, Hanser Pub., New York, (1993)
3. L.A. Utracki: Polymer Alloys and Blends, Hanser Publishers, New York, 1989.
4. Joel R. Fried, Polymer Science and Technology, Prentice Hall Professional, USA, 2003.

Course: CELLULOSE AND PAPER TECHNOLOGY		
Language: English		
Lecturer: Prof. Zlata Hrnjak – Murgić, PhD		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory		
Seminar	**1**	**15**
		Overall: 45
		ECTS: 4

PURPOSE:

To introduce students with wood as a material and production of cellulose from different types of wood. Manufacture of wood pulp and technical pulp into paper. Production of paper packaging and other products based on cellulose as a natural polymer.

THE CONTENTS OF THE COURSE:

Lecture:

16. Wood and wood fibres.
17. The chemistry of wood–cellulose, hemicellulose, lignin.
18. Cellulose technology–prepared wood chip.
19. Groundwood technology.
20. Semi-cellulose technology–neutral sulphite process, cold alkali process.
21. Sulphite cellulose technology– alkaline process.
22. 1st partial test
23. Chemical regeneration of white and black liquor.
24. Paper technology–fillers, adhesives, dyes.
25. Preparation of paper pulp.
26. Paper making machine.
27. Analysis of paper.
28. Types and preparation of corrugated cardboard.
29. 2nd partial test

Laboratory:

1. Analysis of α, β, χ cellulose.

Visit to industry:

PAN paper mill Zagreb

GENERAL AND SPECIFIC COMPETENCE:

Students will be introduced to the natural polymer cellulose, its gaining of wood and application for the production of paper, cardboard charcoal etc. Paper recycling and applications.

KNOWLEDGE TESTING AND EVALUATION:

Partial tests (2 times) (written) or exam (written and/or oral)

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

University of Zagreb student survey

LITERATURE:

5. I. Opačić, Kemijska prerada drva (Chemical processing of wood), Zagreb, 1967.
6. M. Bravar, N. Ban, J. Rolich, Kemijska tehnologija celuloze i papira sa zadacima (Chemical technology of pulp and paper), Interna skripta, Tehnološki fakultet, Zagreb, 1972.
7. J. C. Roberts, The Chemistry of Paper, The Royal Society of Chemistry, Cambridge, 1996.
8. F. Kljajić, Kemijska prerada drva (Chemical processing of wood), Školska knjiga, Zagreb, 2000.

Course: Bioseparation Processes		
Language: English		
Lecturer: Prof. Bruno Zelić, PhD		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**0**	**0**
Seminar	**1**	**15**
		Overall: 45
		ECTS: 4

PURPOSE:

The goal of the course in downstream processing is to provide an insightful overview of the fundamentals of downstream processing for biochemical product recovery. Emphasis is given to process integration with a system's view to allow the students to understand the impact of change in one unit's operations on others in the process.

THE CONTENTS OF THE COURSE:

1st week
introduction, bioprocesses and classification of bioprocesses, specificity of biological materials, definition and characterization of bioproducts: biomass, extra-cellulat and intra-cellular products, classification of bioseparation processes

2nd week
bioseparation process selection, (1) pretreatment, (2) solid-liquid separation, (3) volume reduction, (4) purification, (5) formulation of biological products

3rd week
methods for pretreatment of biological products, isolation of intra-cellular products, mechanical and non-mechanical methods for breakdown of cell walls, overview of industrially important methods do breakdown of cell walls

4th week
solid-liquid separation of biological products: (1) filtration (vacuum filtration and filter presses), (2) sedimentation, (3) centrifugation (tube, disc and scroll type centrifuge)

5th week
separation of biological products (i): (1) evaporation, (2) distillation, (3) rectification1
1st partial test

6th week
separation of biological products (ii): (1) liquid-liquid extraction (mixer-settler, extraction column, centrifugal extraction), (2) precipitation

7th week
separation and purification of biological products (iiia): (1) microfiltration, ultrafiltration and nanofiltration, (2) dialysis, (3) pervaporation

8th week
separation and purification of biological products membrane processes (iiib): (1) reverse osmosis, (2) electrodialysis

9th week
purification of biological products (i): (1) chromatographic methods: basic concepts, columns and systems, (1) size exclusion chromatography, (2) affinity chromatography, (3) ion-exchange
2nd partial test

10th week
purification of biological products (ii): chromatographic methods: monolithic chromatography

11th week
purification of biological products (iii): crystallization, drying, lyophylization

12th week
alternative bioseparation processes: extraction with supercritical fluids

13th week
formulation of biological products: extrusion, fluidized bed drying. enzyme immobilization, formulation of pharmaceuticals, tableting

14th week
fully integrated separation of bioproducts; methodology and overview of industrial processes

15th week
3rd partial test

GENERAL AND SPECIFIC COMPETENCE:

Methodological approach for separation, isolation and purification od biological products: biomass, intra-cellular and extracellular products.

KNOWLEDGE TESTING AND EVALUATION:

1. Partial test or **2. Written exam**

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

University of Zagreb student survey

LITERATURE:

1. E. Holzbecher: Environmental Modeling using Matlab®, Springer-Verlag, Berlin, 2007.
2. J. Mikleš, M. Fiklar: Process Modeling, Identification and Control, Springer-Verlag, Berlin, 2007.
3. Plazl, M. Lakner: Uvod v modeliranje procesov, Univerza v Ljubljani, Ljubljana, 2004.
4. J.B. Snape, I.J. Dunn, J. Ingham, J.E. Prenosil: Dynamics of Environmental Bioprocesses, VCH, Weinheim, 1995.
5. K.T. Valsaraj: Elements of Environmental Engineering, Thermodynamics and Kinetics, Lewis Publishers, Boca Raton, 2000.
6. W.W. Nazaroff: Environmental Engineering Science, John Wiley & Sons, New York, 2001.

Course: Introduction to nanotechnology		
Language: English		
Lecturer: Prof. Sanja Lučić Blagojević; Prof. Stanislav Kurajica		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**0**	**0**
Seminar	**2**	**30**
		Overall:60
		ECTS: 4

PURPOSE:

Accepting of the basic terms of nanotechnology. Acquiring knowledge on properties of nanomaterials. Getting acquainted with methods of preparation and characterization of nanomaterials. Acquaint with the most important kinds of nanomaterials and its applications.

THE CONTENTS OF THE COURSE:

1. Concepts of nanoscience and nanotechnology, molecular nanotechnology. History of nanotechnology, Gordon E, Moore, Richard P. Feynman, Eric K. Drexler, R. Kurzweil. Phenomena on nano-level: quantum effects, surface to volume ratio, the dominance of electromagnetic forces.

2. Properties of nanomaterials: physical, mechanical, chemical, optical, electrical, magnetic. Tunelling effect, quantum confinement, quantum dots, nanostructure, magical numbers. Hall-Petch effect, superparamagnetism, giant magnetoresistance, lotos effect.

Laboratory exercise 1. The determination of crystallite size using Scherrer method.

3. Characterization of nanomaterials. Scanning electron microscope, transmission electron microscope, scanning tunneling microscope, atomic force microscope.

Laboratory exercise 2. Synthesis of silver nano-particles.

4. Nano-manufacturing: top-down approach: photolitography, soft litography, microcontact printing, nano-print litography, dip-pen nanolitografy, high-energy milling, PVD, CVD.

Laboratory exercise 3. The preparation of superparamagnetic nano-particles.

5. Nano-manufacturing: bottom-up approach: precipitation, crystallization, colloids, colloid stabilization, solid suspensions, self-assembly, micelles, thin films, self-assembled monolayers, dendrimers, super-latices, sol-gel method. Nanomanipulation, contact and contactless nanomanipulation. The aims for nanomanipulation.

Laboratory exercise 4. Sol-gel synthesis of SiO_2 nanoparticles.

6. Trends in nanotechnology: Nanomaterials (nano-structured materials, smart materials, ageless materials), nanoproducts (electronics, medicine, environment, industrial technology). Nanorobots. The applicative potential of nanomaterials. Sociological

acceptance of nanomaterials. Riscs of nanotechnology Future of nanotechnology.

7. I. Partial exam

8. Carbon nanostructures; Fullerene – synthesis, properties, reactivity, potential application; Carbon nanotubes – molecular and supramolecular structure, intrinsic properties, synthesis, purification, modification, application

9. Nanoscale electronic, Development of microelectronic devices and technology, Structure and operation of MOF transistor; Transistor scaling, Nanoscaled MOFSET transistors;

10. Molecular electronic – possibilities, preparation and investigation of molecular devices; Molecular switches, transistors and similar devices; Electronic with DNA molecules; Single electron electronic devices

11. Nanocomposites – preparation, structure and properties

12.-13. Nanobiotechnology – biomimetic nanostructures, interface with biologic structure and functions: Biomolecular motors – MEMS and biomolecular motors. Operations and functions of motor proteins; Biotechnology of motor proteins; Science and engineering of molecular motors, Engineered devices; Molecular motors in technological application

14. II. Partial exam

GENERAL AND SPECIFIC COMPETENCE:

Knowledge of basic concepts of nanoscience and nanotechnology. Noticing the diversity properties of nano-materials and macro-materials and understand the reasons of these differences. Knowledge of ways of getting nanomaterials on the principle top-down and bottom-up. Knowledge of basic methods of characterization of nanomaterials. Understanding the trends in nanotechnology.

KNOWLEDGE TESTING AND EVALUATION:

Partial exams, written/oral exam

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student questionnarie

LITERATURE:

1. Di Ventra M., Evoy S., Heflin R.J., Introduction to Nanoscale Science and Technology, Springer, 2004.
2. Owens P.,Introduction to Nanotechnology, John Wiley & Sons, 2003.
3. Wilson M., Kannangara K., Smith G., Simons M., Raguse B., Nanotechnology, basic science and emerging technologies, Chapman &Hall, 2002.

2nd year

Course: Process economy		
Language: English		
Lecturer: Prof.dr.sc. Ljubica Matijašević		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**0**	**0**
Seminar	**1**	**15**
		Overall: 45
		ECTS: 5

PURPOSE:

Learning basics of process economics, for students of technical studies.

THE CONTENTS OF THE COURSE:

Week 1

Introduction. Why are basics of economics necessary for chemical engineers? Economics vs economy. Company as a production and business system.

Week 2

Engineering economic analysis. Equipment cost and value. Cash flow. Basic financial terminology. Investment and time value of money. Examples.

Week 3

Time value of money. Compound interest types and calculation. Continuous compounding. Examples.

Week 4

Cash flow diagram (CFD). Annuity and discounting. Annuity calculation from present and future value. Examples.

Week 5

Inflation and effective interest accounting for inflation. Amortisation. Examples.

Week 6

Investment profitability criteria – basics. Discounted and undiscounted profitability.

Week 7

Project analysis. Net present value (NPV) or net present worth (NPW) for comparing alternatives. Finding interest for project profitability. Examples.

Week 8

NPV meaning in equipment selection. Capitalized cost method. Equivalent annual operating cost method. Common denominator method. Examples.

Week 9

Estimating risks in profitability assessment. Supply and demand influence on product price and profitability. Quantification of supply, demand and risks. Examples.

Week 10.

Costs in production systems. Cost and production capacity. Fixed and variable costs – total and average. Examples.

Week 11

Costs and laws of returns. Examples. Marginal cost and marginal return. Reagibility coefficient. Examples.

Week 12

Costs over long time periods. Costs and size of a plant. Growth theory and company growth management.

Week 13

Internal and external conditions of company growth. Growth factors, conditions and paths. Examples.

Week 14

Product price structure. Structure costs. The costs vs. the overall business – methods of calculation. Full cost accounting method and direct method. Break-even point and the safety factor. Break-even point and the safety factor.

Week 15

Static and dynamic methods for investment evaluation.

GENERAL AND SPECIFIC COMPETENCE:

Students are able to understand basics of financial accounting, profitability and costs of production processes. These are competences necessary for Feasibility studies.

KNOWLEDGE TESTING AND EVALUATION:

3 partial tests. Final grade is calculated as their average. Alternative: written and oral exam.

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student poll.

LITERATURE:

1.Peters& Timmerhaus, PLANT DESIGN AND ECONOMICS FOR CHEMICAL ENGINEERS, Mc Graw Hill, 1991

2.R. Turton, R.C. Bailie, W.B. Whiting, J.A. Shaeiwitz, ANALYSIS, SYNTHESIS, AND DESIGN OF CHEMICAL PROCESSES, 2nd ed. Prentice Hall International, University Huston, 2003 (Chapter 7 – Engineering Economic Analysis)

3.I.Santini, TROŠKOVI U POSLOVNOM ODLUČIVANJU, Hibis, Centar za ek.consulting, 1999

4.V. Gašparović, TEORIJA RASTA I UPRAVLJANJE RASTOM PODUZEĆA, Školska knjiga Zagreb, 1996

5.T.G. Eschenbach, ENGINEERING ECONOMY, Applying theory to practice, Oxford University Press, Oxford, 2003

Course: Formulation engineering		
Language: English		
Lecturer: Prof. Mirela Leskovac; Prof. Sanja Lučić Blagojević		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**-**	**-**
Seminar	**1**	**15**
		Overall: 45
		ECTS: 5

PURPOSE:

To introduce students with principles and application of product engineering with the aim of formulation and designing of products with desired application properties according market demands. This can be achieved by synthesis of new knowledge about product engineering methods and by application of generic knowledge about materials and processes in design of products with added value through integration of industrial design, engineering, production and marketing.

THE CONTENTS OF THE COURSE:

P (1-3): Product engineering and design. Paradigms of chemical engineering. The concept and methodology of product design: needs, ideas, selection, production process. Integration design of chemical processes and product homogeneous and structured products. The connection function properties, processes and applications. Pyramid chemical product. Quality factors of product. Systematization of formulation of the product. Multilevel approach in product development. Integration of product and process engineering. Key tasks in chemical product engineering. The path to the prototype product.

1st partial exam

Field work (1 day): Analysis of production in selected industry.

P (4-6): Surfaces and interfaces phenomena and selected processes in the formulation engineering. Surface and interface. Compatibility. Effective adhesion at the interface and optimization of properties. Multiphase colloidal systems. Important processes of separation in product engineering: dissolution, extraction, re-crystallization, adsorption. Models and parameter for miscibility estimation of the components in the formulation.

P (7): The rheology of complex fluids and the product as function of formulation engineering. Rheological models. Effects of rheological parameters in product engineering. The application of rheometrical techniques in quality control and product formulations. Dependences and application of rheological properties of selected products.

2nd partial exam

Field work (1 day): Analysis of production in selected industry.

P (8-10): Formulations and properties of liquids as function of product engineering. Properties and production of dispersions, suspensions, emulsions, microemulsions, pastes, heterogeneous mixture. Stability of emulsions, suspensions and dispersions.

P (11): The formulations and properties of the solid as function of product engineering. Properties and stabilization of foams. The solid formulations of powders, agglomerates, granules and microcapsules.

P (12-13): The functional properties of the product. Detergents. Pharmaceutical. Pigments and dyes. Cosmetic products. Agro-products. Food. Applying the methodology of product engineering for the product with added value. Multileveled approach. Reaching new functionality in the product. Quality Factors. Physical features. The function of the product application.

3rd partial exam

S (14-15): Seminar / Project assignment for students: a case study. Analysis of the concept according to the defined objectives. The path to the prototype product.

GENERAL AND SPECIFIC COMPETENCE:

General competencies of students extend by exploration and application of product engineering and design in new product development, as a new paradigm of chemical engineering, as well as by integration of market needs and manufacturing functions in the creation of a new product.

Specific competencies related to the introduction of tools and methods in product engineering and industrial design, in development and in formulation process of a new product by integration and application of already acquired specific generic knowledge that should be applied in the realization of a new product added value.

KNOWLEDGE TESTING AND EVALUATION:

Partial exams; written / oral exam.

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student questionnaire.

LITERATURE:

1. V. Kovačević, M. Leskovac, S. Lučić Blagojević, Produktno inženjerstvo i dizajn proizvoda, interna skripta, 2010.
2. H. Mollet, A. Grubenmann, Formulation Technology: Emulsions, Suspensions, Solid Forms, Wiley-VCH, 2001.
3. K.T. Ulrich, S.D. Eppinger, Product Design and Development, McGraw-Hill International EDITION, 2008.
4. W.D. Seider, J.D. Seader, D.R. Lewin, S. Widagdo, Product and Process Design Principles, John Wiley & Sons, 2009.
5. E.L. Cussler, G.D. Moggridge, Chemical Product Design, Cambridge University Press, 2001.
6. I. Benedek, Pressure-Sensitive Formulation, VSP, 2000.

Course: Polymer Engineering		
Language: Croatian		
Lecturer: Prof. dr. sc. Zlata Hrnjak-Murgić, prof. dr. sc. Marko Rogošić, prof. dr. sc. Emi Govorčin-Bajsić		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	3	45
Laboratory	1	15
Seminar	1	15
		Overall: 75
		ECTS: 5.0

PURPOSE:

Students get acquainted with the types of polymerization reactions: radical, step, ionic, copolymerization and ring opening polymerization. Students learn about elementary steps of radical chain polymerization: initiation, propagation, termination, chain transfer. Students become familiar with the industrial implementation of polymerization reactions: bulk polymerization, solution polymerization, suspension and emulsion polymerization.

Students meet the principles of modelling of polymerization reactions – the subject of modelling is the chemical reaction (i.e. interdependence of molecular weight distribution, conversion and reaction time) as well as the physical effects occurring in parallel to polymerization. Students analyse basic types of polymerization reactors.

Students get acquainted with large-scale polymers and characteristic application properties of polymers as engineering materials. Students learn about the fundamentals of polymer processing as well as tailoring of properties of polymer engineering materials. Students learn to understand the evolution of properties in due course of the processing stage, starting from the virgin polymer to the shaped product.

THE CONTENTS OF THE COURSE:

1. Monomers with double C=C bond, monomers with functional groups, polymer nomenclature as dependent on the polymerization mechanism
2. Polymerization mechanisms: chain or radical, step or condensation, ionic polymerization (cationic and anionic)
3. Coordination polymerization, ring opening polymerization, copolymerization
4. Large scale production of polymers: bulk polymerization and solution polymerization
5. Heterogeneous polymerization: emulsion polymerization and suspension polymerization
6. Molecular weights of polymers, weight distribution, number distribution, integral distribution, differential distribution, analytical distribution

functions, dispersity

7. Modelling of the step polymerizations in the batch reactor. Interdependence of the reactive species concentrations as well as molecular weight distribution on the kinetic parameters, time, conversion, asymmetry. Polymerizations of the type AB, A_2+B_2, AB + XB. Polymerization reversibility. Geometric distribution.
8. Modelling of chain polymerizations. Ideal anion polymerization in the batch reactor. Interdependence of the reactive species concentrations as well as molecular weight distribution on the kinetic parameters, time, conversion. Poisson distribution. Non-ideal anion polymerization. Cation polymerization. Radical polymerization in the batch reactor. Interdependence of the reactive species concentrations as well as molecular weight distribution on the kinetic parameters, time, conversion. Physical effects associated with radical polymerization, gel-effect, vitrification, cage effect.
9. Modelling of copolymerization. Step copolymerizations. Sequence distribution. Radical copolymerization. Composition drift. Branching associated with step polymerization. Critical conversion. Gel, sol, pendant fraction, elastic fraction. Branching associated with radical polymerization, backbiting.
10. Modelling of polymerization reactors. Step, ideal anion and radical polymerization in the homogeneous and segregated continuous stirred tank reactor, respectively. Macromixing, micromixing. Tubular reactor, in the turbulent flow, recirculation, laminar flow, Newtonian and non-Newtonian behaviour. Extruder as a reactor. Modelling heterogeneous polymerizations, suspension and emulsion polymerization kinetics.
11. Phases of the production of a polymer-based product. Modification of the structure and properties of polymer materials. Thermal properties. Thermomechanical curve. Calorimetric properties. Deformation of solids. Dynamic mechanical properties, cyclic loads. Rheological properties of polymers. Rheological models.
12. Classification of the polymer processing. Technologies for additivation and reshaping of polymers. Heat and energy balance of polymer processing. Correlating polymer processing characteristics with processing and application properties of polymer materials.
13. Extrusion process. Extruder characteristics. Material characteristics and structuring in the extrusion process. Injection moulding of polymers. Injection moulding machines. Adjustable parameters in the process of polymer shaping using injection moulding.
14. Shaping of reinforced plastics associated with the chemical transformation; thermosets/glass fibres. Reinforced thermoplasts; thermoplasts/glass fibres, granulate, pressing. BMC and SMC processes. Cellular materials peculiarities. Shaping.
15. Multiphase polymer systems. Composition, phase ratio and phase morphology in multiphase polymer systems and their impact on the structure and properties. Modification and stability of multiphase polymer systems. Compatibilization and miscibility.

GENERAL AND SPECIFIC COMPETENCE:

General competences:

1. understanding of the particularities of macromolecular systems in relation to low-molecular systems as well as their analysis

2. understanding of the techniques of polymer material synthesis and characterization – may be extended to other classes of materials
3. application of the previously adopted concepts of chemical engineering onto polymerization reactions; mastering of the particularities of polymerization reactions
4. general improvement of the engineering methodologies of graphical presentation, reporting in written form etc.

Specific competences:

1. knowledge of the polymer materials synthesis methods
2. knowledge of the large-scale polymer material production processes and ways of controlling those processes
3. knowledge of the polymer materials processing methods

KNOWLEDGE TESTING AND EVALUATION:

Partial exams. Written final exam, if partial exams failed. Evaluation of seminar written reports. Final evaluation shall, beside partial exam results, take into account the overall student effort.

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student inquiry

LITERATURE:

Compulsory

1. D. W. Clegg, A. A. Collyer, Structure and Properties of Polymeric Materials, The Institute of Materials, London, 1990.
2. C. Hall, Polymer Materials, J. Wiley & Sons, New York, 1990.
3. T. A. Osswald, G. Menges, Materials Science of Polymers for Engineers, Carl Hauser Verlag, Munchen,1995.
4. G. Odian, Principles of Polymerization, 4. izd. Wiley-Interscience, New York, 2004.
5. N. A. Dotson, R. Galván, R. L. Laurence, M. Tirrell, Polymerization Process Modeling, Wiley-VCH, New York, 1996.

Additional

1. A. Collyer, L. A. Utracki, Polymer Rheology and Processing, Chapman & Hall, Hampshire, 1990.

2. H. L. Williams, Polymer Engineering, Elsevier Sci. Publ. Comp., N. Y., 1985

Course: Solid and Hazardous Waste Treatment		
Language: English		
Lecturer: **Assoc. Prof. Marija Vuković Domanovac, PhD** **Prof. Zlata Hrnjak-Murgić, PhD**		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**2**	**30**
Seminar	**0**	**0**
		Overall: 60
		ECTS: 5,0

PURPOSE: Understanding of types, characteristics, quantities and composition of waste. The implementation of an integrated waste management. Recovery and disposal of solid and hazardous wastes. Overview of types of remediation of soil contaminated by waste.

Understanding the impacts of pollution by polymer waste, prevention of environmental pollution, polymer waste management; industrial and municipal.

THE CONTENTS OF THE COURSE:

1st week: Introduction to terminology, divisions and general information on waste

2nd week: Overview legislation, national strategies and waste management plan for the implementation of an integrated system for sustainable waste management

3rd week: Waste prevention and separate waste collection

4th week: Waste composting and mechanical biological waste treatment

5th week: Thermal and material waste recovery

6th week: Landfill sites and remediation of contaminated soil

7th week: 1st partial test

8th week: Types and application of polymeric materials

9th week: Introduction into polymer chemistry

10th week: The impact of the environment on the properties of polymeric materials

11th week: Homogeneous and heterogeneous polymer waste

12th week: Collection, separation and processing technologies of polymer waste

13th week: Recycling of polymer waste (mechanical recycling)

14th week: Recycling of polymer waste (chemical recycling)

15th week: 2nd partial test

GENERAL AND SPECIFIC COMPETENCE: Understanding of problems, decision making and behaviour in society and the economy by applying acquired knowledge, in accordance with the integrated waste management system

Gain the knowledge of different types of polymer waste, its recycling technologies and processes. Specifically, the knowledge: of types and properties of polymer waste, of polymer waste stream, of technological processes and treatment procedures before recycling and recycling practices.

KNOWLEDGE TESTING AND EVALUATION:

Partial tests (2) (written) or exam (written and/or oral)

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

University of Zagreb student survey

LITERATURE:

1. Tchobanoglous, G., Theisen, H., Vigil, S.A., Integrated Solid Waste Management - Engineering Principles and Management Issues, McGraw Hill, 1993.
2. White, P., Franke, M., Hindle, P., Integrated Solid Waste Management: A Lifecycle Inventory, Blackie Academic& Professional, Glasgow 1994.
3. Williams, P.T., Waste Treatment and Disposal, John Wiley & Sons Ltd, Chichester 2005.
4. Smith, L., Means J., Barth E., Recycling and Reuse of Industrial Wastes, Battelle Press, Columbus, 1995.
5. Nazaroff, W.W.,.Alvarez-Cohen, L., Environmental Engineering Science, John Wiley&Sons, Inc. New York, 2001.
6. Andrady, A. L., Plastics and the Enviroment, John Wiley & Sons, Hoboken, New Jersey, 2003.
7. Azapagic, A. and al., Polymers, the Enviromental and Sustanible Development, J. Wiley & Sons, N.Y. 2003.

Course: Technologies of Dyes and Coatings		
Language: English		
Lecturer: Prof. Zlata Hrnjak-Murgić, PhD **Assoc. Prof. Ana Lončarić Božić, PhD** **Prof. Sanja Papić, PhD**		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**3**	**45**
Laboratory	**2**	**30**
Seminar		
		Overall: 75
		ECTS: 5

PURPOSE:

Familiarizing students with binders and main components of the coatings, which determinate the finale properties of coatings and the area of application. Acquainting with coatings synthesis and manufacturing processes. Gaining knowledge about the characterisation of coating.

Introduction to basic concepts of color. Understanding of the correlations between the chemical structures of organic compounds and their color. Learning classification of organic dyes and basic chemical and application properties of individual groups. Gaining knowledge of the technology of production of selected organic dyes and pigments.

THE CONTENTS OF THE COURSE:

1st week: Introduction about coatings and introduction about binders

2nd week: The process of binder formation; autooxidative, radical and condensation polymerization

3rd week: The properties of the coatings; chemical, physical, mechanical

4th week: The binders of natural origin; resins, herbal oils, cellulose derivatives

5th week: Synthetic resins; alkyd, epoxy, polyurethane, silicone, epoxy, acrylic

6th week:

7th week:

8th week:

9th week:

10th week:

11th week: Basic concepts of color. Empirical correlations between the chemical structure of organic compounds and their color. Industrial applicabillity of colored compounds.

12th week: Classification and characteristics of certain groups of organic dyes. Color Index.

13th week: Areas of application of organic dyes (textile dyes, nontextile dyes, functional dyes and optical brighteners)

14th week: Production processes of organic dyes from selected chemical and application groups.

15th week: Organic pigments: optimization of their syntheses and physical conditioning operations. The impact of crystal structure and particle size on the application properties of pigments.

GENERAL AND SPECIFIC COMPETENCE:

Understanding the process of synthesise of binders, the ability to analyze and understand the structure – properties relationship. Competence to solve the problems related to the synthesis, structure and properties.

KNOWLEDGE TESTING AND EVALUATION:

Partial tests (3 times) (written) or exam (written and/or oral)

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

University of Zagreb student survey

LITERATURE:

1. Swraj Paul, *Surface Coatings: Science and Technology*, 2nd Edition, J. Wiley&Sons, N.Y. 1996.
2. H. F. Mark, N. M .Bikales, C. G. Overberger i G. Menges, Encyclopedia of Polymer Science and Engineering, J. Wiley & Sons, New York, 1989.
   - F. Lennart Marten, *Vinil Alcohol Polymers*, Vol 17, p. 198.
   - Thomas P. Blomstrom, *Vinil Acetal Polymers*, Vol 17, p. 166
   - Ivor H. Updegraff, *Amino Resins*, Vol 1, p. 752
   - H. J. Lanson, *Alkyd Resins*, Vol 1,p. 752
   - S. S. Labana, *Cross-linking*, Vol 4. p. 362
3. H. Zollinger, Color Chemistry, VCH, Weinheim, 1987.
4. K. Hunger, Industrial Dyes, Wiley-VCH, Weinheim, 2002.

Course: Electrochemical Engineering and Products		
Language: English		
Lecturers: Marijana Kraljić Roković		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**1**	**15**
Seminar	**0**	**0**
Field work		**1 (day)**
		Overall:45
		ECTS: 5

PURPOSE:

The objective of this course is to provide fundamentals of electrochemical kinetic and mass transport in electrochemical processes as well as to *connect* student´s prior *knowledge* to *new* topics and to apply it to issues concerning electrochemical reactors and electrochemical processes. The aim of this course is also to give introduction about most important electrochemical industrial processes and products.

THE CONTENTS OF THE COURSE:

Week 1
Introduction. Electrochemical systems. Metal/electrolyte interface. Electrochemical transformations. Faraday's low. Conductors, electrolyte, electrochemical cell. Practical meaning of ΔG in electrochemical systems, comparison of electrolysis and galvanic cell.

Week 2
Charge transfer at metal/solution interface. Relationship between current and reaction rate. Equilibrium at metal /solution interface. Butler-Volmer equation. Partial anodic and cathodic current, exchange current, overpotential. Reversible and irreversible reactions.

Week 3
Mass transport in electrochemical processes. Different types of transport in electrochemical processes (diffusion, migration, convection). Diffusion layer, stationary and non stationary diffusion processes.

Week 4
Mass transport in electrochemical reactor (diffusion, convection, migration). Hydrodynamic boundary layer and Nernst diffusion layer. Forced and free convection. Dimensionless numbers defining mass transport in electrochemical reactor.

Week 5
Mass balances. Heat balances, Joule heating. Heat balances for aluminium production process.

Week 6
Electrocrystallisation, ad-atom formation, nucleation, crystal growth. Metal electrodeposition.

Week 7
Current distribution (primary, secondary and tertiary)

Week8:
Mass transport in electrochemical reactor (diffusion, convection, migration). Hydrodynamic boundary layer and Nernst diffusion layer. Dimensionless numbers defining mass transport in electrochemical reactor.

Week 9:
Exam

Week 10:
Electrochemical cell and electrode design, separators (membranes and diaphragms), electrode materials and catalysis. Electrochemical process optimisation.

Week 11:
Aluminium production process (Hall-Heroult Process). Chlor-alkali process.
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Week 12:
Industrial processes in organic electrochemistry.

Week 13:
Electrochemical power sources: battery, supercapacitors, fuel cells

Week 14:
Application of renewable power sources in electrochemical processes.

Week 15:
Exam

Laboratory exercises
1. Diffusion polarisation.
2. Current and potential distribution
2. Zinc electroplating
3. Electrolytic silver refining
2. Fuel cell

GENERAL AND SPECIFIC COMPETENCE:

General competencies:

- Ability to design and conduct scientific experiment and data interpretation
- Ability to work in a team and development of good communications skills
- Developing of communication skills in written, oral and graphical forms
- Analyze and optimize the electrochemical processes practice.
- Apply methodologies of chemical and electrochemical engineering in practice.

- Manage and plan electrochemical processes.

Specific competencies

- Applying fundamental knowledge of electrochemistry and chemical engineering to electrochemical cell design.
- Applying electrochemical engineering to solve different practical problems.
- Familiarity with the most important electrochemical processes.

KNOWLEDGE TESTING AND EVALUATION:

Two progress evaluations during the course.

Knowledge testing after the laboratory work.

Written exam.

Oral exam.

MONITORINGOF THE COURSE QUALITY AND SUCCESSFULNESS:

Student's survey.

LITERATURE:

1. H. Wendt, G. Kreysa, Electrochemical Engineering: Science and Technology in Chemical and Other Industries, Springer, Berlin, 1999.
2. D. Pletcher, F. C. Walsch, Industrial Electrochemistry, Chapman and Hall, 1990.
3. C. A. Vincent, B. Scrosati, Modern Batteries: An Introduction to Electrochemical Power Sources, Second Edition, John Wiley & Sons, Inc., New York, 1997.
4. Electrochemical engineering lectures at faculty web sites

Optional courses

Course: Polymer nanocomposites		
Language: English		
Lecturer: Prof. Sanja Lučić Blagojević		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**0**	**0**
Seminar	**1**	**15**
		Overall: 45
		ECTS: 4

PURPOSE:

To introduce students with access of design of nanocomposite polymer materials aiming to achieve specific properties. The objective can be achieved by integrating knowledge from the field of polymer materials, inorganic materials, and knowledge about the modelling of the interface polymer / filler.

THE CONTENTS OF THE COURSE:

L1 - Polymeric materials. The importance and application of polymeric materials. Classification of polymer materials by origin, by application properties, according to the type of repeating units, according to the forms of macromolecules. Mechanisms of polymerization: step, chain; homogeneous and heterogeneous processes of polymerization. The structure of polymers: configuration and conformation of macromolecules. Super-molecular structures. Physical properties of polymers. Additives to polymer materials. Fillers as modifiers of properties.

L2 - Differences between micro and nanocomposites. Polymer Composites. Interphase polymer - filler: mechanisms of adhesion, the application of adsorption theory. Thermodynamics of interfacial free energy, coefficient of wetting, thermodynamic work of adhesion. Chemisorption theory. Differences between nanocomposites and microcomposites: filler particle size, size of the interface, morphology, fraction of matrix in the interphase layer.

L3-5 The types of nanofillers. *Carbon nanotubes*: molecular and supramolekulna structure, properties (mechanical properties, electrical properties). Processing of nanotubes: laser ablation, arc discharge, chemical vapor deposition. Composition and purification of the reaction products. Surface modification (covalent and non-covalent)

The layered nanofillers: types, structure, organic modification of layered nano-filler. *Equi-axed nanofillers*: types, production, surface modification.

Quantum dots: types, structure, quantum effects, properties. Surface modification of quantum dots: with amphiphilic polymers, multidentate polymeric ligands, polymers functionalized at the ends of the chain, quantum dots encapsulated by dendrimers.

1st partial exam

L7-9 Preparation of polymer nanocomposites. The distribution and the dispersibility of fillers in the polymer matrix. *Preparation p*rocess for composites with carbon

nanotubes: preparation of the solution, stirring the mass of the polymer, the mixing in the melt, in situ polymerization.
Preparation of nanocomposites with layered nano-fillers: intercalated and exfoliated morphology, instrumental techniques for morphology investigation. Methodology and thermodynamics of individual processes: intercalation of polymer or prepolymer, in situ intercalation polymerization, melt intercalation. The impact of factors on the morphology of the melt intercalation process. The degradation of the system during the preparation of the melt intercalation.
Preparation of polymer nanocomposites with equi-axed nano-fillers. The process for preparing the melt and solution, in situ polymerization of the polymer, the in situ polymerization of the inorganic phase is formed.
Preparation of nanocomposite system quantum dot / polymer. Quantum dots in polymer colloids - a methodology for preparing nanocomposites with different methods, advantages and disadvantages of different methods of preparation. Systems of layer-by-layer quantum dot / polymer. Controlled binding of polymer layers and quantum dots. Quantum dots in polymers bulk and thin polymer films.

L10-11 Properties and application of polymer nanocomposites. Mechanical properties: the influence of types of nano-filler, filler particle size and thermodynamics of the polymer / filler morphology, failure mechanisms and features of the mechanical behavior (modulus, tensile strength, toughness). Effect of nanofiller on the permeability of gases and liquids: the concept of tortuous diffusion. Dimensional stability of nanocomposites. The thermal stability of the nanocomposites. Effect of nanofillers on flammability of polymers. Electrical properties. Optical and optoelectronic properties.

L12 2nd partial exam

L13-15 Student seminars

GENERAL AND SPECIFIC COMPETENCE:

The course develops the general students' competence of analysis and synthesis of scientific knowledge and presentation in oral form.

Specific competencies courses include connecting knowledge engineering polymer materials and surface and interfacial engineering in multiphase polymer systems, broadening and deepening the knowledge of the structure, properties, production and application of polymer nanocomposites as advanced materials, and knowledge about the selection of techniques and methods for the characterization of multiphase systems and quality control of the final products.

KNOWLEDGE TESTING AND EVALUATION:

Partial exams, writing and oral exam

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student questionnaire.

LITERATURE:

1. P. M. Ajayan, L. S. Schadler, P. V. Braun, Nanocomposite Science and Technology, Wiley – VCH, 2003.
2. T. J. Pinnavaia, G. W. Beall, Polymer-Clay Nanocomposites, John Wiley and Sons Inc., 2001.
3. A. I. Nakatani, R. P. Hjelm, M. Gerspacher, R. Krishnamoorti, Filled and Nanocomposite Polymer Materials, Vol.661, Materials Research Society, 2001.
4. R.Vaia, R. Krishnamoorti, Polymer nanocomposites: Synthesis, Characterization and Modeling, American Chemical Society, 2001.
5. Y. S. Lipatov, Polymer Reinforcement, Chem. Tec. Publishing, Ontario, 1995.

Course: **Additives for polymer materials and products (optional)**
Chemical Engineering
graduation; 1st and 2nd year

Language: English

Lecturer: Mirela Leskovac

TEACHING	WEEKLY	SEMESTER
Lectures	**2**	**30**
Laboratory	**1**	**15**
Seminar	**-**	**-**
		Overall: 45
		ECTS: 4

PURPOSE:

Familiarizing students with the most important additives which are used for modification, improvement of properties and resistance of polymer materials and their products, focused on mechanisms of their action and application, as well as on economic and ecological aspects of their application.

THE CONTENTS OF THE COURSE:

L-1 An introduction to polymer additives. Classification of additives for polymer materials and products, principles of their action, properties and application; ecological and economical impacts of polymer additives.

L-2 Modifiers of physical properties of polymer materials; principles of their action, classification, properties and applications. The polymer additives efficiency.

L-3 Improvement/ Modification of mechanical properties. Impact modifiers: toughness and macromolecular modifiers. Additives for improvement of strength, processibility and stability: fillers, reinforcing agents and coupling agents.

L-4 Blowing agents; chemical and physical blowing agents; characteristics and factors acting on blowing.

L-5 Plasticizers: Solubility parameter, theory of plasticization, primary and secondary plasticizers. Classification of plasticizers. Plasticizer efficiency.

L-6 Modifiers of optical properties: dyes, pigments and optical brighteners. Classification, properties and application. Criteria for selection of pigments.

L-7 Modifiers of surface properties. Lubricants: reducing of friction, surface abrasion and adhesion. The effect of lubrication on the polymer processing.

L-8 Conductivity: antistatic and conductive additives, action mechanism, classification, properties and application.

L-9 Additives that have a protecting effect against polymer aging and degradation; action mechanism, classification, properties and application.

L-10 Effects of chemically and physically active media, effect of ionizing radiations, mechanical and thermal degradation.

L-11 Heat stabilizers; the influence of heat stabilizers. Thermo-oxidative degradation: action mechanism of antioxidants.

L-12 Photo-oxidative degradation: action mechanism of UV stabilizers, classification and application.

L-13 Flammability: burning mechanism of polymers, flame retardants; action mechanism of retardants, classification, properties and applications.

L-14 Microbiological degradation: action mechanism of biocides; properties and application.

L-15 Methods used to incorporate additives into polymer matrices. Ecological aspects of application of additives for polymer materials and their products. Technical trends and new market requests.

Laboratory exercises:

I. PROPERTIES OF POLYMER ADDITIVES

LE-1) Surface phenomena and surface tension measurement by pendant drop method.

II. OXIDATIVE STABILITY OF POLYMER MATERIALS

LE-2) Influence of additives on the oxidative stability of materials; determination of oxidation induction time, OIT
LE-3) Influence of additives on the oxidative stability of materials; determination of oxidation induction temperature, OIT*
LE-4) Influence of additives on the thermal stability of polymer materials.
LE-5) Polymer flammability **-** Limited oxygen index (LOI)

III. PRINCIPLES OF POLYMER PLASTICIZATION

LE-6) Influence of plasticizers on the polymer material properties.
LE-7) Evaluation of plasticizers efficiency.
LE-8) The influence of plasticizers on the polymer surface properties (study of plasticizers migration).

L-Lectures, **LE**-Laboratory exercises

GENERAL AND SPECIFIC COMPETENCE:

Acquiring knowledge required to obtain satisfactory properties of polymeric materials and quality. Knowledge relevant to the selection of additives and features crucial for ensuring the quality and stability of engineering polymers depending on the specific requirements of the application.
Specific competencies include training of future experts to apply the acquired knowledge in the production process and quality control.

KNOWLEDGE TESTING AND EVALUATION:

Partial exams; written / oral exam.

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student questionnaire.

LITERATURE:

1. M. Leskovac, *Dodatci za polimerne materijale i proizvode*, Interna skripta, 2008.
2. Z. Janović, Polimerizacije i polimeri, Hrvatsko društvo kemijskih inženjera i tehnologa, 1997.
3. L. H. Sperling, Introduction to Physical Polymer Science, Wiley Interscience, New Yersey, 2006.
4. Jan C.J. Bart, Additives in polymers (Industrial Analysis and Applications), John Wiley & Sons Ltd, England 2005
5. J. T. Lutz, R.F. Grossman, Polymer Modifiers and Additives, Marcel Dekker, 2001.
6. J. Štepek, H. Daoust, Additives for Plastics, Springer-Verlag, New York, 1983.

Course:	**Characterization and identification of the products (optional)** Chemical Engineering graduation; 1^{st} and 2^{nd} year (1^{st} and 3^{rd} semester)
Language: English	
Lecturer:	**Prof. Mirela Leskovac, PhD** **Prof. Emi Govorčin Bajsić, PhD** **Prof. Zlata Hrnjak-Murgić, PhD**

TEACHING	WEEKLY	SEMESTER
Lectures	**2**	**30**
Laboratory	**0**	**0**
Seminar	**1**	**15**
		Overall: 45
		ECTS: 4

PURPOSE:

Familiarising with the techniques used to characterisation and identification of materials very essential in the development of new materials, the improvement of existing materials and the quality verification of materials and final products.

THE CONTENTS OF THE COURSE:

WEEK (1-4)

L (1) Introduction to the characterization and identification, relationship structure-properties of materials.

L (2-3) The chemical, physical, electrical and optical properties of polymers.

L (4-5) Techniques of characterization: GCP, FTIR, UV / VIS, NMR.

S (1-4) Practical teaching - interpretation of spectra (FTIR, NMA). Molar mass determination.

WEEK (5)

PARTIAL TEST - 1^{st} partial test

WEEK (6-9)

L (6-7) Thermal analysis. Thermal properties of materials.Techniques of thermal analysis. Differential scanning calorimetry (DSC) technique. Characterization and identification of materials by DCS technique. The type of DSC instruments.

L (8-9) Dynamic mechanical technique (DMA). Characterization of materials by DMA. Primary viscoelastic functions. Secundary viscoelastic functions. Time-temperature superposition (TTS). The influence of the compositions and conditions of the measurements on the viscoelastic functions.

L (10) Thermogravimetry analysis (TGA). Application of TGA technique. Thermal stability determination by TGA technique. Kinetic of thermal degradation.

S (5-8) Practical teaching - thermal properties - DMA, DSC, TGA

WEEK (10)

PARTIAL TEST - 2^{nd} partial test

WEEK (11-14)

L (11-12) Surface characterization. Surface and interfacial phenomena and processes of heterogeneous systems. Cohesion, adhesion, contact angle, Young's equation. The surface tension of the liquid and the surface free energy of solids and measurement techniques.
Surface free energy determination by contact angle measurement. Goniometer. Models for calculating the surface free energy (Zisman, Owens-Wendt, Wu, Acid-base model).

S (8-11) Practical teaching - Surface characterization

L (13-14) The mechanical properties of materials and influential factors. The types of loading. Tensile testing. Stress-strain curve. Elastic and plastic deformation.
Time-dependent deformation, viscoelasticity, relaxation processes. Creep and stress relaxation. Cyclic loading-unloading (hysteresis).

S (12-14) Mechanical properties of materials

L (15) Microscopic techniques for materials characterization. Terms in microscopy. The characteristics of different types of microscopes. Selection of microscopy techniques and sample preparation.

S (15) Practical teaching - Microscopy of materials

WEEK (15)

PARTIAL TEST - 3rd partial test

L-Lectures, **S** - Seminar

GENERAL AND SPECIFIC COMPETENCE:

The students are trained to work with selected techniques of materials and products characterization.
They are going to gain the knowledge and competence on certain methods and techniques of characterization and identification of polymers. Independent performance of analysis and quality control of materials and final products.

KNOWLEDGE TESTING AND EVALUATION:

Partial tests (3 times) (written) or exam (written and/or oral)

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student questionnaire.

LITERATURE:

1. G. Kümpf, Characterization of Plastics by Physical Methods, Hanser Pub. München 1986.
2. A. A. Collyer, L. A. Utracki, Polymer Rheology and Processing, Elsevier Sc. Publ. Co., Inc., New York , 1990.
3. B. Wunderlich, Thermal Analysis, Academic Press, Inc., London, 1990.
4. A. R. West, Solid State Chemistry and its Applications, Wiley and Sons, Brisbane, 1984.
5. Ovid, Science Direct, Web of Science

Course: Molecular spectroscopy		
Language: English		
Lecturer: Prof. Irena Škorić, Ph.D., Prof. Vesna Volovšek, Ph.D.		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**1**	**15**
Seminar		
		Overall: 45
		ECTS: 6

PURPOSE: To inform students with physical base of molecular spectroscopy and with application of individually each method in chemistry, especially with interpretation of spectra in determination of structures of organic compounds.

THE CONTENTS OF THE COURSE:

1. Interaction of electromagnetic radiation and matter, Electromagnetic spectrum, Quantization of energy and molecular energy levels, Absorption and emission of electromagnetic radiation, Half-width and intensities of spectral transitions.
2. Molecular symmetry, Elements of symmetry, Point groups, Tables of character, Election rules and transition probability.
3. Vibrational spectroscopy, Experimental methods.
4. Molecular vibrations of diatomic molecules, Molecular vibrations of polyatomic molecules, Characteristic vibration.
5. Analysis of vibrational spectra.

COLLOQUIUM

6. NMR spectroscopy: Basic approaches, Nuclear magnetic moment. ^{1}H NMR spectra: Chemical shift and shielding, Integrals, Chemical environment and chemical shift, Magnetic anisotropy, Coupling constant.
7. NMR spectroscopy. ^{13}C NMR spectra: Chemical shifts of carbon-13, integration in ^{13}C NMR spectrum, NOE effect, Heteronuclear coupling of carbon with deuterium, Fluorine-19 and Phosphorus-31.
8. NMR spectroscopy. Spin-spin coupling: Mechanism of coupling, coupling constants of spectrum of first and second order, Long-range coupling.
9. – 11. NMR spectroscopy. Additional chapters in one-dimensional NMR: Exchange of protons in H_2O and D_2O, Tautomerism, Protons on the nitrogen atom, Effect of the solvent on chemical shift; Advanced NMR techniques: DEPT experiment, Two-dimensional spectroscopic methods: COSY, HETCOR

COLLOQUIUM

12. UV/Vis spectroscopy and fluorescence: Instrumentation, Presentation of spectra, Solvents, Chromophores, Effect of conjugation

13. UV/Vis spectroscopy and fluorescence: Woodvards rule for enons, Aromatic compounds, Visible spectrum, Color in compounds

COLLOQUIUM

14. Mass spectroscopy: Mass spectrometer, GC/MS, Mass spectrum, Determination of molecular weight and formula, Effect of isotopes

15. Mass spectroscopy: Fragmentation

COLLOQUIUM

GENERAL AND SPECIFIC COMPETENCE:

Students will be able to analyze obtained results and apply it in determination of structures of organic compounds, by combining spectroscopic methods which they studied in this course.

KNOWLEDGE TESTING AND EVALUATION:

Exam will be held through colloquiums after each major methodological units. Students who do not pass colloquia (total 4) will take written test.

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student questionnaire

LITERATURE:

1. Banwell, C. N., McCash, E. M., *Fundamentals of Molecular Spectroscopy*, McGraw-Hill College, 1995.
2. Pavia, D. L., Lampman, G. M., Kriz, G. S., *Introduction to Spectroscopy*, Third Edition, Brooks/Cole Thomson Learning, Australia, 2001.
3. Silverstein, R. M., Webster, F. X., *Spectrometric Identification of Organic Compounds*, Sixth Edition, John Wiley & Sons, Inc., New York, USA, 1997.

Course: Environmental management systems		
Language: English		
Lecturer: Associate prof. Ana Lončarić Božić, PhD		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**0**	
Seminar	**1**	**15**
		Overall: 45
		ECTS: 4

PURPOSE: Introduction to the aims, methodology and structure of Environmental Management Systems (EMS). Overview of knowledge and skills for development and implementation if EMS as one of sustainable development tools.

THE CONTENTS OF THE COURSE:

1st week – Preventive approach in environmental protection and management. Basic principles and elements of sustainable development. Introduction to EMS based on Deming's cycle.

2nd week – Basic terms and definitions. Overview of ISO 14001 (HR EN ISO 14001:2009) standard. Purpose of standardisation. Positive features of EMS implementation.

3rd week –Basic roles and focus of EMS. Structure and main elements of EMS. Concept of continual improvement.

4th week – Requirements of ISO 140001 for EMS. Environmental policy. Objectives and targets. Examples of setting "smart" objectives.

5th week –Elements of planning process. Environmental aspects and impacts. Identification of legal requirements and significant aspects. Case studies.

6th week – Significance of defined roles, resources and responsibilities for successful implementation of EMS. Competences and communication.

7th week –Types and management of EMS documentation. Differences between documents and records. Case studies.

8th week –1st partial exam

9th week – Emergency preparedness and response. Analysis of processes and activities, aspects and potential impacts; case study.

10th week – Assessment of compliance of EMS with ISO 14001 standard. Identification of non-conformances and appropriate corrective and preventive actions. EMS audit and management review. Identification of significant aspects and impacts: service industry case study.

11th week – Basic elements and methodology of Life cycle assessment (LCA) methodology. LCA as sustainable development tool.

12th week – Cleaner production. Correlation of EMS with waste management strategy within Cleaner production. Identification of waste sources and corresponding preventive measures of Cleaner production. Cleaner production methodology; case study.

13th week – Differences and similarities of environmental management systems according to EMAS and ISO 14001.

14th week – Occupational health and safety; OHSAS18001. Integrated management systems.

15th week – Programme Responsible care. Principles and guidelines. Correlation of Responsible care elements with environmental management system.

GENERAL AND SPECIFIC COMPETENCE:

Adoption of proactive approach in environmental protection and management. Understanding the opportunities of continual improvement of environmental performances by adoption and implementation of EMS.

KNOWLEDGE TESTING AND EVALUATION:

1. Partial preliminary exams

2. Written exam

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student survey

LITERATURE:

1) Sheldon, C.: ISO 14000 and Beyond, Environmental management systems in real world, Greenleaf Publishing, UK,1997.
2) Lectures

Course: Adhesion and adhesive products		
Language: English		
Lecturer: Prof. Sanja Lučić Blagojević		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**0**	**0**
Seminar	**1**	**15**
		Overall: 45
		ECTS: 4

PURPOSE:

To introduce students to the functional characteristics of products which are used as adhesives and sealants in understanding their structure and properties, quality factors and their target applications in bonding technologies. The emphasis is on the effects of surface phenomena, environmental influences and stresses in the application. Within Analysis of samples - a case study in a seminar in selected experimental exercises, students develop specific knowledge and skills that enable them to assess the quality and characteristics of adhesive materials, as well as their choice for a particular purpose.

THE CONTENTS OF THE COURSE:

L-Lectures (1-15); LE-Laboratory exercises; S- Seminar (1);

L (1-3) Application of surface science. Definition and application of following terms: surface tension, surface and interfacial energy, the thermodynamic work of adhesion, wetting, spreading and debonding. Inhomogeneity of surface and measurements.

L (4-6) Practical adhesion. The application of mechanisms and theories in analyzing results of the adhesion bonding. Mechanical, diffusion, adsorption, chemical, electrostatic theory in practice. Criteria for achieving quality adhesion bonds.

LE - Determination of parameters of adhesion

L (7-9) Characterization of surfaces. Analysis of the specificity of polymer surfaces. Application of thermodynamics and solubility parameters in assessing the adhesion properties of the surface. The effects of surface modification. Application of the method for the characterization of surfaces.

L (10-15) The adhesive products. The application of scientific methodology of product engineering in the analysis pyramid of the product. Types of adhesives and sealants. The specifics of their application. Characteristics of the structure and properties of the matrix and the impact on the formulation and implementation of quality factors. Examples of adhesives and sealants given purpose.
Structural and non-structural adhesives. Epoxies, urethanes, neoprene, cyanoacrylates as base adhesives. Acrylic, Bituminous, polysulfide, silicone, polyether and polyurethane sealants. The advanced adhesive products based on nanotechnology. A new generation

of silane-terminated organic seal. Analysis of the practical implementation of Adhesion bonding. The elements for optimal selection of adhesives and sealants.
LE - testing of adhesive compound
S

GENERAL AND SPECIFIC COMPETENCE:

General competencies of students complement with application of basic knowledge of surface phenomena, which are essential for proper adhesion at the interface between two materials in the application process of bonding, as well as designing new products for the market.
Specific competencies are related to the possibility of appropriate modifications of bonding process by modification and activation of surfaces in industrial applications, as well as the selection of appropriate product for a given application.

KNOWLEDGE TESTING AND EVALUATION:

Partial exam, written exam

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student questionnaire.

LITERATURE:

1. V. Kovačević, Adhezija i adhezijski proizvodi, interna skripta, 2009.
2. A.J. Kinloch, Adhesion and Adhesives; Science and Technology, Chapman & Hall, London, UK, 1995.
3. K.L. Mittal, Adhesion Measurement of Films and Coatings, VSP, Utrecht, 1995.
4. A. Pizzi, K.L. Mittal, Handbook of Adhesive Technology, 2nd Ed., Marcel Dekker, Inc., New York, 2003.
5. K.L. Mittal, A. Pizzi, Adhesion Promotion Techniques: Technological Applications, Marcel Dekker, Inc., New York, 2004.
6. E.M. Petrie, Handbook of Adhesives and Sealants, Mc-Graw-Hill, New York, 2000.

Course: DEGRADATION AND MODIFICATION OF POLYMERS

Language: English

Lecturer: **Prof. Zlata Hrnjak – Murgić, PhD**

TEACHING	WEEKLY	SEMESTER
Lectures	2	30
Laboratory	0	0
Seminar	1	15
		Overall: 45
		ECTS: 4

PURPOSE:

The purpose of this course is to introduce the students to degradation and modification of polymers. This course elaborates mechanisms of degradation of various types of polymers. The students will learn about characterization techniques of degradation products and modification of polymers. The modification leads to new kinds of polymers with improved properties. Degradation and modification are connected to the recycling of polymers and environmental impact.

THE CONTENTS OF THE COURSE:

Lectures:

Introduction to degradation processes. Mechanisms of degradation.

Oxygen and ozone activity. Thermal and photo-oxidation.

Mechanical degradation.

Degradation of polyolefins.

Degradation of biopolymers. Hydrolyzable polymers.

1st partial test

Modification of polymers: multifunctional systems - compatibility

Thermodynamics of multifunctional systems

Polymer blends,

Polymer composites

Chemical modification of polymers (graft polymerization)

Chemical modification of polymers (copolymerization)

Physical modification of polymers (homogenization in the melt, in solution)

Modification of fillers

2nd partial test

Seminar:

- Making presentations and / or written seminar paper on a given topic

GENERAL AND SPECIFIC COMPETENCE:

To introduce the students to the degradation of polymers and how to modify polymer with polymers and additives to obtain improved and functional polymer properties.

Students will gain the basic knowledge of multifunctional systems and their compatibility; understand their thermodynamic, get to know the processes of preparing blends and composites.

KNOWLEDGE TESTING AND EVALUATION:

Partial tests (2 times) (written) or exam (written and/or oral)

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

University of Zagreb student survey

LITERATURE:

H. Mark, N. Bikales, C. Overberger, G. Menges, Encyclopedia of Polymer Science and Engineering, John Wiley & Sons, New York, **4**, (1985)

C. Chan, Polymer Surface Modification and Characterization, Hanser Pub., New York, (1993)

L.A. Utracki: Polymer Alloys and Blends, Hanser Publishers, New York, 1989.

Joel R. Fried, Polymer Science and Technology, Prentice Hall Professional, USA, 2003.

Course: POLYMER ENGINEERING MATERIALS

Chemical Engineering

graduation; 1st and 2nd year (1st and 3th semester)

Applied Chemistry

graduation; 1st and 2nd year (1st and 3th semester)

Language: English

Lecturer: Prof. Emi Govorčin Bajsić, PhD

TEACHING	WEEKLY	SEMESTER
Lectures	**2**	**30**
Laboratory	**2**	**30**
Seminar	**0**	**0**
		Overall: 60
		ECTS: 4

PURPOSE:

Review of polymer systems and properties of importance for the polymers like engineering materials as well as basic of processing and designing of polymer engineering materials properties.

THE CONTENTS OF THE COURSE:

1st week: Term and review of polymer materials. Structure features and composition.

2nd week: Requirements and properties of polymer engineering materials. Mechanic static properties. Deformation and rheology.

3rd week: Viscoelastic properties. Time dependence of deformation and stress.

4th week: Thermal properties. Thermomechanical curve. Deformation states.

5th week: Rheologycal properties. Rheologycal models.

6th week: Cyclic stress. Viscoelastic functions. Relaxation spectrums. Specificity of polymer engineering materials.

7th week: Durability of materials. Physical degradation. Aging with chemical reaction. Degradation. Kinetic models.

8th week: Wear and perishing of polymer engineering materials.

9th week: Multiphase polymer systems. Modification of properties.

10th week: Modelling of multiphase polymer systems for individual application. Additives.

11th week: Overview of procedure of processing. Extrusion. Moulding.

12th week: Specificity of processing of thermoplastics, duromers, elastomers and thermoplastic elastomer.

13th week: Cellular materials. Forming.

14th week: Reinforced materials. Forming of reinforced materials, thermoplastics and duromers. Control of properties through process features.

15th week: Polymer waste. Mixed polymer waste. Recycling.

GENERAL AND SPECIFIC COMPETENCE:

Understanding structure/properties relations of polymer engineering materials. Importance for processing and application.

KNOWLEDGE TESTING AND EVALUATION:

Partial tests (2 times) (written) or exam (written and/or oral)

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student questionnaire.

LITERATURE:

Materials received on the lecture and web site materials.

1.C. Hall, Polymer Materials, J. Wiley & Sons, New. York, 1990.

2.V. Eisele, Introduction to Polymers Physics, Spring Verlag, New York, 1990.

3.R. G. Griskey, Polymer Process Engineering, Hapman and Hall, New York, 1995.

4.W.M. Kuliche, Fliessverhalten von Stoffen und Stoffgemischen, Huthig & Wepf Verlag Basel, 1996.

Additional literature:

1.H.L.Williams, Polymer Engineering Elsevier Sci. Publ. Comp. , N.Y., 1985.

2.A.A. Collyer and L.A. Ultracki, Polymer Rheology and Processing, Chapman & Hall, Hampshire, 1990.

Course: Industrial Waste Water Treatment – Graduate study Chemical Engineering		
Language: English		
Lecturer: Felicita Briški, Ana Lončarić Božić		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**2**	**30**
Seminar	**0**	
		Overall: 60
		ECTS: 5

PURPOSE: This course provides knowledge about the sources of waste water, their characteristics, and the most important contaminants present in industrial wastewaters with respect to possible effects and problems in treatment. It also includes an overview of different conventional and advanced treatment processes applied in industrial wastewater treatment.

THE CONTENTS OF THE COURSE:

LECTURES:
Week 1: Care and preserve water quality. The definition of municipal and industrial wastewater.
Week 2: Characteristics of wastewater, physical, chemical. Sources and effects of pollutants.
Week 3: The effects of pollutants on equipment for wastewater treatment.
Week 4: Industrial wastewater characterization and mineralization of contaminant. The goals of wastewater treatment .
Week 5: Overview of physical and chemical methods of wastewater treatment and process units. Coagulation / flocculation. Settling. Filtration.
Week 6: Chemical treatment. Neutralization. Reduction. Oxidation. The processes of membrane separation.
Week 7: Advanced oxidation processes: photolysis, TiO_2 photocatalysis, ozonacija, oxidation with hydrogen peroxide, peroxone process and Fenton and Fenton-like processes, high-voltage pulse electric discharge. Disposal of chemical sludge. Optimization of physico-chemical treatment processes.
Week 8. 1st partial exam
Week 9: Overview of biological treatment of wastewater, and environmental and toxic effects.
Week 10: Factors microbial growth. Kinetics of microbial growth.
Week 11: The process of treatment with activated sludge. Nitrogen removal (nitrification, denitrification). Biological phosphorus removal.
Week 12: Aerobic biofilters: the structure of the filter, oxygen supply and hydraulic load. Rotating biodiscs.
Week 13: Anaerobic process: micro-organisms and the influence of environmental factors on the process of digestion. Gasses produced during digestion and potential use.
Week 14: Treatment and disposal of activated sludge. Optimization of biological processes.
Week 15: 2nd partial exam.

Laboratory exercises: Sampling methods, physico-chemical and microbiological analysis and determine the ecotoxicity of wastewater, physico-chemical and biological treatment of the selected model wastewater laboratory equipment, data processing.

GENERAL AND SPECIFIC COMPETENCE: Acquiring knowledge needed to solve problems in industrial wastewater treatment by application of chemical engineering methodology.

KNOWLEDGE TESTING AND EVALUATION: Two partial exams (after a certain whole material) that are recognized as passed exam if both positively evaluated, and the written and oral exam within specified examination periods.

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student questionnaire

LITERATURE:

1. T.J.Casey, Unit Treatment Processes in Water and Wastewater Engineering, John Wiley & Sons, New York, 1997

2. W. Viessman, M. J. Hemmer, Water Supply and Pollution Control, Addison-Wesley, Amsterdam, 1998.

3. S. Bumble, Computer simulated plant design for waste minimization/pollution prevention, Lewis publishers, New York, 2000.

4. W.Bitton, Wastewater Microbiology, John Wiley & Sons, New York, 1996.

5. H.J. Rehm, G. Reed, A. Puhler, P. Stadler, Environmental Processes I, vol. 11a, Wiley-VCH. Weinheim, 1999.