FORM 2

1) Course teacher: dr. sc. Miroslav Jerković, Assistant Professor	
2) Name of the course: Mathematics I	
3) Study programme (undergraduate, graduate): undergraduate	
4) Status of the course: obligatory	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. Distinguish and correctly use various number structures, their notation and available operations. 2. Apply coordinate systems (plane, space and higher-dimensional) and corresponding basic mathematical constructions: vectors, matrices and systems of linear equations. 3. Use elementary functions, distinguish their graphs and be able to interpret the corresponding relationship between dependent variables. 4. Master the notion of derivative, as well its physical and geometrical interpretation. Be competent to apply the notion of derivative to model and solve practical problems. 5. Actively use the corresponding basic procedures in program packages Mathematica or Matlab.	**6) Learning outcomes at the level of the study programme:** 1. Apply obtained competence in using numbers for quantitative description of physical properties. 2. Use the knowledge of coordinate systems, matrices and vectors to model engeneering problems. 3. Apply functions and their derivations in analysis of engineering problems.

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Real and complex numbers	- distinguish natural, integer, rational, real and complex numbers and their notation - calculate with real numbers, their approximate values, and learn to estimate their values - understand relations among	- for a given number, determine the number type, its value, its value and equivalent notation, as well as learn how to represent it geometrically - execute given operations

	numbers by being able to solve simple equations and inequalities - apply numbers for writing down the values of physical quantities	with numbers algebraically and numerically, exactly and approximately - determine the relation among the given numbers, set and solve a simple equation and inequality - interpret a connection among the given physical quantities, as well as among their numerical values
2. Two-dimensional, three-dimensional and n-dimensional real vector space	- define and graphically represent a coordinate system on a line, in plane and in space, as well as understand the generalization to higher dimensions - apply the notion of coordinate system to represent geometrical and physical relation between various quantities - define analitically a notion of vector in real vector space, use various equivalent notations and be able to use operations on vectors - interpret vector and its components form the engineering point of view (forces, velocity etc.)	- represent a point or a set of points, given by their coordinate values - write down the analytical expression representing a geometrical or physical relation between quantities - execute given vector operations
3. Some transformations of plane and space – the notion of matrices and linear operators	- define matrix and its elements - apply vectors and matrices to write down some basic transformations of plane and space: symmetry, projection, translation, rotation - distinguish various types of matrices: square matrix, symmetric matrix, diagonal	- determine columns, rows, elements, type and order of a given matrix - determine the matrix representation of a given transformation, or, vice versa, determine the transformation out of a given matrix representation - determine the type of a

	matrix etc.	given matrix
4. Algebra of matrices. Inverse matrix and determinant	- define operations with square matrices, be able to use these operations and compare them with number operations - define the notion of inverse matrix and its state its properties - define the matrix determinant for matrices of second and third order	- execute the given matrix operations - calculate the determinant of a given matrix of second or third order
5. Scalar, vector and mixed product of vectors	- geometrically define the angle between two vectors - define and calculate the scalar product of vectors, and establish a relationship with the notion of angle between two vectors - analitically, geometrically and physically define the vector product; learn to calculate it and use it to find the area given by two vectors - define the mixed product, calculate it and use it to find the volume determined by three vectors	- represent a relation between two vectors, regarding the angle between them - write down the formulas for scalar product of vectors and for the angle between vectors, and apply them to given vectors - write down the formulas for vector and mixed product of vectors, and apply these formulas to given vectors
6. Systems of linear equations and solution methods	- define the notion of a system of linear equations, and its set of solutions - define and apply the matrix notation for a system of linear equations - solve some simple systems by using, where appropriate, the inverse matrix method, Cramer rule or the Gauss-Jordan method - calculate the determinant	- write a matrix notation of a given linear system - solve a given system using the required, or appropriate, method - calculate the determinant and inverse of a given matrix, using elementary matrix operations

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	and inverse of a square matrix, by using the elementary matrix operations	
7. Notion and geometrical meaning of eigenvalues and eigenvectors (not obligatory)	- define the notions of eigenvalue and eigenvector of a matrix - interpret geometrically and physically these two notions - determine eigenvalues and eigenvectors in concrete examples - explain the special role of symmetric matrices	- check if a given number (vector) is an eigenvalue (eigenvector) of a given matrix - determine and interpret the eigenvalues and eigenvectors of a given matrix of second order
8. Notion of function, its graph and inverse function	- present the notion of a function and interpret it as an operation and notation of a relation between dependent quantities - define the notion of a graph of function and the notion of a graph equation - state basic properties of functions and graphical interpretion of these properties - define the inverse function, its graph and sketch the connection to equation solving	- calculate the values of a given function and represent those values as points of its graph - determine the value of a given function by using its graph - interpret the properties of a function if its graph is given and vice versa, represent graphically a function with specific property - present a graphical solution of a given equation and estimate the solution graphically
9. Elementary functions. Functions important in engineering and natural sciences.	- define the notion of elementary function, give a list of elementary functions and their inverse functions - represent graphically basic elementary functions and their inverse functions (powers and roots, exponential and logarithmic functions, trigonometric and arcus functions)	- calculate the values of a given elementary function - sketch the graph of a given basic elementary function - solve a given equation (exponential, logarithmic, trigonometric etc.) exactly, as well as approximately

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	- graphically interpret important properties of elementary functions (growth and decline, extremes, convexity and concavity, inflection points) - solve equations related to basic elementary functions - sketch the importance of applying elementary functions on engineering problems	
10. Notion of sequence, limit of a sequence and limit of a function	- define the notion of sequence of numbers and its series, as well as the notion of limit - approximately and exactly determine the limit of some important sequences - define and graphically represent the limit of a function - state some important limits of functions	- determine and write down the expression for the general term of a simple sequence given by its first few terms - calculate the limit of a given sequence - calculate the limit of a given function
11. Notion of derivative, its geometrical and physical meaning	- present the analytical definition of point derivative of a function, as well as its functional derivative - intepret the derivative physically (notion of velocity) - intepret the derivative geometrically (notion of inclination) - approximately determine the value of derivative by using the graph of a function - use the definition of a derivative to obtain the derivatives of some simple functions (as for power or	- using the definition of derivative, find derivatives of some basic functions, as for square root or square power - using the graphical representation, estimate the relative speed of change of one quantity, as compared to the other quantity

	root functions)	
12. Properties of derivative. Derivatives of elementary functions	- state the properties of functional derivatives and use them to calculate the derivatives - list the derivatives of basic elementary functions - calculate the derivatives of basic elementary functions (power function, exponential function, sinus and cosinus functions and their inverses)	- by using the table of derivatives, as well as the properties of the derivative operation, find the derivative of a given polynomial, a product or quotient of given elementary functions - find the derivative of a function composed out of given functions from the table of derivatives
13. Linear and quadratic approximation. Taylor series	- list and apply formulas for linear and quadratic approximation of a function - geometrically and analytically interpret linear approximation - derive the formula for the tangent line in a point of a graph of a function, and be able to interpret it geometrically - state the general formula for Taylor series of a function, and present the Taylor series for some basic elementary functions - apply Taylor series to approximately calculate values of a given function	- use the linear and quadratic approximations, as well as Taylor series, to calculate the approximate values of a given function - determine linear and quadratic approximations and the Taylor series for x0=0 for the following functions: exp(x), sin(x), cos(x), 1/(1-x)
14. Increasing and decreasing functions, convexity and concavity, inflection points and their physical meaning	- interpret increse and decrease of a function, as well as local extremes, by using the notion of first derivative, and apply this interpretation to a given problem - inetrpret convexity and concavity, as well as inflection points, by using the	- apply to a given function

FORM 2

	notion of second derivative, and apply this interpretation to a given problem - distinguish necessary and sufficient conditions in terms of derivatives, for a function to have a specific property stated above	
15. Qualitative analysis of a function by using a notion of derivative.	- use the competence obtained in Teaching unit 14 to some more involved functions	

FORM 2

1) Course teacher: dr. sc. Vladimir Dananić, associate professor	
2) Name of the course: Physics I	
3) Study programme (undergraduate, graduate): undergraduate	
4) Status of the course: mandatory	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. Explaining the physical processes and phenomena 2. Analyzing and solving physical problems using mathematical skills (mathematical formulation of physical problems) 3. Graphical representation of the laws of physics 4. Interpretation of the obtained results 5. Relating the acquired knowledge in solving physical problems	**6) Learning outcomes at the level of the study programme:** 1. Ability to apply the laws of physics 2. Acquiring computational skills 3. Correlating the acquired knowledge 4. Application of scientific methods in solving problems 5. Deductive and inductive reasoning

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	Learning outcomes	Evaluation criteria
1. Kinematics	- to describe different kinds of motion through kinematic quantities (position, velocity, acceleration)	- Explaining physical concept - Mathematical formulation of physical problem - Describing the model and its restrictions
2. Dynamics	- to interpret and apply Newton's laws and the laws of conservation of linear and angular momentum - to establish the equation of motion - to explain the relationship between different dynamic	- Explaining physical concept - Mathematical formulation of physical problem - Describing the model and its restrictions

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	quantities (force, linear momentum, angular momentum, impulse, torque) - to recognize some fundamental forces in nature (Gravity)	
3. Work and Energy	- to explain the relationship between work, potential and kinetic energy - to interpret and apply the law of conservation of energy - to derive the potential energy for some conservative forces with their grafical representation	- Explaining physical concept - Mathematical formulation of physical problem - Describing the model and its restrictions
4. Oscillations and Waves	- to describe simple harmonic motion and apply its equiation to different periodic motions in nature -to describe different kinds of waves by means of characteristic quantities (wavelength, period, frequency, angular frequency, amplitude)	- Explaining physical concept - Mathematical formulation of physical problem - Describing the model and its restrictions
5. Heat and Temperature	- to explain relationship between different thermodinamic quantities (heat, temperature, pressure, volume, internal energy, entropy) through thermodynamical and statistical approach. - to derive the work done in different thermodynamic processes	- Explaining physical concept - Mathematical formulation of physical problem - Describing the model and its restrictions

FORM 2

1) Course teacher: Svjetlana Krištafor (Assistant Professor), Ivana Steinberg (Assistant Professor)	
2) Name of the course: General Chemistry	
3) Study programme (undergraduate, graduate): Undergraduate	
4) Status of the course: Basic	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. To apply acquired knowledge that is necessary for understanding other branches of chemistry. 2. To solve chemical problems based on fundamental chemical principles. 3. To demonstrate basic laboratory skills in handling chemical substances. 4. To analyze the structure of three different states of matter. 5. To argue the properties of individual elements with respect to the position of an element in the periodic table.	**6) Learning outcomes at the level of the study programme:** 1. Knowledge and understanding of essential facts, concepts, principles and theories relating to chemistry and chemical engineering. 2. Ability to recognise and solve qualitative and quantitative problems using the appropriate chemical principles and theories. 3. Competence in the evaluation, interpretation and synthesis of chemical information and data. 4. Safe handling of chemical materials, taking into account their physical and chemical properties, including any specific hazards associated with their use. 5. Carry out standard laboratory procedures and use instrumentation involved in synthetic and analytical work, in relation to both organic and inorganic systems. 6. Monitoring, by observation and measurement, of chemical properties, events or changes, and the systematic and reliable recording and documentation thereof. 7. Interpret data derived from laboratory observations and measurements in terms of their significance and relate them to appropriate theory. 8. Skills in planning and time management, and the ability to work autonomously. 9. Study skills and competences needed for

	continuing professional development.

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Introduction to chemistry; Quantum world; Quantum mechanics.	The student will list the properties of matter and distinguish elements from compounds, pure substances from mixtures of substances. According to the modern theory of the atomic structure, the student will explain the uncertainty principle of quantum mechanics and outline the energy levels and forms of atomic orbitals. Based on the absorption and emission of electromagnetic radiation student will compare the ground and excited states of atoms.	- to identify the property as a chemical or physical, intensive or extensive - to distinguish molecules, atoms and ions - to describe the structure of atoms - to write the electronic configuration of neutral atoms and ions
2. Chemical bonds; Molecular shape and structure;	The student will distinguish covalent and ionic chemical bonds and give examples of covalent and ionic compounds. The student will define the valence and core electrons from the position of the element in periodic table. The student will write Lewis symbols of elements and apply them when drawing Lewis structures. Based on the quantum theory of chemical bonding, the student will sketch the energy	- to draw the Lewis structures of molecules and ions - to determine the dipole character and bonding (ionic or covalent) based on the electronegativity of elements - to predict the type, length and strength of chemical bonds - to distinguish the hybridization types and explain the difference between sigma and pi bonds

	levels of the molecules, write electronic configuration of molecules and estimate the molecular (non)stability.	
3. Gases, liquids and solids; Reaction thermodynamics; Physical and chemical equilibria.	The student will explain the difference between ideal and real gases and compare different states of matter based on the intermolecular interaction. The student will also explain the role of enthalpy in a chemical reaction, estimate (non)spontaneity of the process, determine the speed and order of chemical reaction and estimate its direction. The student will compare the acids and bases.	- to calculate *p*, *V*, *n* or *T* at defined conditions using gas laws - to outline and explain the types of intermolecular interactions - to calculate the change in enthalpy and Gibbs free energy of a chemical reaction - to calculate and analyse the chemical equilibrium constant - to calculate the pH of the solution
Electrochemistry; Coordination compounds – electronic structure and properties of complexes; Chemical kinetics; Nuclear chemistry.	The student will describe and identify reactions in electrochemical cells and to determine their (non) spontaneity. The student will determine the rate constant and order of chemical reaction. The student will also define the influence of the catalyst on the speed and direction of chemical reaction. The student will connect the temperature dependence of the speed of chemical reaction. The student will analyse the different types of radioactive decay and determine the energy changes that accompany nuclear reactions.	- to balance the redox reaction chemical equations - to calculate the potential of electrochemical cell - to calculate the rate constant of a chemical reaction based on its activation energy - to write and balance the nuclear reaction equation - to calculate the energy changes during nuclear reactions

FORM 2

1) Course teacher: Marinko Markić

2) Name of the course: Computer Programming and Application

3) Study programme (undergraduate, graduate):undergraduate

4) Status of the course: obligatory

5) Expected learning outcomes at the level of the course (4-10 learning outcomes):	**6) Learning outcomes at the level of the study programme:**
1. Solving simple problems applying Matlab software package 2. Solve simple programming problems using structured programming 3. Identify and explain numerical method for: solving nonlinear algebraic equations, numerical integration, solving ordinary differential equitation 4. Apply numerical method for: solving nonlinear algebraic equations, integration, solving ordinary differential equitation 5. Recognition of the possibilities of scientific resources on the Internet	1. The ability to identify, define and solve simple chemical engineering problems 2. The ability to choose and apply appropriate mathematical numerical methods for problem solving 3.The skill to perform mathematical calculations, including error analysis and application of corresponding criteria for acceptability assessment of the results and applied models, 4.The ability to apply basic information and communication technologies

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1.Programming Basic	- Explain the concept and basic properties of the algorithm - Apply an algorithm flow chart - Identify the program development phase - Apply standard algorithms for: computing the mean numbers, search the smallest and the largest among the numbers, working with natural numbers (addition,	- Apply the principles of structured programming for the development of standard algorithms - Draw a flow chart of the developed algorithm-

	multiplication, computing factorial, divisibility number with the default number), replace the contents of variables, sorting array elements (Bubble sort) -	
2. Matlab Basic and Matlab programming	-- Distinguish the data types - Describe working with arrays, vectors and matrices Apply selection structures - Use data entry and printing - Write mathematical expressions with the use of arithmetic, relational and logical operator and appropriate functions, including M-functions - Apply decisions command (single, multiple if statement) - Apply repetition structures (for-end, while-end, nested) - Graphically display data - Apply commands for saving and loading data	-Define and explain the data types in Matlab, (floating point and single and double precision numbers) - Define variables in Matlab, their distribution - Describe the definition of a series of numbers in Matlab, commands linspace and logspace, - Specify commands for drawing two-dimensional graphs in Matlab and their syntax, specify commands to draw more coordinate system or system within the same graphic windows and their syntax, - Write a program in Matlab script file which includes: data entry, use variables, the assignment statement, arithmetic operations, relational and logical operators, work with arrays, vectors and matrices, application functions, command decisions, repetition, print the results, save results to the file, draw a graph,
3. Errors in Numerical Methods	-Define (specify) sources of error - Give examples of sources of errors	- Describe sources of error

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	- Distinguish the sources of error	
4. Iterative Methods for Solving Nonlinear Algebraic Equations	-Describe methods of solving algebraic equations with one variable (Iterative method, Newton-Raphson, successive bisection, secant, Regula falsi) - Distinguish the methods for solving nonlinear algebraic equations - Explain the method algorithm - Compare the methods	Draw graphical representation of calculating the roots of the equation - Write algorithm methods and draw appropriate flowchart - Specify which conditions must satisfy the algebraic equation. - Compare the advantages and disadvantages of different methods
5. Numerical integration	-Describe methods for numerical integration (trapezoid rule, Simpson, Romberg) -Distinguish the methods for numerical integration - Explain the method algorithm - Compare the methods	Draw methods graphical representation - Write algorithm methods and draw appropriate flowchart - Compare the advantages and disadvantages of different methods
6. Numerical solution of ordinary differential equations	-Describe methods for the solution of ordinary linear differential equations (Taylor, Euler, Runge-Kutta) - Distinguish between methods - Explain the method algorithm on the example - Choose the appropriate numerical method to solving linear differential equations - Compare the various methods - Compare with the exact numerical solution	- Draw a methods graphical representation - Describe the method algorithm - Draw flowchart methods - Write a program in Matlab (script file) for a given differential equation and method. The differential equation is defined in a function file. Calculate relative percentage error. Draw a graph with the numerical solution, print the results on the monitor and write them to a file. - Compare the advantages

FORM 2

		and disadvantages of various methods
7. Scientific resources on the Internet	- Define basic concepts of data and information - Define basic concept of a database - Collect information from databases on the Internet - Evaluate the relevance of the collected data - Develop a critical attitude towards the source of the data collected	- Apply the keywords and logical operators in searching databases on the Internet - Compare the data collected from the internet with respect to their source - Argue the use of the data obtained

FORM 2

1) Course teacher: Prof. dr. sc. Veljko Filipan	
2) Name of the course: BASICS OF MECHANICAL ENGINEERING	
3) Study programme (undergraduate, graduate): undergraduate	
4) Status of the course: mandatory	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. apply basic rules and standards in engineering graphical communication 2. apply principles of engineering mechanics to the simplest systems 3. understand interconnection between loads, stresses and strains 4. differentiate basic loading form on simple structure elements 5. understand basic materials properties and their testing methods …..	**6) Learning outcomes at the level of the study programme:** 1. capacity to apply knowledge in practice, in particular problem-solving competences, relating to both qualitative and quantitative information 2. ability to engage in interdisciplinary team-working 3. apply fundamental principles for identification of simple engineering problems 4. define and solve simple engineering problems with relevant methodologies 5 study skills and competences needed for continuing professional development …..

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	Learning outcomes	Evaluation criteria
1. basics of engineering graphics	- apply basic rules and standards in engineering graphical communication - understand graphical symbols for process laboratory elements	- sketch orthogonal view of simple laboratory equipment on the basis of isometric view - mark dimensions of simple elements on technical sketch - repeat the symbols of some common laboratory elements
2. basics of applied mechanics	- apply fundamental principles of engineering mechanics for analysis of the simplest elements	- simplify the connections between bodies in simplest multibody systems and define the equilibria conditions

	- define equilibria conditions of simplest engineering problems - understand difference between real and allowable stresses	- calculate stress and strains of simplest elements under simplest loads - determine thermal stresses of a simple rod - determine dimensions of simplest loaded elements
3. basic properties of engineering materials and their testing methods	- understand interconnections between internal structure, properties and the application of engineering materials - describe some mechanical, chemical, physical and technological properties of materials and their testing methods	- describe diagrams of static testing methods results - calculate allowable stress of materials - repeat mechanical, chemical physical and technological properties of materials

University of Zagreb
Faculty of Chemical
Engineering and Technology

FORM 2

1) Course teacher: Zvonimir Glasnovic, Associate Professor
2) Name of the course: Fundamentals of Electrotechnics
3) Study programme (undergraduate, graduate): Chemical Engineering, Applied Chemistry, Environmental Engineering
4) Status of the course: Undergraduate

5) Expected learning outcomes at the level of the course (4-10 learning outcomes):	**6) Learning outcomes at the level of the study programme:**
1. Apply the basic principles of electrical engineering to solve basic circuits; 2. Apply the analogue electronic circuits in chemical engineering problems; 3. Apply digital electronic circuits (CPU, sensors, actuators etc.) and a digital computer to manage complex technological processes in chemical engineering; 4.Identify techniques for protection of electric shock; 5. Manipulate with electronic instrumentation.	1. Analyze complex circuits; 2. Apply the methodology of Electrical and Electronics in the development of chemical engineering processes; 3. Use the systems and methods for monitoring and controlling of the technological processes; 4. Apply a systematic approach to solving problems of electrical engineering and electronics in chemical engineering.

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	Learning outcomes	Evaluation criteria
1. Basic principles of electrical engineering and electronics	- Explain the principle representation engineering systems (diagram); - Explain the concept of electric current and the effects that it causes; - Explain the concept of density of electric current; - Explain the concept of electric voltage and methods for its preparation; - Explain the concept of	- Sketch basic block diagram of electrical system; - Solve relationship between current, charge and time in battery; - Calculate load of electric conductors; - Calculate four characteristic values of resistor; - Calculate any of the required values of electrical

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	electrical resistance; - Explain the variation of resistance with temperature; - Analyze superconductivity conditions and material.	resistor.
2. Basic DC circuits	- Interpret basic relationships in electrical circuits and connect them to the universal energy principles; - Interpret Ohm's law; - Interpret the voltage distribution in resistors (voltage drop); - Interpret current distribution on resistors; - Interpret resistors in series connection; - Interpret resistors in parallel connection; - Interpret resistors in complex network;	- Solve elementary circuit; - Analyze the current-voltage conditions in elementary circuit; - Demonstrate current-voltage characteristics in the elementary circuit; - Analyze current-voltage conditions in a series connection of resistance; - Analyze the current-voltage conditions in a parallel resistance; - Analyze the current-voltage opportunities in complex circuits.
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FORM 2

1) Course teacher: prof. dr. sc. Ivica Gusić, Full Professor / dr. sc. Miroslav Jerković, Assistant Professor
2) Name of the course: Mathematics II
3) Study programme (undergraduate, graduate): undergraduate
4) Status of the course: obligatory

5) Expected learning outcomes at the level of the course (4-10 learning outcomes):	**6) Learning outcomes at the level of the study programme:**
1. Apply indefinite integral to problems inverse to the derivative problem 2. Use definite integral to solve the problem of area and apply it in solving engineering problems 3. Adopt the notion of a function of several variables, its derivatives and integral, and apply it to study the relations among several dependent quantities 4. Use differential equations of first and second orders to solve mathematical and physical problems 5. Actively use the corresponding basic procedures in program packages Mathematica or Matlab.	1. Apply the indefinite and definite integrals to model an engineering problem. 2. Apply the differential calculus of functions of several variables to model an engineering problem. 3. Use ordinary and partial differential equations to model an engineering problem.

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	Learning outcomes	Evaluation criteria
1. Indefinite integral and computation methods.	- define the primitive function and indefinite integral of a function - show competence in using the basic properties of indefinite integral, and in applying them in calculations - apply methods of partial	- for a given elementary function determine a primitive function - check if a give function is a primitive function of a given function - introduce an appropriate substitution to a given

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	integration and substitution - apply indefinite integral to solving some simple engineering problems	integral - derive the differential equation of radioactive decay and solve it by integration - derive the differential equation of the vertical shot and solve it by integration
2. The area problem – definite integral. Leibnitz-Newton formula.	- establish a connection between the problem of area under curve and the notion of definite integral - interpret geometrically and estimate the definite integral for a positive, as well as for a general function - calculate the definite integral by using the Leibnitz-Newton formula - sketch and geometrically interpret the properties of definite integral	- represent geometrically and estimate the value of the definite integral of a given simple function - calculate the value of the definite integral of a given simple function
3. Methods for calculating the definite integral. Improper integral.	- derive and apply the formula for partial integration of the definite integral - derive and apply the formula for integration by substitution of the definite integral - define and represent graphically the improper integral - calculate the given improper integral	- using the method of partial integration, calculate the appropriate definite integral - using the method of substitution, calculate the appropriate definite integral - calculate and represent graphically the improper integral of a given function
4. Geometric application of definite integral.	- use the definite integral to calculate the area of plane domain - derive and apply the formula for volume of the rotational body	- represent graphically, estimate and calculate the area of a plane domain bounded by given curves - calculate the volume of a ball

		- calculate the volume of a cone
5. Application of definite integral to natural sciences.	- apply the definite integral to calculate the mass, barycentre and moment of inertia of a nonhomogeneous line segment with a given mass density function - explain above formulas - use the definite integral to interpret the problem of a work of a line force	- calculate the mass of a nonhomogeneous segment with a given mass density function - estimate and calculate the barycentre of a nonhomogeneous segment with a given mass density function; interpret the result - calculate the moment of inertia for a nonhomogeneous segment with a given mass density function - calculate the work of a line force given by F(x)=-kx; interpret the result
6. Notion of a function of two variables, its graph and partial derivatives.	- define a function of two variables and apply it to the problem of a relation among three dependent quantities - determine the domain of a function of two variables, and evaluate it - define and calculate the partial derivatives of first and second order for a function of two variables - physically and geometrically interpret the first order partial derivatives at a given point of a function of two variables	- determine the natural domain of a given function of two variables - determine partial derivatives and partial derivatives at a particular point for a given function of two variables
7. Linear and quadratic approximation of a function of several variables.	- write down the formula for linear approximation of a function of two variables and comment on analogy with the case of single variable - apply linear approximation to calculate the approximate	- determine linear and quadratic approximation for a given function of two variables - determine the increment and approximate increment for a given function of two

	values - write down the formulas for increment and approximate increment of a function of two variables and comment on analogy with the case of single variable - apply the formula for the approximate increment of a function - write down and apply the formula for quadratic approximation of a function of two variables	variables
8. Local extremes of a function of several variables.	- define the local extremes for a function of two variables and comment on analogy with single variable case - state and explain the necessary conditions for local extremes - apply the above criterion, by using partial derivatives of first and second order - apply the above criterion to solve some mathematical and engineering problems (the minimization problem)	- determine the local extremes for a given function of two variables - apply the local extreme criterion to solve a given minimization problem
9. Multiple integrals – consecutive integration.	- define the notion of definite integral for a positive function of two variables along the plane domain, and interpret it as a volume - by using the formula for consecutive integration, calculate the definite integral on the given domain - define and calculate the definite integral of a general function	- represent graphically the integral of a given positive function of two variables - calculate the integral of a given function of two variables, over a given plane domain - introduce the appropriate polar substitution in a given integral

	- apply polar coordinates to calculate the definite integral of a function of two variables.	
10. Application of the multiple integral.	- interpret the distribution of mass for a nonhomogeneous plane domain using the mass density function - sketch the derivation of the formula for the mass of a nonhomogeneous plane domain using its mass density function - apply formulas for determining the mass and barycentre of a nonhomogeneous plane domain	- calculate the mass of a given nonhomogeneous plane domain - estimate and calculate the barycentre of a given nonhomogeneous plane domain
11. The notion of ordinary differential equation, integral curve and initial conditions.	- state the general form of ordinary differential equations of first and second order - define the general and particular solutions - solve some simple differential equations and graphically represent the solution via integral curves - define initial conditions and their role	- determine the order of a given differential equation - check if a given function represents a solution of a given differential equation - find and represent graphically the general solution of a given simple differential equation
12. Application of ordinary differential equations. Cauchy's problem.	- state and solve the Cauchy problems of first and second order and interpret them physically	- derive and solve the Cacuhy problem of cooling (heating) - derive and solve the Cauchy problem of linear motion with constant force applied - derive the Cauchy problem of a oscillation of a particle along a line
13. Methods for solving some types of first and second	- apply the method of	- solve a given differential equation of first or second

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order ordinary differential equations.	variable separation - state and solve homogeneous and nonhomogeneous linear differential equation of first order - state and solve homogeneous and nonhomogeneous linear differential equation of second order with constant coefficients	order - solve the Cauchy problem of a oscillation of a particle along a line; interpret the solution
14. The notion of partial differential equation, its solution and initial and boundary conditions.	- state the general form of partial differential equations of first and second order - define and physically interpret initial and boundary conditions	
15. Application of partial differential equations (not obligatory).	- state the differential equations for vibration of a string and heat conduction, together with the corresponding initial and boundary conditions	

FORM 2

1) Course teacher: Šime Ukić

2) Name of the course: Analytical Chemistry I

3) Study programme (undergraduate, graduate): undergraduate study – Applied Chemistry

4) Status of the course: obligatory

5) Expected learning outcomes at the level of the course (4-10 learning outcomes):

1. To define analyte, analytical signal and analytical information.
2. To explain basic principles how to manage chemical analysis.
3. To define chemical equilibrium constants, law of mass action, and Le Chatelier's principle.
4. To apply principles of chemical equilibrium for analyte's separation and identification/determination from complex matrix.
5. To differentiate homogeneous and heterogeneous chemical equilibrium systems.
6. To predict behaviour of chemical reaction related to variation in pH value or due to common ion and/or ionic strength effect.
7. To apply acquired knowledge within good laboratory practice while writing laboratory reports.

6) Learning outcomes at the level of the study programme:

1. To demonstrate understanding of basic facts, terms, principles, and theories related to analytical chemistry
2. To demonstrate ability to recognize and solve qualitative analytical problems by applying adequate chemical principles.
3. To demonstrate competence in assessment, synthesis, and interpretation of obtained chemical information.
4. To apply gained knowledge in practice, especially for problem solving based on qualitative information.
5. To demonstrate safe handling with chemicals, taking their chemical properties in consideration.
6. To perform standard laboratory procedures for analysis of inorganic systems.
7. To monitor chemical properties and/or changes and their systematic notation.
8. To interpret obtained laboratory observations: meaning and connection with relevant theory.

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	Learning outcomes	Evaluation criteria

FORM 2

1. Introduction to analytical chemical analysis: from sample, over analytical signal to analytical information. Limit of detection. Chemical reaction and chemical equilibrium.	- To define analyte, analytical signal and analytical information. - To explain basic principles how to manage chemical analysis.	- To apply basic principles of managing chemical analysis for analyte's identification or determination.
2. Protolytic reactions, reactions of complexes, electrochemical reactions, and precipitation reactions.	- To define chemical equilibrium constants, law of mass action, and Le Chatelier's principle. - To apply principles of chemical equilibrium for analyte's separation and identification/determination from complex matrix.	- To write chemical reaction and express related chemical equilibrium - To solve computational tasks by applying law of mass action and Le Chatelier's principle. - To compute pH-value of acid, alkali, amphoteric, and buffer solutions - To demonstrate knowledge about complex stability - To demonstrate knowledge about spontaneity of redox reactions - To compute solubility product constant
3. Reactions in homogeneous and heterogeneous systems, complex sample.	- To differentiate homogeneous and heterogeneous chemical equilibrium systems. - To predict behaviour of chemical reaction related to variation in pH value or due to common ion and/or ionic strength effect.	- To identify analyte by applying acid-base, complex, redox, or precipitation reactions.
4. Laboratory practice	- To apply principles of chemical equilibrium for analyte's separation and identification/determination from complex matrix. - To apply acquired	- To demonstrate understanding of systematic analysis of cations and anions by applying principles of selective precipitation and

	knowledge within good laboratory practice while writing laboratory reports.	dissolution - To analyse and interpret the obtain results

FORM 2

1) Course teacher: Associate professor dr. sc. Stjepan Milardovic	
2) Name of the course: Inorganic Chemistry	
3) Study programme (undergraduate, graduate):Undergraduate (Applied Chemistry)	
4) Status of the course: Basic	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): It is expected that the student will be able: 1. From electronic configuration to recognize stable and less stable oxidation states in the different groups of elements. 2. Used the information about standard reduction potential for prediction atoms stability in ground state. 3. Recognize the stability of hydrides and oxides using the information of atoms electronegativity 4. Make conclusion about chemical reactivity of atoms in ground state based on ionization energy data …..	**6) Learning outcomes at the level of the study programme:** 1. Students have using knowledge and skills gained during the courses for problem solving in the field of chemical technology 2. The knowledge and skills gained during the courses can be used for problem solving in the field of science. 3. Applied the knowledge and skills gained during the courses as a base for additional studying. 4. The knowledge gained during the courses can be good base for the lifetime education. …..

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	Learning outcomes	Evaluation criteria
1. The low of chemical periodicity and periodic table. Periodic trends in physical and chemical properties along the periods and along the groups. Periodicity of chemical properties (electronegativity, ionization energy, electron affinity, oxidation numbers,	After the course students will be able to -explain the periodic trends in first ionization energy, electronegativity and atomic radii for the elements H to Rn -use the information about standard reduction potentials for prediction oxidation and	Students answers the question based on application of theoretical principles Students solve the worked examples applying theoretical knowledge

standard-state reduction potential), periodic trends in physical properties (melting point, boiling points, etc.)	reduction trends across a row and periods -explained the periodic trends in physical properties for the elements across a row and the periods	
2. Hydrogen 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.	After the course students will be able to -compare reactivity of atomic and molecular hydrogen -use the information about standard reduction potentials of metals for hydrogen preparation from water or from aqueous solution of acid and bases. -predict the boiling points of hydrides (13th, 14 th, 15th, 16th and 17th groups of elements) and explained the boiling points change inside the group of the elements. -analyze the difference in boiling and melting points	Students answers the question based on application of theoretical principles Students solve the worked examples applying theoretical knowledge
3.The elements of 18th group (noble gases) Atomic and physical properties of the elements. Preparation production and use.Compounds of xenon and compounds of other noble gases, polymeric and intermediate hydrides). The hydrogen bond and hydrogen isotopes.	After the course students will be able to -explain oxidation properties of XF_2 and recognize potential oxidation state from electron configuration of xenon	Students answers the question based on application of theoretical principles Students solve the worked examples applying theoretical knowledge
4.The elements of 17th group (the halogens) The general chemical	After the course students will be able -to recognize stable and less stable oxidation state from	Students answers the question based on application of theoretical principles application

properties of the halogens 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. Oxoacid and oxoacid salts (preparation and properties).	electron configuration of halogens -analyze stability and bond order in two atomic halogens molecules using MO diagram -to conclude about strength of hydrohalous and hypohalous acid based on electronegativity difference between hydrogen and halogens -to draw the Lewis structures of halogen oxo acid to predict the strength of acid	Students solve the worked examples applying theoretical knowledge
5. The elements of 16th group (chalcogens) 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 (O2) ozone (O3) and atomic oxygen (O). The properties of oxygen compounds concerning negative oxidation state (O2-), (O22-),(O2-), (O3-) and positive oxidation state (O2+). Physical properties and structure of water, oxoacids of sulphur, selenium and tellurium, thioacids. Redox properties along the group	After the course students will be able to - recognize stable and less stable oxidation state from electron configuration of chalcogens - conclude about stability of hydro (oxides, sulfide, selenides and tellurides) based on electronegativity difference between hydrogen and chalcogens -conclude about bond order and magnetic properties of oxygen, oxide, peroxides and superoxides using MO diagram -conclude about molecular and atomic oxygen reactivity based on reaction entalphy -analyze acid-base and redox properties of oxygen compouns (oxidation state -2 to 0)	Students answers the question based on application of theoretical principles Students solve the worked examples applying theoretical knowledge

6. The elements of 15th group (nitrogen group of the elements) 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 (N2O, NO, NO2, N2O3, N2O5) and oxoacid of nitrogen. Preparation, use and chemical properties of hydrides of nitrogen, phosphorus, arsenic, antimony and bismuth.	After the course students will be able to -recognize stable and less stable oxidation state from electron configuration of 15th group of elements -conclude about stability of hydrides and oxides of 15 the group of elements by using data about electronegativity -analyze redox properties of elements (15th group) in ground state using information about standard reduction potentials -conclude about reactivity of elements in ground state using data about ionization energy - explain preparation acid-base and redox properties of ammonia -compare reactivity, stability acid base and redox properties of ammonia, phosphine, arsine and bismuthine -conclude about bond order of N2O, NO, NO2, N2O3, N2O5 using MO diagram for nitrogen and oxygen -compare acid strength for oxo acid of 15th group of element oxidation state +3 and +5	Students answers the question based on application of theoretical principles Students solve the worked examples applying theoretical knowledge
7. The 14th group of the elements (carbon group)	After the course students will be able to	Students answers the question based on application

The general chemical properties of the carbon group of the elements. Preparation, physical and chemical properties of carbon (diamond, graphite, fullerene, graphene) CO and CO2. Chemical properties of the carbon (negative oxidation state) compounds (carbides) and silicon (silicides). 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.	-recognize stable and less stable oxidation state from electron configuration of 14th group of elements -conclude about stability of hydrides and oxides of 14 th group of elements by using data about electronegativity -analyze redox properties of elements (14th group) in ground state using information about standard reduction potentials -conclude about reactivity of elements in ground state using data about ionization energy -analyze properties of compounds containing the elements in oxidation state -4,-2 and 0 -explain hydrolysis of tin and lead compound -explain the preparation of silicates by condensation of $Si(OH)_4$ -prepare the silicon of desired length of Si chain	of theoretical principles Students solve the worked examples applying theoretical knowledge
8. The 13th group of the elements (boron group) 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 boric acid.	After the course students will be able to - recognize stable and less stable oxidation state from electron configuration of 13th group of elements -conclude about stability of hydrides and oxides of 13 th group of elements by using data about electronegativity	Students answers the question based on application of theoretical principles Students solve the worked examples applying theoretical knowledge

FORM 2

Preparation, use and chemical properties of aluminum, aluminum trihalides, amphoteric properties of aluminum and aluminum passivity. Chemical properties of indium and gallium compounds.	-analyzed redox properties of elements (13th group) in ground state using information about standard reduction potentials -explain the reactivity of aluminum in ground state -compare the chemistry of silicides, carbides and borides and also silanes and boranes -explain the preparation of polyborates by condensation of B(OH)3	
9.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	After the course students will be able to -conclude about reactivity of elements in ground state using data about ionization energy -explain typical reaction of alkaline earth elements -	Students answers the question based on application of theoretical principles Students solve the worked examples applying theoretical knowledge
10. 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.	After the course students will be able to conclude about -reactivity of elements in ground state using data about ionization energy -explain typical reaction of alkaline elements	Students answers the question based on application of theoretical principles Students solve the worked examples applying theoretical knowledge
11. Preparation and properties of metals	After the course students will be able to -explain periodic trends in group of 3d, 4d, 5d.	Students answers the question based on application of theoretical principles Students solve the worked

	-compared stability of complex for 3d, 4d and 5d elements -quantitative analyze of electron absorption spectra for various d^n system - describe magnetic properties of complex compounds and color of metals	examples applying theoretical knowledge
12. Chemical reactivity and trends of chemical and physical properties along the group of the lanthanides and actinides. The general properties of the elements of the 4th and 5th group of the elements, oxides, sulphides, oxoanions and complexes of titanium, zirconium and hafnium.	After the course students will be able to -use electronegativity data for make conclusion about hydrides, sulphides and oxides stability -write the electronic configuration of elements end conclude about possible oxidation states - -	Students answers the question based on application of theoretical principles Students solve the worked examples applying theoretical knowledge
13. Chemical reactivity and trends of chemical and physical properties along the d-group of elements (vanadium, chromium and manganese). Oxides and the most important compounds (oxidation states 2, 3, 4, 5 and 6).	After the course students will be able to -write the electronic configuration of elements end conclude about possible oxidation states - explain the stability and pH equilibrium of chromate and dichromate -write the Lewis's structure for chromate and dichromate and explain the geometrical shape -explain the preparation of Cr 3+ compounds based on	Students answers the question based on application of theoretical principles Students solve the worked examples applying theoretical knowledge

	amphoteric properties of Cr_2O_3 -explain the properties of MnO_2 in acidic and base medium	
14. Chemical reactivity and trends of chemical and physical properties along the d-group of elements (iron, cobalt and nickel) and 8th, 9th and 10th group of elements. Oxides, oxyanions, complexes.	After the course students will be able to -write the electronic configuration of elements end conclude about possible oxidation states -conclude about solubility of metals in acidic solution -explain the properties of Fe^{2+} and Fe^{3+}hexacyano complexes -explain the properties of Co^{2+} and Co^{3+} complexes	Students answers the question based on application of theoretical principles Students solve the worked examples applying theoretical knowledge
15. Chemical reactivity and trends of chemical and physical properties along the d-group of copper and zinc (11th and 12th group of elements). Oxides, oxyanions, complexes, biochemistry of copper.	After the course students will be able to -write the electronic configuration of elements end conclude about possible oxidation states -explain the stability of Cu^{2+} and Au^{3+} compounds -explain oxidation of gold and silver by oxygen and explain importance of formation of cyano complexes	Students answers the question based on application of theoretical principles Students solve the worked examples applying theoretical knowledge

FORM 2

1) Course teacher: dr. sc. Vladimir Dananić, associate professor
2) Name of the course: Physics II
3) Study programme (undergraduate, graduate): undergraduate
4) Status of the course: mandatory

5) Expected learning outcomes at the level of the course (4-10 learning outcomes):	**6) Learning outcomes at the level of the study programme:**
1. Explaining the physical processes and phenomena 2. Analyzing and solving physical problems using mathematical skills (mathematical formulation of physical problems) 3. Graphical representation of the laws of physics 4. Interpretation of the obtained results 5. Relating the acquired knowledge in solving physical problems …..	1. Ability to apply the lows of physics 2. Acquiring computational skills 3. Correlating the acquired knowledge 4. Application of scientific methods in solving problems 5. Deductive and inductive reasoning …..

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	Learning outcomes	Evaluation criteria
1. Electrostatics	- to describe different kinds of electric phenomena and interactions through electrostatic quantities (charge, Coulomb force, electrostatic energy, potential and voltage, electric current)	- Explaining physical concept - Mathematical formulation of physical problem - Describing the model and its restrictions
2. Magnetostatics	- to explain the origin of magnetic phenomena and interactions and to establish the conections between different quantities (magnetic field, electric current, Lorentz	- Explaining physical concept - Mathematical formulation of physical problem - Describing the model and its restrictions

	force)	
3. Alternating electric and magnetic fields	- to explain the relationship between alternating electric and magnetic fields - to describe the applications (alternating current, electromagnetic waves)	- Explaining physical concept - Mathematical formulation of physical problem - Describing the model and its restrictions
4. Optics	- to explain and apply the laws of geometric and wave optics to different optical instruments (mirrors, lenses, gratings)	- Explaining physical concept - Mathematical formulation of physical problem - Describing the model and its restrictions
5. Fundamental principles of quantum physics	- to explain differences between classical and quantum quantities - to apply quantum mechanical description to some phenomena in micro world	- Explaining physical concept - Mathematical formulation of physical problem - Describing the model and its restrictions

FORM 2

English language (basic course)

COURSE AIM: Gaining competences like reading, oral and written fluency in the English language related to chemistry. Individual classification of new vocabulary by using the on-line dictionaries to acquire correct pronunciation and placing it in the e-class glossary. As part of the course students will infer basic vocabulary of chemical terminology in English, adjectives that describe the various states of matter, compounds and solutions, and ways in which they can read chemical equations, rules when to use the definite article and the indefinite articles. The students will also demonstrate the rules pertaining to the order of adjectives in a sentence, the comparison of adjectives and superlative form of adjectives and adverbs. They will also illustrate how to write a CV, do the revision tests on their own in the e-class, take part in group work and put their group work in the e-portfolio.
DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES OF THE STUDENTS:
General competencies: pronunciation of basic chemistry elements and names of compounds, acids, molecules and reading of numbers, equations as well as naming the ionic compounds in English.
Specific competencies: describing the characteristics of a material by using adjectives, use of suffixes and prefixes, comparison of adjectives, adverbs and linking words.
STUDENT OBLIGATIONS: The students are obliged to attend classes and are to put their CV in their e-portfolio (Euro pass CV). They are obliged to practice solving the revision tests to prepare for the midterm tests. They become eligible to attend the midterm tests by attending class regularly. Students must have their indexes or ID cards in order to take part in written tests. If they are not eligible to attend the midterm tests then they have to take the final written and oral tests at the end of the second semester. The oral test refers to the lab experiment they did as a group which should be in their e-portfolio. They have to orally explain the lab report in order to get a final grade.
SIGNATURE REQUIREMENTS: The students must attend 80 percent of all classes and take part in the language exercises during class, write their CV (Euro pass CV) and put their group work and CV in the e-portfolio. They are to pass the revision tests in the e-class on their own. They have to pass all written and oral exams for the final grade.
TEACHING METHOD: lectures, individual work on the e-class and e-portfolio, language exercises such as reading, pronunciation, answering questions, pair work, group work, use of computer and consultations according to necessity.
METHOD OF ASSESSMENT:
Written midterm tests (60 percent or more on both midterm tests) and e-portfolio content
Written final exam (minimum 60 percent to pass) and oral exam (presentation of lab experiment conducted at the University and filmed) which is linked to the filmed lab experiment group work in their e-portfolio.
QUALITY CONTROL AND SUCCESS OF COURSE: anonymous student survey
METHOD PREREQUISITES:
Access to a computer and knowledge of e-class and e-portfolio passwords in the Moodle and Merlin programs.
COURSE LEARNING OUTCOMES:
1 students will generate basic concepts of chemistry terminology in English

FORM 2

2 students will explain new vocabulary and demonstrate pronunciation of it by learning it on
their own with the aid of on-line dictionaries
3 students will demonstrate how to use the e-portfolio at the beginners level
4 students will examine the additional materials in the e-class
5 students will prepare for the midterm tests by practicing the revision tests in the e-class

PROGRAM LEARNING OUTCOMES:

1 students will interpret the expert terminology used in the field of chemistry today
2 students will generate use of English grammar at the beginners level
3 students will write their own Euro pass CV in English and put it in their e-portfolio
4 students will use the e-class and e-portfolio programs on their own

FORM 2

English language (advanced course)

COURSE AIM: To gain competencies for advanced reading, oral and written correspondence in the English professional language of the students trait. Independent learning of new vocabulary by using the on line dictionaries that also provide US and UK pronunciation. The students will know how to apply basic technical terminology and learn to negotiate in English. Preparing the students for oral presentations in English for future international conferences. Students will have mastered the basic technical terminology in English during this course. Students will also become familiar with some of the customs of the United States and the United Kingdom.

THE DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES OF STUDENTS:

General competencies: pronunciation of specific terminology that is related to various branches of technology in English.

Specific competencies: writing their own CV and seminar paper. Correct use of grammar.

STUDENT OBLIGATIONS: Students are required to attend lectures and are obliged to place their Euro pass CV in their e-portfolio. They are also expected to solve the revision tests in their e-class. They have to attend the midterm tests if they are eligible to do so, depending on their attendance record. They are obliged to bring their Index or ID card to class during midterm and final tests.

SIGNATURE ELIGABILITY: In order to get a signature at the end of each semester the student must be present in class for 80 percent of the lectures and take part in the exercises during class, write their CV and correct it, place their CV in their E-portfolio.

The student must pass midterm exam 1.

MANNER OF TEACHING: lectures, language exercises (reading, pronunciation, understanding, speaking), independent learning (e-class), pair work, group work, individual answering questions related to the subject matter, grammar exercises and consultations if need be.

ASSESSMENT MANNER AND EXAMINATION:

Written tests (minimum of 60 percent or more scored on each midterm test excuses the student from having to take the final written and oral tests). They also have to have both seminar papers in the e-portfolio in order to get the final grade.

Written test (minimum of 60 percent in order to pass) and oral test (explanation of lab experiment)

QUALITY CONTROL AND COURSE SUCCESS: anonymous student survey

METHOD PREREQUISITES:

Access to a computer and knowledge of password to access e-class and e-portfolio in the Moodlu or Merlin programs. Each student has to have their access code to enter these programs.

LEARNING OUTCOMES OF THE COURSE:

1 students will describe basic concepts of technology and summarize the terminology in English

2 students will individually learn and be able to repeat the pronunciation of new vocabulary

3 students will practice using the e-portfolio at an advanced level

FORM 2

4 students will individually examine the additional material in the e-class
5 students will individually prepare themselves for the midterm tests by reviewing the revision tests in their e-class

LEARNING OUTCOMES AT PROGRAM LEVEL:

1 students will recognize expert terminology used in their field of technological expertise
2 students will demonstrate use of English grammar at the advanced level
3 students will demonstrate how to write a CV in English (Euro pass CV) and a lab report
4 students will practice the use of the e-portfolio and e-class programs on the computer

University of Zagreb
Faculty of Chemical
Engineering and Technology

FKITMCMXIX

FORM 2

1) Course teacher: Lidija Furač, Senior Lecturer	
2) Name of the course: Stoichiometry I	
3) Study programme (undergraduate, graduate): undergraduate	
4) Status of the course: elective course	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. Students will acquire a quantitative approach to solving chemical problems. 2. Students will be able to interpret the mutual numerical relationships of reactants and products in a chemical reaction. 3. Students will develop mental activity in problem solving 4. Students will develop consistency in solving tasks from start to finish. 5. Students will be able to set up proper chemical equations with appropriate stoichiometric coefficients. 6. Sudents will be able to set appropriate mathematical equations with clearly defined physical quantities and measurement units. 7. Students will develop the ability to perceive and solve complex problems of chemical calculations in several different ways.	**6) Learning outcomes at the level of the study programme:** 1 Knowledge and understanding of essential facts, concepts, principles and theories relating to chemistry and chemical engineering, 2. Ability to recognise and solve qualitative and quantitative problems using the appropriate chemical principles and theories, 3. Competence in the evaluation, interpretation and synthesis of chemical information and dana 4. Capacity to apply knowledge in practice, in particular problem-solving competences, relating to both qualitative and quantitative information, 5. Numerical reasoning, numeracy and calculation skills, including such aspects as error analysis, order-of-magnitude estimations, and correct use of units, -
7) Teaching units with the corresponding learning outcomes and evaluation criteria	

FORM 2

Teaching unit	Learning outcomes	Evaluation criteria
1. Equations and chemical calculus. Dimensional analysis. Significant figures. The general approach to solving complex problems of chemical calculation.	The student will define what is the measurement, which is determined by measuring and how to express the measured data and measurement uncertainty. The student will distinguish the difference between accuracy and precision. The student will define the significant figures and use dimensional analysis in solving problems.	- to define the basic SI units and using them to perform dimensional analysis of all other physical size -to determine the measurement uncertainty - to determine the accuracy and precision - to apply the rules for the determination of significant figures and calculate the measurement results that contain different numbers of significant figures.
2. Atomic mass. Molecular mass. Molar mass. Moles. Inconverting moles, mass and Avogadro's number. Stoichiometry laws. (The law of conservation of mass, The law of equivalent proportions,The law of definite proportion**,** The law of multiple proportions).	The students will define nuclides , isotopes and isobars,the atomic unit of mass, relative atomic and molecular mass, moles, mass and Avogadro's number number**.** The students will applay Stoichiometry laws.	- to identify and distinguish izotpe of isobars - to determine the composition of isotopic mixture and the molecular weight of the mixture - to determine the molecular and molecular weight -to apply knowledge of stoichiometric laws in problem tasks -
3. Quantitative relationships in chemical compounds. The quantitative composition of chemical compounds. The empirical formulas of the chemical compound. The composition of matter.	The student will explain quantitative and qualitative meaning of chemical symbols and formulas. The student will define the concept of database computing. The student will explain scheme of chemical account which must contain the contents of the task , the balance of material and quantitative relations set and the required substances in the problem. The student will choose the way and methodology of	- student will be able interpret qualitative and quantitative formula of a chemical compound - will be able to calculate the unit ratio of the quantitative significance of chemical formula and based on that count amount required with constant control of logical mathematical account (eg . when the unit ratio > or < 1 , the sum of percentages must be 100 %) - to choose the base of calculation - to be able to calculate the

FORM 2

	problem solving The student will define the concept of empirical and molecul formula and different possibilities of calculating The student will define calculations for the percentage composition of compounds.	empirical and molecule formula of the compounds and compositions thereof
4. Chemical reaction and stoichiometric coefficients. Quantitative relationships in chemical reactions. Quantitative relationships of substances and mixtures of components	The student will explain quantitative and qualitative meaning of chemical reaction and connect with stoichiometric laws. The student will define the settings for an accurate representation of the chemical reaction. The student will defined redox rules.	- to balance the chemical reaction including redox reactions - to interpret the stoichiometric coefficients in the equation of a chemical reaction
5: The stoichiometry of the chemical reaction. The limiting reagent (reactant). Excess reactant. Stoichiometric amounts of reactants. Stoichiometric amounts of products.	The student will define the the limited reactant, reactant in excess, stoichiometric amount of reactant andthe product .	- to determine stoichiometric coefficients in chemical reaction, limited reactant and reactant in excess of pure substance.
6. The reactants in the stoichiometric ratio. Yield percent of reaction. Yield percent of the limiting reactant. Yield percent of the excess reactant.	The student will the degree of completion of reaction , the yield of the reaction , the loss of the relevant reactant , the loss of the reactant in excess and loss of product.	-to be able to calculate the relevant reactant , reactant in excess , the degree of completion of reaction , the yield of the reaction , the loss of the relevant reactant , the loss of the reactant in excess of that product losses to the pure substance.
7. Stechiometry of chemical reaction in solid-solid systems.	The student will connect knowledge acquire in previous sessions and apply it to complex systems solid –	- to solve complex example which contain more chemical reactions in a single process for solid-solid systems.

	solid systems.	
8. Test 1		
9. The composition of the solution. Stoichiometry of the chemical reaction in solid – solution system	The student will defined quantitative ways of expressing the composition of the solution The student will connect the knowledge acquire in previous sessions and apply it to complex systems, solid – solution systems.	-to solve complex example which contain more chemical reactions in a single process for solid-solution systems.
10. Stoichiometry of the chemical reaction in solution-solution system.	The student will defined quantitative ways of expressing the composition of the solution The student will connect the knowledge acquire in previous sessions and apply it to complex systems, solution – solution systems.	- to solve complex example which contain more chemical reactions in a single process for solution-solution systems.
11. The law of combining volumes. Avogadro's law. The molar volume of gas. The relation of volume and weight of the chemical reactions. Changing the volume of gases with changing pressure and temperature.	The student will defined molar volume and density of gas and gas mixtures. The student will explain the quantitative relationship between the mass and volume of gases in reactions. The student will explain the quantitative relationships of pressure, temperature and volume of gas in the reaction.	- to be able to calculate the volumes of reactants and products including limited reactant - to be able to calculate te molar mass of gas mixtur - to apply the knowledge of the gas laws in problem tasks
12. Stechiometry of chemical reaction in gas - gas systems and redox reactions.	The student will connect knowledge acquire in previous lectures and apply it to complex systems, gas	-to solve complex example which contain more chemical reactions in a gas - gas systems and redox reactions

FORM 2

	gas and redox reactions.	
13. Stechiometry of chemical reaction in gas-solutions systems.	The student will connect knowledge acquire in previous lectures and apply it to gas-solutions systems.	-to solve complex example which contain more chemical reactions in gas-solutions systems.
14. The stoichiometry of chemical reactions in determining the composition of the mixture. The stoichiometry of chemical reactions applied to very complex systems (gas-solid-solution).	The student will connect knowledge acquire in previous lectures and apply it to very complex systems **(**gas-solid-solution).	-to solve complex example which contain more chemical reactions it to very complex systems **(**gas-solid-solution).
15. Test 2.		

FORM 2

1) Course teacher: Lidija Furač, Senior Lecturer	
2) Name of the course: Stoichiometry II	
3) Study programme (undergraduate, graduate): undergraduate	
4) Status of the course: elective course	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. Students will acquire a quantitative approach to solving chemical problems. 2. Students will be able to interpret the mutual numerical relationships of reactants and products in a chemical reaction. 3. Students will develop mental activity in problem solving 4. Students will develop consistency in solving tasks from start to finish. 5. Students will be able to set up proper chemical equations with appropriate stoichiometric coefficients. 6. Sudents will be able to set appropriate mathematical equations with clearly defined physical quantities and measurement units. 7. Students will develop the ability to perceive and solve complex problems of chemical calculations in several different ways.	**6) Learning outcomes at the level of the study programme:** 1 Knowledge and understanding of essential facts, concepts, principles and theories relating to chemistry and chemical engineering, 2. Ability to recognise and solve qualitative and quantitative problems using the appropriate chemical principles and theories, 3. Competence in the evaluation, interpretation and synthesis of chemical information and dana 4. Capacity to apply knowledge in practice, in particular problem-solving competences, relating to both qualitative and quantitative information, 5. Numerical reasoning, numeracy and calculation skills, including such aspects as error analysis, order-of-magnitude estimations, and correct use of units,

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	Learning outcomes	Evaluation criteria

FORM 2

1. Equations and chemical calculus. Dimensional analysis. Significant figures. The general approach to solving complex problems of chemical calculation.	The student will define what is the measurement, which is determined by measuring and how to express the measured data and measurement uncertainty. The student will distinguish the difference between accuracy and precision. The student will define the significant figures and use dimensional analysis in solving problems.	- to define the basic SI units and using them to perform dimensional analysis of all other physical size -to determine the measurement uncertainty - to determine the accuracy and precision - to apply the rules for the determination of significant figures and calculate the measurement results that contain different numbers of significant figures.
2. Energy changes during chemical reactions and phase transitions.	The students will define the internal energy of chemical systems The student will apply the First law of thermodynamics to chemical reactions. The student will explain the relationship between the internal energy of the reactants and products of chemical reactions with heats of reaction (exothermic , endothermic chemical reactions). The student will define the standard enthalpies and standard enthalpies of reaction . The student will define the reaction enthalpy at constant pressure and explain the meaning of its units of measurement kJ / mol. The student will define and explain the sign of the reaction enthalpy (exothermic, endothermic chemical reactions) The student will explain Hess's law and its applied to thermochemical equation.	- to applay First Law of Thermodynamics to calculate internal energy and heats of reaction and enthalpy change. - to applay Hess's law to thermochemical equation calculate - to calculate the standard enthalpies of formation, standard enthalpies of change for chemical reactions - to apply reaction stoichiometry on heats of reaction - to draw entalphy diagrams - to be able to independently independently solve a very complex thermochemical task

FORM 2

	The student will define the heat capacity of a system.- The student will write scheme of phase transitions in the system of ice - water vapor.	
3. Chemical equilibrium. The law of mass action. The rate of chemical reaction. The chemical equilibrium constant. Le Chatéllierov principle . Chemical equilibrium in the reaction system gas - gas , gas - solid phase , solution - solid phase (hardly soluble salts) .	The student will define the dynamic nature of equilibrium and rate of forward and reverse reaction. The student will define the nature of equilibrium, law of mass action expression for the constant chemical balance. The student will explain the meaning of the numerical value of the equilibrium constant of an equilibrium system The student will define Le Chatéllierov principle and its application to explain the behavior of the chemical equilibrium of the reaction system. The student will predict the dependence of equilibrium chemical reactions on the temperature and the change of the total pressure and partial pressures of reactants and products in the reaction system gas - gas and gas - solid phase. The student will explain and demonstrate mathematical relationship numerical value of the pressure , concentration,mol and other equilibrium constants in the reaction system gas - gas and gas - solid phase , depending on the relation between the total mol of reactants and the total mol products.	- to determing the equilibrium reaction equation and equilibrium constant from experimnetal data -to apply La Chatéllierov principle and stoichiometric laws and set the balance of substances in a state of equilibrium before and after the change of the composition (homogeneous and. heterogeneous mixture) -to calculate equilibrium constant for different systems (gas-gas, gas – solid, solutions- solutions) - to predict the direction of net change - to predict direction of reaction changing the amount of reacting species, external pressures , volume or temperature in gasious equilibria

	The student will apply the stoichiometric laws to define the composition of the reaction system in a equilibrium state. The student will define the equilibrium reaction in the system solution - solid phase and explain the expression for the solubility product of sparingly soluble chemical compounds The student will apply the principle of Le Chatéllierov the chemical balance in the system solution - solid phase	
4. Test 1.		
5., 6.,7., 8.,9.,and 10. Equilibria in electrolyte solutions . The activity of the ion. The ionic strength of the solution . The equilibrium constant . The constant ionization . Ionic product of water , pH concept . Strengths and weaknesses monoprotonske and polyprotic acid . Cationic acid . Equilibria in solutions of salts . Hydrolysis of salts monoprotonskih and polyprotic acids. Buffer solutions .	The student will define and explain the concept of activity and ion activity coefficient, the ionic strength of the solution and explain its importance in the account and measurements in electrolyte solutions. The student will applay the law of chemical equilibrium thermodynamic and define the equilibrium constant in electrolyte solutions The student will define, explain and perform mathematical expression for the ionic product of water at 25^0C., the concept of pH, the relationship between pH, pOH and product ion water The student will apply knowledge of the dependence of the equilibrium constant temperature and explain the numerical value of pH and the neutral aqueous solution as a function of temperature	- to write expression for the equilibrium constant of that equilibrium reaction solution of acids, bases, salts or mixtures - to be able to calculate the pH values of different slutions, degree of ionization of acid or base, degree of hydrolysis, pH value of buffer solutions - to determinte solubility product constant and molar solubility and explain common ion effect in solubility equilibria

	(the pH of a neutral solution of 7 different). The student will define the strengths and weaknesses mono- and polyprotonic acids and bases and explain the difference in their behavior in aqueous solutions. The stident will define the concept of the degree of ionization (dissociation) monoprotonic weak acids and bases The student will apply the degree of ionization as a criterion for the selection of approximative or non approximative account for solutions of weak acids and bases. The student will explain to account the pH very dilute solution of a strong acid or base. The student will define the concept of conjugate acid, or. base and on the basis of previous knowledge to determine their strength, to define cationic acid , to-define the concept of hydrolysis of anions of weak acids and cations of weak bases and derived an expression for the constant hydrolysis. The student will apply knowledge of the hydrolysis and the corresponding chemical equations to explain the pH of aqueous solutions of salts monoprotonic acids and bases, . The student will explain the amphoteric character of the ions produced of polyprotonic acids, will	

FORM 2

	explain the hydrolysis of salts formed by neutralization of polyprotic acids with strong bases. The student will predict acidity or alkalinity of the solution based on the equations of competitive equilibrium reactions in solutions of salts polyprotic acids and numerical values of proper equilibrium constant. The student will define a buffer solution and buffer solution as a mixture of polyprotic acids and their salts. The student will explain the action of the acidic and basic buffer solutions with the addition of a strong acid or base in the buffer solution	
11. Physical properties of the solution . The solubility of solids and gases.	The student will defined solubility of solids and gases in a solvent, indicate the parameters that influence the solubility of solids. The student will demonstrate and apply the Henry's law on the solubility of gases in liquid. The student will determine the change in the quantity of dissolved gas in the mixture of solution. The student will determine the change in pressure of the gas above the solution at constant temperature. The student will be able to specify the parameters that influence on solubility of solids and explain the influence of each parameter	- to determine solubility of solids and gases in a solvent - to apply the Henry's law and ideal gas low in tasks - to determine partial pressures of gases in the mixture and their solubilitay

	on the specified solubility.	
12. Colligative properties of solutions. Osmotic pressure . Raoult's law. Freezing point depression and boiling point elevation. Osmotic pressure of the solution	The student will define the concept of colligative properties of solutions. The student will explain the impact of the activity of the ion and the degree of ionization in solutions of strong and weak electrolytes on colligative properties of the solution. The student will define and explain the diffusion and osmosis, define the osmotic pressure of the solution The student will- perform Vant Hoffov equation for osmotic pressure and explain the analogy with the general gas law The student will demonstrate and explain Raoult's law, freezing point depression and boiling point.	- to applay Vant Hoffov equation , Raoult's law , Dalton's law of partial pressure and expressions of freezing point depression and boiling point elevation to different default , simple and complex tasks in the field of colligative properties of solutions of strong and weak electrolytes .
13. Electrochemistry . Redox balance. Electrode potential . The standard hydrogen electrode. Standard reduction potential . Nernst equation for electrode potential . Galvanic cell. .	The student will define the process of oxidation and reduction reactions in general, cathode and anode reaction,, redox balance and corresponding equilibrium constant. The student will explain the the potential difference at the interface metal / solution of metals ions, the potential difference at the interface : Pt - solution containing reduced and oxidized form of a redox system in ionic form, or redox system in which one component of the gas and the other ion.	- to apply the stoichiometric laws, previously acquired knowledge about redox reactions, the laws of chemical equilibrium in the system of solid - liquid , Nernst's equation for electrode potential and the expression for the electromotive force in a galvanic cell, on the different set of simple and complex tasks in galvanic cell.

	The student will explain the concept of half-cell and the formation of a galvanic cell, explain the processes that take place in the galvanic cell. The student will describe the standard hydrogen electrode (SHE), and define the standard electrode potential of a redox system – The student will define the standard state a redox system (concentration , temperature , pressure) The student will explain the Nernst equation for electrode potential and the Nernst equation for electrode potential hydrogen electrode in non-standard conditions.	
14. Electrolysis. Faraday's laws.	The student will define and explain the process of electrolysis and electrolysis cells. The student will predict electrolysis reactions with inert and active electrodes. The student will explain Faraday's laws of electrolysis and connect Ohm's law and First Farday᾽s law of electrolysis.	-to apply the laws of stoichiometry , Ohm's law , Faraday's laws and knowledge acquired in the previous lesson for the different default simple and complex problems in the field of electrolysis. -
15. Test 2		

FORM 2

FORM 2

1) Course teacher: Prof. Silvana Raić-Malić, PhD	
2) Name of the course: Organic Chemistry I	
3) Study programme (undergraduate, graduate): Undergraduate	
4) Status of the course: Required	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. To analyze the structure of organic compounds and define the nature of chemical bonds in organic molecules based on molecular orbital theory and hybrid atomic orbitals, 2. To define the basic types of organic reactions and explain their reaction mechanisms with the recognition of reactive intermediates in reaction, 3. To identify functional groups in molecules and define corresponding class of compounds, to apply IUPAC rules for naming of organic compounds, 4. To explain conformations of alkanes and cycloalkanes, define and name isomers, 5. To select reactions of alkanes, alkenes, alkynes, alcohols, ethers, 6. To subdivide and compare reactions in which alkyl halides, alkenes, alkynes, alcohols and ethers are involved, 7. To generate synthetic approach in preparation of target compounds.	**6) Learning outcomes at the level of the study programme:** 1. Knowledge and understanding of essential facts, concepts, principles and theories relating to chemistry and chemical engineering, 2. Ability to recognise and solve qualitative and quantitative problems using the appropriate chemical principles and theories, 3. Competence in the evaluation, interpretation and synthesis of chemical information and data, 4. Safe handling of chemical materials, taking into account their physical and chemical properties, including any specific hazards associated with their use, 5. Carry out standard laboratory procedures and use instrumentation involved in synthetic and analytical work, in relation to both organic and inorganic systems.

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Carbon compounds and introduction to structural theory of organic chemistry	- to analyze the structure of organic compounds and define the nature of chemical bonds in organic molecules based on molecular orbital theory and hybrid atomic orbitals, - to define resonance structure, - to describe and relate sp^3-, sp^2- and sp-hybridisation in structure	- to distinguish ionic and covalent bonds of selected compounds, - to indicate bond angle of given compounds, - to define the formal charges and draw the Lewis structure of given compounds, - to draw resonance structure of

FORM 2

	of compounds,	compounds,
2. Introduction to organic reactions: acids and bases	- to define acids and bases, - to identify the strength of acids and bases, - to explain the relationship between structure and function of acid, - to relate heterolytic bond cleavage with corresponding intermediates which are formed in reactions,	- to recognize organic compounds as acids and base, - to apply theory of acids and bases on examples of organic compounds, - to distinguish homolytic and heterolytic bond cleavage and relate them with some examples of compounds,
3. Classes of carbon compounds, functional groups	- to differentiate functional groups in molecules and subdivide compounds according to functional groups, - to apply IUPAC rules for naming of organic compounds,	- to draw structural formula of organic compounds according to name of compound and *vice versa*, - to recognize the physical properties of compounds on the basis of their structure,
4. Alkanes – conformational analysis and introduction to synthesis	- to explain conformations of alkanes and cycloalkanes, define and create a name of isomers, - to describe conformations of alkanes and cycloalkanes, - to define energy changes and stability of alkanes,	- to draw conformations of given alkanes and cycloalkanes, - to define energetic preferable conformers, - to draw conformers using Newman projection formula and sawhorse formula,
5. Stereochemistry and chirality	- to identify and name constitutional isomers and stereoisomers, - to recognize the biological significance of chirality, - to define relative and absolute configuration (CIP system of rules), - to discriminate stereoisomers of cyclic compounds,	- to give examples of constitutional isomers and stereoisomers, - to identify chiral molecules, *meso*-compounds, define absolute configuration of compounds using CIP system of rules, - to draw steroisomers of compounds with one or more stereogenic carbons using Fischer projection formulas,
6. Ionic reactions – nucleophilic substitution reactions of alkyl halide, elimination reactions of alkyl halide	- to distinguish nucleophilic substitution reactions in relation to kinetics, mechanism of reaction and stereochemistry, - to interpret competition of substitution reactions with elimination,	- to draw structures of products formed in given examples for substitution and elimination reactions, - to illustrate by examples factors favoring S_N1 versus S_N2 reactions and E1 versus E2,

FORM 2

7. Alkenes and alkynes: synthesis and properties, the addition reaction	- to explain structure of alkenes and alkynes and list reaction for their synthesis from alkyl halides or alcohols, - to describe a mechanism of addition reaction and explain reactive intermediates formed in reaction, - to explain electrophilic addition reactions in relation to structures of substrate and various reagents,	- to discriminate and compare nucleophilic substitution and elimination reactions, - to illustrate by examples regioselectivity in elimination reactions applying Hoffman's and Zaitsev's rule and Markovnikov's rule in addition reactions, - to draw structural formula of products in reactions of alkyl halides, alcohols and alkenes along with determination of stereochemistry of reactions,
8. Radical reactions	- to define radicals reactions and relative stability of obtained radicals, - to explain multiple substitution reaction versus selectivity, - to describe radical polymerization of alkenes,	- to list an examples of radical reactions along with explanation of mechanisms of these reactions, - to distinguish stability of structurally different radicals, - to illustrate by example stereochemistry of radical reaction, - to write an example of radical polymerization,
9. Alcohols and ethers	- to explain physical properties of alcohols and ethers, - to combine different methods in the synthesis of alcohols from alkenes and carbonyl compounds, - to define reactions for preparation of ethers, - to explain the strategy of application of protecting groups, - to define reactions of alcohols and ethers.	- to illustrate by examples regioselective syntheses of alcohols from alkenes, oxidation-reduction reactions and reactions of organometallic compounds along with a mechanism for these reactions, - to choose appropriate reagents in the syntheses of alcohols and ethers, as well as in their reactions, - to create synthesis using appropriate protecting groups of alcohols, - to choose efficient methods for synthesis of selected ethers.

FORM 2

1) Course teacher: Marica Ivanković; Jelena Macan

2) Name of the course: Physical chemistry I

3) Study programme (undergraduate, graduate): undergraduate, Applied Chemistry

4) Status of the course: mandatory

5) Expected learning outcomes at the level of the course (4-10 learning outcomes):

1. To define fundamental laws of physical chemistry related to gasses, thermodynamics and phase equilibria.
2. To apply mathematics in derivation of the laws
3. To prepare and perform laboratory experiments
4. To analyze and interpret experimental results
5. To write laboratory reports

6) Learning outcomes at the level of the study programme:

1. -To recognise and solve qualitative and quantitative problems using the appropriate chemical principles and theories

2. To perform simple experiments with available laboratory equipments and devices

3. To apply good laboratory safety practice

4. To present research results related to their study subject (orally and in writing)

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Gases	-To describe the gases laws and sketch them in p-V-T diagrams -To derive the ideal gas law using the thermodynamic and the kinetic-molecular approach -To derive the Van der Waals equation of state of real gases -To prepare and perform the laboratory experiment: *Determination of Molecular Mass by Victor-Meyer's*	- To analyze and interpret p-V-T diagrams of ideal and real gases -To calculate the properties of ideal and real gases - To determine the molecular mass of an unknown easy volatile liquid - To explain the mathematical derivation of the equations of state

	Method - To analyze and interpret experimental results and to write laboratory report	
2. Thermodynamics	-To describe 1st, 2nd and 3rd law of thermodynamics as well as Hess's law and Kirchhoff's Law -to distinguish irreversible (spontaneous) and reversible processes -to distinguish and define heat capacities at constant pressure or volume - to distinguish and define state functions (internal energy, enthalpy, entropy , Gibbs energy) -to derive the temperature and pressure dependence of Gibbs energy -To prepare and perform the laboratory experiment: Calorimetry: Determination of the heat of reaction - To analyze and interpret experimental results and to write laboratory report	-to explain the basic terms and principles of classical thermodynamics - to calculate the changes in state functions – - to determine experimentally the heat of reaction - To explain the mathematical derivation of the dependence of Gibbs energy on pressure and temperature
3. phase equilibria	- To describe phase changes, define the phase equilibria; and sketch phase diagrams -To derive Clapeyron's and Clausius Clapeyron's equation, Rauolt's law, Henry's law, Nernst's distribution law and Van't Hoff's law of osmotic pressure -To prepare and perform the laboratory experiments: Cryoscopy, Boiling diagram,	-To analyze and interpret phase diagrams -to apply Clapeyron's and Clausius Clapeyron's equation -- to determine experimentally the freezing point depression - to construct Boiling point diagram from obtained data

	Nernst's distribution law -To analyze and interpret experimental results and to write laboratory report	-To define equilibrium conditions -To explain the mathematical derivations of Clapeyron's and Clausius Clapeyron's equation, Rauolt's law, Henry's law, Nernst's distribution law and Van't Hoff's law of osmotic pressure

FORM 2

1) Course teacher: Associate Prof. Dragana Mutavdžić Pavlović

2) Name of the course: Analytical Chemistry II

3) Study programme (undergraduate, graduate): Undergraduate, 2nd year

4) Status of the course: required

5) Expected learning outcomes at the level of the course (4-10 learning outcomes):	**6) Learning outcomes at the level of the study programme:**
1. Distinguish between systematic and random errors and their impact to analytical result. 2. Apply the principles of gravimetric determination to determination of analytes in real samples. 3. Apply the principles of titrimetric determination to determination of analytes in real samples. 4. Distinguish the primary from secondary standards. 5. Numerical reasoning; set up and numerically solve the analytical problems. 6. Apply the principles of the good laboratory practice.	1. Carry out standard laboratory procedures and use instrumentation involved in analytical work. 2. Capacity to apply knowledge in practice, in particular problem-solving competences, relating to both qualitative and quantitative information. 3. Knowledge and understanding of essential facts, concepts, principles and theories relating to chemistry and chemical reactions. 4. Interpret data derived from laboratory observations and measurements in terms of their significance and relate them to appropriate theory. 5. Numeracy and calculation skills, including such aspects as error analysis, order-of-magnitude estimations, and correct use of units.

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Introductory lecture - introduction to quantitative chemical analysis	- define the analytical process and all its steps, - predict which method for the analysis have to choose and how to develop, - define division of separation techniques,	- distinguish between the individual steps of the analytical process and their importance, - apply previously acquired knowledge on selection methods depending on the

FORM 2

	- define the concept of the real sample	given topics
2. Errors in analytical process	- distinguish between systematic and random errors and their impact on the analytical result, - apply various statistical tests of significance depending on the obtained measurement data, - define the importance of significant figures and their determination	- distinguish the accuracy and precision, - for a given problem to determine which of the tests applied and how to access the data obtained by measuring, - identify significant digits
3. Gravimetric determination	- define and distinguish terms such as deposition, nucleation and crystal growth, - distinguish precipitation from homogeneous medium of classical deposition, - distinguish the characteristics and pollution of crystalline and colloidal precipitate, - apply the principles of gravimetric determination to determination of analytes in real samples	- illustrate and explain the diagrams of nucleation and the relative supersaturation, - set up the appropriate stoichiometric ratio for a given problem, - numerically solve the tasks of gravimetric determination on the basis of the measurement data set
4. Titrimetric determination	- differentiate the primary from secondary standard substances, - distinguish neutralization, redox, complexometric and precipitation titrations and their basic principles, - differentiate the types of indicators and ways of indicating the end point of titration, - define the equivalent unit for each type of titration and distinguish the determination of each of them, - apply the principles of titrimetric determination to determination of	- on the basis of a given analytical problem, conclude between four types of titration which type could be applied and how, - sketch titration curve, - write the corresponding chemical reactions for a given analytical problem, - set up and numerically solve tasks in titrimetry from defined metrics

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	analytes in real samples	
5. Laboratory exercises	- apply the standard laboratory procedures in chemical analysis, - apply the principles of good laboratory practice, - properly collect and process measurement data, - write the appropriate laboratory report	- write a laboratory notebook, - demonstrate independence in work, - determine the analyte amount in the unknown sample using the gravimetric or titrimetric principles of determination and numerically express the results based on the measurements obtained data

FORM 2

1) Course teacher: Ivica Gusić
2) Name of the course: Statistical and Numerical Methods
3) Study programme (undergraduate, graduate): Undergraduate
4) Status of the course: Obligatory

5) Expected learning outcomes at the level of the course (4-10 learning outcomes):	**6) Learning outcomes at the level of the study programme:**
1. Apply principles from descriptive statistics in data analysis 2. Outline basic principles from probability theory 3. Outline and apply basic knowledge about continuous and discrete random variables. 4. Apply principles and techniques of estimations and tests in making decision about population using sample. 5. Apply procedures from programme package Excel.	1. Apply descriptive statistics to analyse results of measurements 2. Apply probability theory to model problems in engineering 3. Apply statistics to make decision in situations from engineering

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1-2. Elements of descriptive statistics	- distinguish between population and sample - recognize and distinguish discrete and continuous statistical data - group and present statistical data - determine various data means and measures of dispersion	-- recognize in given situations the type of statistics data and sample - group given data, determine rang, frequencies and relative frequencies, arithmetic mean, mod, median, quartiles, variance and standard deviation
3. Notion of the probability.	-- recognize elementary events and events - calculate probability in simple situations	- given an experiment, determine elementary events, describe events and calculate probability
4. The conditional probability. The	-recognize and apply conditional probability of an	-apply independence under a suitable circumstances.

independence	event - recognize and apply independence in successive repetition of an experiment	
5. Notion of the random variable (discrete and continuous).	-define random variable and its distribution -distinguish between discrete and continuous random variable -interpret probability as the area under the graph of density function -calculate probability	- determine the distribution of a given random variable - given the density function, determine the function of distribution
6. Expectation and variance	-calculate expectation and variance	-given the density function , calculate the expectation and variance
7. Binomial and Poisson distribution	-define the binomial distribution - recognize the binomial distribution and apply it in modelling engineering problems - define the Poisson distribution - recognize the Poisson distribution and apply it in modelling engineering problems	-recognize in concrete situations the binomial random variable, determine its range and distribution -apply the Poisson distribution in suitable situations
8. Normal distribution	- define the exponential distribution and recognize it in concrete situations -apply the exponential distribution in modelling engineering problems -- define the normal distribution and recognize it in concrete situations -apply the normal distribution in modelling engineering problems - interpret and apply the three-sigma rule	-write down the density function and the distribution function of the exponential variable, and present its graphs -calculate probability of a concrete exponential distribution --write down the density function of the normal distribution and present the graph -apply the normal distribution in given situations
9. Estimation of parameters.	- estimate the arithmetic mean and variance of a population by arithmetic	- given a sample, estimate the arithmetic mean and variance of the population

	mean and variance of a sample	
10. Confidence interval.	- define confidence intervals for expectation and variance. - determine confidence intervals for expectation and variance (by using an appropriate statistical package)	-given a sample, estimate confidence intervals for expectation and variance of the population
11. Basic of hypothesis testing, t-test and F-test	- outline procedures for testing hypothesis - explain the notion of the significance level -apply t-test and F-test (by using an appropriate statistical package)	-test a given hypothesis under various alternative hypothesis and various significance levels
12. Chi-square test	- describe Chi-square test - apply Chi-square test (by using an appropriate statistical package)	-sketch the procedure of Chi-square test for various distributions
13. Least square method. Correlation coefficient	- sketch the problem of adjustment of experimental data to theoretical ones - describe and apply the least square method for linear relationship - calculate the correlation coefficient	-given a statistical data, determine regression coefficients (directly and by using an appropriate statistical package) -given a statistical data, determine and comment the correlation coefficient
14. Interpolation of function (optional content)	- sketch the problem of interpolation of the function and its solution -explain and apply the Lagrange interpolation polynomial -explain and apply the cubic spline	- given the points, determine the corresponding Lagrange polynomial (by using an appropriate statistical package) - given the points determine the corresponding cubic spline (by using an appropriate statistical package)

FORM 2

1) Course teacher: Prof. Irena Škorić, Ph.D.	
2) Name of the course: Organic chemistry II	
3) Study programme (undergraduate, graduate):Applied Chemistry	
4) Status of the course: undergraduate	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. to recognize and use the vocabulary of organic chemistry 2. to draw correct structural representations of organic molecules with functional groups 3. to use the knowledge from stereochemistry while analyzing mechanisms in organic chemistry mechanisms in organic chemistry 4. to write acceptable transformations and mechanism of reactions for aromatic, carbonyl and heterocyclic compounds 5. to compare the reactivity of each of the groups or organic compounds depending on their functional groups and reactions conditions 6. to suggest the most likely reaction pathway for new molecules that were not given as an example through the course 7. to derive the standard preparative procedures that are being used for synthesis of simple organic compounds	**6) Learning outcomes at the level of the study programme:** 1. to use the knowledge in chemistry, chemical technology, especially the ones that are alinked with modern use in the biochemical systems 2. to be able to explain biochemical cycles using the knowledge on the overall strategy of metabolism 3. to estimate the influence of build and biological activity at the level of biomolecules 4. to apply the basic knowledge from applied chemistry in understanding the term of central dogma of molecular biology

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	Learning outcomes	Evaluation criteria
1.Aldehydes and ketones; nucleophilic additions on the carbonyl group	- to use the vocabulary of organic chemistry for carbonyl compounds,	- to evaluate on the reaction path of the electrophilic addition of the given

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	heterocycles and nitrogen compounds; - to draw correct special representations of organic molecules that contain carbonyl and amino groups	heterocyclic compound
2. Carboxylic acids and their derivatives; Amines and like compounds with nitrogen	- to write acceptable transformations in the reactions of nucleophilic addition at the carbonyl group of an aldehyde, ketone, carboxylic acid or their derivative - to compare the reactivity of an amine depending on their structure	-to conclude on the possibility of mutual translations of the derivatives of carboxylic acids from one to another - to recommend synthesis for differently substituted aromatic compounds via diazonium salts from corresponding amines
3. Heterocyclic compounds; Synthetic polymers; Biomolecules	- to propose the most likely reaction pathway in the reaction of electrophilic addition at different heterocycles - to use the knowledge on the types of polymerization at given examples of synthesis of polymers	- to determine the alkalinity of heterocyclic compounds depending on their heteroatom - on the basis of the knowledge gained recommend different modifications of the structure of synthetic polymers in the interest of improvement of their properties

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<table>
<tr><td colspan="3">1) Course teacher: Krešimir Košutić (Full Professor)</td></tr>
<tr><td colspan="3">2) Name of the course: Physical Chemistry II</td></tr>
<tr><td colspan="3">3) Study programme (undergraduate, graduate): The undergraduate study of Applied Chemisty</td></tr>
<tr><td colspan="3">4) Status of the course: mandatory</td></tr>
<tr><td>5) Expected learning outcomes at the level of the course (4-10 learning outcomes):
1. Knowledge of the fundamental laws of physical chemistry, chemical equilibrium, surface phenomena (surface tension and adsorption), electrochemical equilibrium and chemical kinetics
2. Capacity to apply knowledge of mathematics and derive equation (which clearly describe the physical phenomenon under consideration)
3. Ability to prepare and make laboratory experiments
4. Analyze and interpret the results of experiments
5. Prepare laboratory reports</td><td colspan="2">6) Learning outcomes at the level of the study programme:
1. knowledge and understanding of essential facts, concepts, principles and theories relating to chemistry and chemical engineering,
2. ability to recognise and solve qualitative and quantitative problems using the appropriate chemical principles and theories,
3. competence in the evaluation, interpretation and synthesis of chemical information and data,
4. safe handling of chemical materials, taking into account their physical and chemical properties, including any specific hazards associated with their use,
5. carry out standard laboratory procedures and use instrumentation involved in synthetic and analytical work, in relation to both organic and inorganic systems
6. interpret data derived from laboratory observations and measurements in terms of their significance and relate them to appropriate theory
7. skills in planning and time management, and the ability to work autonomously</td></tr>
<tr><td colspan="3">7) Teaching units with the corresponding learning outcomes and evaluation criteria</td></tr>
<tr><td>Teaching unit</td><td>Learning outcomes</td><td>Evaluation criteria</td></tr>
</table>

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1.-2. Chemical equilibrium	- Describe the chemical equilibrium in the conditions of constant pressure and temperature using the Gibbs energy, derive thermodynamic equilibrium constant - Describe the response of equilibria to temperature and pressure - Derive van't Hoff reaction isobars - Describe the homogeneous and heterogeneous chemical equilibria	-Compute equilibrium constant in the examples of homogeneous and heterogeneous equilibrium - Analyze and interpret the Haber Bosch synthesis of ammonia, optimize process parameters of pressure and temperature
3.-4. Surface phenomena: surface tension and adsorption	Describe the phenomena at the interface: solid-gas, solid-liquid and liquid-gas - Define the surface tension and derivem Gibbs adsorption isotherm - Describe and distinguish the surface-active and non-active substances -describe surface films - Define the phenomenon of adsorption and factors affecting the adsorption and adsorption equilibrium, identify the types of adsorption isotherms - Derive Langmuir isotherm - Prepare and make a 2 laboratory experiments: adsorption and surface tension - Calculate and interpret measurement data and write the Freundlich adsorption isotherm and write a lab report	-Explain importance of surfactants and their application in practice - Recognize the importance of experimental conditions determining the adsorption isotherm, - Freundlich isotherm parameters interpret - Demonstrate skill computation and application Frundlichove, Langmurove and B.E.T. isotherms
5.-9. Electrochemistry: the conductivities of electrolyte solution, equilibrium electrochemistry	- Describe conductivity of electrolytes and distinguish strong from weak electrolyte, define 1st and 2nd	- An experimental determine the conductivity of strong and weak electrolytes - An experimental determine

FORM 2

	Kohlraush' law -Derive an Ostwald's law - Define the concept of activity - Explain the Debye-Hückel theory of strong electrolytes Describe the equilibrium of electrode-solution -Derive the thermodynamic expression for the electrode potential -Define the electromotive force Nernst equation Prepare and make a laboratory experiments of electrolyte conductivity, EMF and Hittorf's number, - Calculate measurement data and interpret the results of the experiment, and write a lab reports	electrode potential, electromotive force (EMF) and Hittorf's number - Demonstrate skill calculating molar conductivity, degree of dissociation, activity coefficients, electrode potentials - Explain the relationship between EMS and the Gibbs energy and utility measurements EMS - Recognize the importance of cell production as the most efficient energy converters
10. Diffusion	-Define the concept of diffusion - Derive the first and second Fick's law - Define and describe the diffusion coefficient determination method	- Recognize and understand the significance of diffusion as a physical phenomenon that precedes chemical kinetics
11-15. The chemical kinetics	Define the rates of a chemical reaction, and the factors that affect the rate of chemical reactions - Define the reaction order - Describe the methods for determining the reaction rate constants and reaction order - List reactions to the kinetic mechanism of the elementary and complex - describe the kinetics of reverse,parallel, and consecutive reactions - describe the temperature dependence of reaction rate (Arrhenius equation)	Explain the importance of chemical kinetics, the rate of chemical reactions and impact to the rate of the reaction using catalysts, inhibitors and retardants - Experimentally determine rate constants, reaction order and interpret the influence of temperature on the rate constant - Demonstrate skill computing Understand and interpret the rate-determining step reactions

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	- Describe the theory of transition state (activated complex) - Define the basic concepts of catalytic reaction Prepare and make a laboratory experiments: Decomposition of H_2O_2, Inversion of saharose - Calculate measurement data and interpret the results of the experiment, and write a lab reports	

FORM 2

1) Course teacher: Assoc. prof. dr. sc. Zvjezdana Findrik	
2) Name of the course: Chemical and Biochemical Engineering	
3) Study programme (undergraduate, graduate): undergraduate	
4) Status of the course: obligatory	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. To apply the law of mass conservation on physical, chemical and biochemical processes 2. To define the process space, system borders, input and output process values 3. To distinguish stationary and non-stationary, open and closed processes 4. To develop mass and energy balances of selected examples 5. To sketch block diagrams of simple chemical and related industries 6. To develop mathematical models of processes with chemical and biochemical reactions in different types of reactors 7. To solve both analytically and numerically (simulate) mathematical models of chemical and biochemical reactions in different types of reactor 8. To estimate the values of kinetic parameters of the model on the basis of experimental data by using the package program SCIENTIST	**6) Learning outcomes at the level of the study programme:** 1. to analyze and optimize processes of chemical and related industries 2. to apply the chemical engineering methodology in the process development 3. to competently participate in interdisciplinary team during process development 5. to apply mathematical methods, models and techniques in solving process problems

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Mass balance of physical process	- to apply the mass balance conservation law on physical processes - to define the process space, system borders, and input and output process variables	- sketch the process scheme of the selected process and identify input and output process flows and values - define an base for the calculation

FORM 2

	- to write mass balances of selected examples - to sketch simple process schemes of the chemical and related industries	- apply the mass conservation law and write mass balances for the selected process - solve the resulting system of independent linear equations
2. Mass balance of chemical process	- to apply the mass conservation law on chemical and biochemical processes - to define and explain process space, borders of the system, and input and output values of the process - to write mass balances of the selected examples - to sketch simple process schemes of the processes in chemical and related industries	-sketch the process scheme for the selected process, define input and output process flows and process values - define a base for the calculation - apply the mass conservation law and write mass balances for the selected process - solve the resulting system of indepedent linear equations
3. Energy balance of physical process	- to apply the energy conservation law on physical processes - to define process space, process borders, input and output process values - to define initial and end process conditions - to apply theromodynamic tables for finding parameters for estimate - to write mass and energy balances of selected examples - to sketch simple process schemes of chemical and related industries	- sketch the process scheme for the selected process, define input and output process flows and process values - to determine a base for the calculation - finding the literature data essential for the energy balance estimate - to apply mass and energy conservation law and write ass end energy balances of the selected process - to solve the system of independent linear equations
4. Ideal reactor types	- to define ideal reactor types - to define input and output values in reactor - to write and explain reactor models for ideal reactor types	- write mass balances in different reactor types for the selected examples
5. Kinetics of chemical and biochemical reaction, and microbial kinetics	- to define and explain kinetic models for chemical and biochemical rection	- write a kinetic model for the selected reaction

	- to define and explain microbial kinetics - to estimate kinetic parameters for selected examples	
6. The development of mathematical models for chemical and biochemical process	- to define and explain the mathematical model of the proces - to write the mathematical model of the process for the selected examples - to solve the mathematical model and estimate the values of kinetic parameters	- write a mathematical model of the process for the selected system - solve the system of independent equations – algebraic or differential
7. Experimental methods for reaction rate determination	- to apply the methods for the determination of reaction rate on the selected examples	- calculate reaction rates for the selected examples
8. Aeration and mixing in biological systems	- to define the specialties of mixing and aeration in biological systems	- sketch and describe the transport of oxygen in biological system (cell) - write mathematical expressions that define the diffusion of gas into liquid - identify special demands for mixing in biological systems

FORM 2

1) Course teacher: Assis. Prof. Krunoslav Žižek, PhD
Prof. Aleksandra Sander, PhD

2) Name of the course: Transport Phenomena and Separation Processes

3) Study programme: Undergraduate study programme Applied Chemistry

4) Status of the course: Required

5) Expected learning outcomes at the level of the course (4-10 learning outcomes):

1. Get acquainted with transport phenomena (momentum, heat and mass transfer), conservation laws they involve, and with the effects of flow regime (that is hydrodynamic conditions) on heat and mass transfer.
2. To utilize the equations in a procedure of pipeline design, and for estimation of transport coefficients upon heat and mass transfer phenomena.
3. To define the properties of particulate systems (for both, dysperse phase and dysperse medium), to learn for the ways of showing/displaying and approximating the particle size distribution.
4. To analyze mechanical separation processes and to study mixing technology for liquid-liquid and solid-liquid dysperse systems.
5. To learn about thermal separation processes and to gain basic knowledges for selecting the separation process system.

6) Learning outcomes at the level of the study programme:

1. Acquisition of skills required for setting up of incoming problems and their quantitative analysis, correct usage of units and thermodynamic tables.
2. To be acquainted with interpretation of laboratory observations and measurements, their meaning and correlation with congruent theory.
3. To plan and manage the time.
4. To evolve the aptitude for independent and team work.

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	Learning outcomes	Evaluation criteria
1. Momentum transport	- to define terms necessary for understanding and description of processes with immanent transport phenomena (momentum, heat and mass transfer) - to memorize and to adopt conservation laws regarding fluid flow phenomena - to define the structure and	- distinguish the mechanisms of transport phenomena - define basic equations that are descriptors for processes with occurring transport phenomena - differ Newton and non-Newton fluids - use conservation laws (regarding fluid flow

FORM 2

	birth of hydrodynamic boundary layer - to understand fundamentals of fluid flow phenomena - to describe characteristic cases (processes) regarding momentum transfer and to apply congruent equations	phenomena) for estimation of pump power required for liquid transport in a pipeline with a complex design - define the effect of flow regime (that is hydrodynamic conditions) on the structure of boundary layer
2. Characterization of coarse disperse phase	- to analyze properties of coarse disperse systems - to recognize methods for characterization of coarse disperse phase, and to summarize interpretation and approximation of particle size distribution	- distinguish disperse system, disperse phase and disperse medium - explain the term of particle shape and concept of equivalent spheres (diameters) - sketch graphs for displaying particle size distribution data
3. Mechanical separation processes	- to define efficiency of a separator - to describe sedimentation and filtration separation processes - to identify inlet and outlet variables	- distinguish total and grade efficiency of a separator - explain efficiency of a separator by using characteristic quantities - explain fundamentals of gravitational sedimentation - explain fundamentals of cake filtration
4. Mixing of fluids and suspensions	- to define degree of mixing in homogenous and heterogeneous systems - to define primary variables that determine the mixing conditions	- distinguish hydrodynamic conditions (flow regimes) for mixing of liquid-liquid and solid-liquid disperse systems - explain possible suspension states and suspending regimes
5. Heat and mass transfer	- to define heat and mass transfer mechanisms - to memorize and understand basic equations for description of steady-state and unsteady state heat and	- explain the influence of the hydrodynamic conditions on heat and mass transfer - calculate heat and mass flow rate

FORM 2

	mass transfer processes - to identify mathematical methods for evaluation of heat and mass transfer coefficients	- explain dimensionless numbers used for heat and mass transfer - apply correlations for evaluation of heat and mass transfer coefficients
6. Heat exchangers	- to adopt working principle of heat exchangers - to identify types of heat exchangers	- distinguish cocurrent, countercurrent and crossflow operation of heat exchangers - define the driving force and the correction factor for the complex geometry heat echangers - calculate the heat transfer area - explain and sketch different types of heat exchangers
7. Extraction and distillation	- to memorize basic criteria for selection of the separation process - to define significant properties for selection of the appropriate system - to memorize and understand separation methods -to define the driving force	- select the appropriate separation process for a given system - illustrate phase equilibrium diagrams - use equilibrium data for determination of the dryiving force - determine graphically and numerically the number of transfer units
8. Drying	- to define drying methods, modes of heat transfer and moisture transport mechanisms - to analyze the influence of the process conditions on the drying kinetics - to analyze the drying curve in order to define the transport mechanism and the	- explain drying methods - illustrate drying curves and define critical parameters - define the influences of internal and external conditions on the drying kinetics - explain humidity charts and illustrate the drying process in it

FORM 2

	drying rate	

FORM 2

1) Course teacher: prof. dr. sc. Marko Rogošić	
2) Name of the course: Thermodynamics of Real Systems	
3) Study programme (undergraduate):	
4) Status of the course: Mandatory	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. students shall describe the concepts of chemical engineering thermodynamics as logical extensions of fundamental physical-chemical laws 2. students shall recognize and select necessary literature thermodynamic data as well as theoretical relations for the description of different thermodynamic functions vs. temperature and pressure relationships for real gases, real solutions and mixtures 3. students shall interpret and apply (at the basic level) different forms of phase diagrams, tables and numerical expressions for the description of thermodynamic functions of real gases and solutions 4. students shall create the system of equations necessary for the description of vapour-liquid and liquid-liquid equilibria problems; based on that they shall solve simple systems of equations	**6) Learning outcomes at the level of the study programme:** 1. students shall recognize the role and importance of thermodynamics within the framework of chemical engineering profession 2. students shall apply (at basic level) the knowledge of thermodynamics for solving chemical engineering problems 3. students shall employ the engineering methodology of graphical presentation of a problem as well as of a problem solution 4. students shall apply computers for solving engineering problems

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	Learning outcomes	Evaluation criteria
1. Thermodynamic properties of real gases and solutions	- students shall apply (at basic level) the equations of state for solving *pvT* behaviour problems of real gaseous mixtures	- students answer the questions regarding the theoretical fundamentals of disclosed concepts - students solve nonlinear

	- students shall reproduce the principles of calculation of enthalpy and entropy using equations of state - students shall interpret the terms of partial molar functions, mixing functions, excess functions, activities as well as activity coefficients - students shall recall the principles of constructing modern activity coefficient models as well as their application	equations of state expressing any of the *pvT* unknowns - students use diagrams to present solutions of the equation of states and they recognise their physical significance - students use diagrams to present their own as well as literature experimental data on the thermodynamic properties of real solutions - students employ graphical and/or numerical methods to determine the characteristic thermodynamic functions of real solutions
2. Phase equilibrium / Chemical equilibrium	- students shall create the system of equations necessary for the description of vapour-liquid, liquid-liquid and solid-liquid equilibria problems - students shall solve simple problems related to vapour-liquid, liquid-liquid and solid-liquid equilibria problems - students shall recognize the basic principles of solving chemical equilibrium problems in real systems	- students answer the questions regarding the theoretical fundamentals of disclosed concepts - students solve simple problems related to vapour-liquid, liquid-liquid and solid-liquid equilibria problems

FORM 2

English language (basic course)

COURSE AIM: The acquisition of competencies such as reading, oral and written fluency in English, illustrating usage of expert engineering terminology. Generating new vocabulary by using on line dictionaries on their own to recall pronunciation and meaning. Preparation of presentations for purposes of practicing oral interpretation for future international conferences. Students are also introduced to some customs regarding the cultures of the United States and the United Kingdom.
DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES OF STUDENTS:
General competencies: pronunciation of expert terminology that refers to various types of engineering and technology in English.
Specific competencies: writing a CV and illustrating usage of English grammar. Orally presenting a lab report which was previously filmed and placed in their e-portfolio.
STUDENT OBLIGATIONS: students are obliged to attend classes and solve all the revision tests in their e-class. They are also obliged to enter new vocabulary in the glossary of their e-class individually. They must have their indeks or ID card when writing midterm tests or final written tests.
SIGNATURE CONDITIONS: 80 percent attendance in each semester and taking part in class by engaging in class work. They must have a Euro pass CV and filmed lab experiment in their e-portfolio.
They must have a positive grade on their midterm test 1.
LECTURES METHOD: Lectures, language exercises in class such as reading, comprehension, pair work, group work, individual group work that is to be placed in their e-portfolios, revision of grammar by individually solving the revision tests in the e-class, consultations if need be every week.
MANNER OF ASSESSMENT AND TESTING:
Written midterm tests (60 percent or more on both midterm tests excludes the need for final written and oral exam)
Final written test (60 percent or more for passing grade) and oral exam (oral presentation of lab experiment in their e-portfolio)
QUALITY CONTRUL AND SUCCESS OF COURSE: Anonymous student survey
METHOD PREREQUISITES:
Access to a computer and knowledge of e-class password and e-portfolio password in Moodle and Merlin programs.
i) COURSE LEARNING OUTCOMES:
1 students will generate basic concepts of engineering terminology in English
2 students will demonstrate individual discovering of pronunciation of new vocabulary and the
definition of the newly acquired expert terms
3 students will demonstrate ability to use the e-portfolio for recording personal improvement
4 students will demonstrate recalling grammar by solving the revision tests in their e-class

j) PROGRAM LEARNING OUTCOMES:

1 students will recall expert terminology used in the various fields of engineering

FORM 2

2 students will generate an advanced usage of grammar in the English language
3 students will recall how to write a CV, cover letter and reply to an job ad in the paper
4 students will use the Merlin and Moodle computer programs to do individual or group work
in their e-class and e-portfolio.

FORM 2

English language (advanced course)

COURSE AIM: Acquiring competencies such as reading, oral and written fluency in English in the field of technology. Individual analysis of new vocabulary by using the on line dictionaries to discover the pronunciation and definition. Individual examination of revision tests in the e-class. Preparation for making oral presentations in English. Students also learn about the customs and cultures of the United States and the United Kingdom.
DEVELOPEMENT OF GENERAL AND SPECIFIC COMPETENCIES OF STUDENTS:
General competencies: pronunciation of expert terminology related to the field of technology in English. Understanding of expert terminology and usage both in written and oral form.

Specific competencies: oral presentation of lab report and entering new vocabulary in the glossary of the e-class. Recalling grammar by revision of tests in the e-class. Practising usage and pronunciation of new vocabulary.

STUDENT OBLIGATIONS AND MANNER OF FULFILMENT: Students are expected to attend at least 80 percent of all classes and are obliged to put their CV and group presentation in their e-portfolio. They are also expected to solve all revision tests in the e-class individually. They have to bring their indeks or ID cards during midterm and final tests.
SIGNATURE CONDITIONS: In order to get a signature at the end of each semester they must attend at least 80 percent of all classes and take part in language exercises, orally present their group work of the lab experiment conducted at the University and placed in their e-portfolio.
They must pass midterm tests 1 and 2.
LECTURE METHOD: Lectures and language exercises such as reading out loud, comprehension, pair work, group work and consultations when necessary.
ASSESSMENT METHOD AND EXAMINATION:
Written midterm tests (60 percent or more on both midterm tests excuses the student from having to take the final written and oral tests)
Final written test (at least 60 percent required to pass) and oral exam (presentation of lab experiment filmed as part of group work and put in their e-portfolio)
QUALITY CONTROL AND SUCCESS OF COURSE: Anonymous student survey
METHOD PREREQUISITES:
Access to a computer and demonstration of using the e-portfolio and e-class programs via passwords in the Merlin and Moodle programs intended for students of Zagreb University.

COURSE LEARNING OUTCOMES:
1 students will be able to use the basic terminology in the field of technology in English.
2 students will explain new vocabulary and arrange it in the e-class glossary individually
3 students will use the e-portfolio to record personal development
4 students will examine the revision tests in the e-class and recognise the grammar and be able to use it in both written and oral communication

PROGRAM LEARNING OUTCOMES:
1 students will understand expert terminology used in the contemporary fields of technology

FORM 2

2 students will review and use English grammar at an advanced level
3 students will conclude how to present a lab report both orally and in writing
4 students will demonstrate usage of the e-class and e-portfolio in the Merlin and Moodle programs intended for students of Zagreb University

FORM 2

1) Course teacher: Zoran Mandić, PhD, associated professor Sanja Martinez, PhD, full professor	
2) Name of the course: Electrochemistry	
3) Study programme (undergraduate, graduate): undergraduate	
4) Status of the course: obligatory	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): After learning students will be able to: - apply fundamental knowledge of electrochemistry to solve practical problems. - define the electrochemical phenomena and processes. - connect the electrochemical knowledge and methodology with knowledge of physical, analytical and general chemistry. - track and measure physical quantities in electrochemistry - use the electrochemical equipment	**6) Learning outcomes at the level of the study programme:** After learning students will be able to: - memorize the basic facts, concepts, principles and theories related to electrochemistry fundamentals, - identify and solve qualitative and quantitative electrochemical problems using suitable electrochemical principles and theory - apply knowledge in practice, especially in solving electrochemical problems on the basis of qualitative or quantitative information - monitor, observe and measure electrochemical parameters, record and document them in a systematic manner

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	Learning outcomes	Evaluation criteria
1. Electrochemical equilibrium and electrochemical thermodynamics	After learning students will be able to: - present a clear picture of the basic electrochemical terms and concepts - give physical picture and describe mathematically types of conductivity and charge carriers	After learning students will be able to: - define the basic electrochemical terms and use basic electrochemical terminology - define relevant electrical concepts and use relevant terminology in the field of

	- describe charge transfer in galvanic circuits with particular emphasis on the charge transfer through the metal / electrolyte and semiconductor / electrolyte interfaces - define electrochemical electrode potential, conduct the measurement of potential and describe various types of reference electrodes. - apply Nernst equation, - describe the double layer, its physico-mathematical background, and its significance in various electrochemical applications - give meaning of the electromotive force of a galvanic cell, thermodynamic parameters of a galvanic cell and thermal effects in a galvanic cell	electricity - sketch galvanic circuits and distribution of potential in them - define the conditions of electrochemical equilibrium and conducted the associated calculations using the Nernst equation and table of standard redox potentials - describe and implement a potentiometric measurement - present graphically and mathematically models describing the double layer and electrokinetic phenomena - calculate or determine from the diagrams the zeta potential. - demonstrate basic knowledge of thermodynamic functions and concepts applied to the electrochemical systems and carry out calculations of thermodynamic functions from laboratory measurements
2. Electrochemical kinetics and mass transport in electrochemical reactions	After learning students will be able to: - Understand the principles of electrochemical reactions - Identify all possible elementary steps in electrochemical reaction mechanisms - Recognize the rate determining step in electrochemical reaction - Analyse current-potential	After learning students will be able to: - Compare electrochemical methodology with general methodologies of chemical reactions - Describe electrochemical kinetics - Explain and derive Butler-Volmer equation - Apply Ficks’ laws in the explanation of the course of

	curves and extract useful data - Select appropriate electrochemical system for electrochemical reactions - Predict the course and pathway of electrochemical reaction from the results obtained from electrochemical analytical methods - Apply the principles of electrochemistry in the design and conducting of electrochemical processes	electrochemical reactions - Setup an electrochemical system for the conducting of electrochemical reaction of laboratory scale - Evaluate the application of electrochemistry in the technology and industry.

FORM 2

1) Course teacher: Prof. Marijana Hranjec, PhD, Prof. Ante Jukić, PhD Prof. Silvana Raić-Malić, PhD	
2) Name of the course: Chemistry of Natural and Synthetic Polymers	
3) Study programme (undergraduate, graduate): Undergraduate	
4) Status of the course: Required	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. To define structure of polypeptides and nucleic acids, 2. To explain and distinguish reactions and syntheses of polypeptide, nucleic acids and their building blocks: amino acids and nucleosides, 3. To identify main carbohydrate classes and differentiate structural characteristics of monosaccharides, disaccharides and polysaccharides, 4. To outline specific reactions of some carbohydrates and their application, 5. To define important macromolecules that contains carbohydrate moiety, 6. To apply mechanism of organic reactions and principles of stoichiometry on polymerization reactions 7. To explain mechanisms of polymerization of synthetic polymers 8. To distinguish and assess the most important chemical and structural properties of synthetic polymers.	**6) Learning outcomes at the level of the study programme:** 1. Knowledge and understanding of essential facts, concepts, principles and theories relating to chemistry and chemical engineering, 2. Ability to recognize and solve qualitative and quantitative problems using the appropriate chemical principles and theories, 3. Competence in the evaluation, interpretation and synthesis of chemical information and data, 4. Carry out standard laboratory procedures and use instrumentation involved in synthetic and analytical work, in relation to both organic and inorganic systems.

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Chemistry of natural compounds – proteins and nucleic acids as well as their building blocks	- to define structure of polypeptides and nucleic acids, - to explain and distinguish reactions and syntheses of polypeptide, nucleic acids and their building blocks: amino	- to distinguish primary, secondary, tertiary and quaternary structure of proteins, as well as primary, secondary and tertiary structure of nucleic acids

	acids and nucleosides, - to describe biologically important natural polymers as proteins or polymers that contain nucleotide moiety.	- to compare different methods for determination of primary structure of polypeptides and to apply these methods in determination of primary structure for selected peptides - to draw appropriate synthetic routes to obtain target peptides and amino acids, as well as oligonucleotides, nucleosides and nucleotides along with application of corresponding protecting groups - to describe methods for determination of base sequence of DNA - to define structural characteristics of biologically important polymers and relate their properties with application
2. Classification, structural characteristics and specific reactions of monosaccharides, disaccharides and polysaccharides; the use of carbohydrates. Important macromolecules containing a carbohydrate portion in their structure.	- to define the main groups of carbohydrates - to define the structural characteristics and specific reactions of basic groups of carbohydrates - to become familiar with the use of carbohydrates - to define some groups of macromolecules with carbohydrate portion in its structure	- to know the basic groups of carbohydrates - to distinguish the main groups of carbohydrates based on their structural characteristics - to know some specific reactions of individual groups of carbohydrates - to know some examples of applications of carbohydrates (sweeteners)
3. Chemistry, synthesis and characterization of synthetic polymers.	- to apply mechanisms of organic chemical reactions and stoichiometry rules on polymerization reactions - to identify and explain polymerization mechanisms for synthetic polymers - to recognize and evaluate the main chemical and structural properties of synthetic polymers	- to determine and explain appropriate reaction mechanism, reactants and products for a given polymerization - to express detailed mechanism of polymerization for specific monomers and to define main kinetic and thermodynamic properties of reactions - to derive copolymerization reativity ratios - to calculate number and weight average molecular weights of polymer

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FORM 2

1) Course teacher: Associated professor Danijela Ašperger, Ph.D.

FORM 2

2) Name of the course: **Instrumental analytical chemistry, Applied Chemistry**	
3) Study programme (undergraduate, graduate): undergraduate **(3rd year, 5th semester, univ. bacc. appl. chem.)**	
4) Status of the course: required	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. Correctly interpret the adopted theoretical knowledge related to methods of instrumental analysis and principles of instruments and procedural knowledge and skills related to practical performance measurement. 2. Explain the connection between basic knowledge in the application of instrumental analysis. 3. The ability to work autonomously on the instruments in the laboratory for instrumental analysis and further autonomously study having a positive attitude about the need for the development of professional competencies. 4. Integrate acquired knowledge and apply them in problem solving and decision making in analytical practice.	**6) Learning outcomes at the level of the study programme:** 1. Ability to apply basic knowledge of the natural sciences in practice, especially in solving problems based on qualitative or quantitative information. 2. Numerical reasoning, numeracy and calculation skills, including such aspects as error analysis, order-of-magnitude estimations, and correct use of units. 3. Competence presentation materials related to the case study (oral and written) professional audience. 4. Monitoring, by observation and measurement, of chemical properties, events or changes, and the systematic and reliable recording and documentation there of. 5. Interpret data derived from laboratory observations and measurements in terms of their significance and relate them to appropriate theory. 6. Conduct risk assessments concerning the use of chemical substances and laboratory procedures. 7 Skills in planning and time management, and the ability to work autonomously. 8. Study skills and competences needed for continuing professional development.
7) Teaching units with the corresponding learning outcomes and evaluation	

FORM 2

criteria		
Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Introduction. The basic components of instruments. The development of instrumentation through history. Classification of instrumental methods. Types of analytical signal. Signal-noise ratio. Calibration procedures.	- Recognize the techniques of instrumental analysis, identify and recognize the instrumental methods of classical and argue the need for calibration of methods. - Describe and argue the signal to noise ratio.	- Classify, define and explain basic theoretical knowledge of the instrumental methods in analytical chemistry.
2. Instrumental methods of analysis	- Use theoretical knowledge related to methods of instrumental analysis (spectrometry, electroanalytical, thermochemical, instrumental separation methods) and the working principles of instruments and procedural knowledge and skills related to practical performance measurement. - Combine basic knowledge and new knowledge gained in the course of instrumental methods. - Identify the strengths and limitations of individual methods.	- Select instrumental analytical method for analysis the analyte in sample. - Choose adequate calibration method for given example (analyte, sample, instrumentation). - Describe the principle of instrumental method.
3. Laboratory exercises	- Practice on the instruments (alone or in a small group) according to the curriculum of exercises. - Operate/use programs related to the work of the instrument. - Apply the statistical processing of numerical data and their graphical presentation. - Ability to record experimental data and write reports autonomously.	- Concisely describe the experimental work - aim, methods, and results. - Autonomously interpretation the results in laboratory report.

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FORM 2

<table>
<tr><td colspan="2">1) Course teacher: Prof. Irena Škorić, Ph.D.
Prof. Vesna Volovšek, Ph.D.</td></tr>
<tr><td colspan="2">2) Name of the course: Molecular spectroscopy</td></tr>
<tr><td colspan="2">3) Study programme (undergraduate, graduate): Applied Chemistry (undergraduate)</td></tr>
<tr><td colspan="2">4) Status of the course: obligatory</td></tr>
<tr><td>5) Expected learning outcomes at the level of the course (4-10 learning outcomes):
1. to be able to explain the physical basis of certain molecular spectroscopy's;
2. to know how to choose appropriate spectroscopic method;
3. to be able to extract relevant data from spectra;
4. to know how to correlate obtained data;
5. to combine spectroscopic methods
6. to develop a logical approach to solving with recommendation of an acceptable structure for the given spectroscopic tasks;</td><td>6) Learning outcomes at the level of the study programme:
1. to apply spectroscopic methods in analysis of the given substrate;
2. to use spectroscopic methods in monitoring of an reaction process;
3. to apply the acquired knowledge in research projects;
4. the ability of selection of appropriate spectroscopic methods in monitoring of use of different materials and in a critical data analysis;</td></tr>
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7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	Learning outcomes	Evaluation criteria
1.Physical basis of molecular spectroscopy	- to determine the kind of interaction of electromagnetic radiation and mater for each of the spectroscopic methods - to explain the ways of detecting signals	- to determine the suitable spectroscopic method - to determine the number of suspected spectroscopic bands, their shape, half width and intensity
2. Different spectroscopic methods (IR, UV/VIS, MS, NMR)	-to define the wave region - to recognize the functional groups and chromophores in	-to recognize and interpret spectra of simple molecules; -to determine the structure of the compound on the basis of

FORM 2

	IR and UV/VIS spectra; - to determine the molecular ion and find characteristic fragments in the MS spectra; -to assign the signals in ^{1}H and ^{13}C spectra to appropriate structural units; - to be able to suggest the structure of the compound on the basis of spectral data;	the given spectra

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FORM 2

1) Course teacher: Dr. Tatjana Gazivoda Kraljević, assis. prof.; Dr. Marijana Hranjec, assoc. prof.
2) Name of the course: Biochemistry
3) Study programme (undergraduate, graduate): Undergraduate
4) Status of the course: Basic

5) Expected learning outcomes at the level of the course (4-10 learning outcomes):	**6) Learning outcomes at the level of the study programme:**
1. Explain the biochemical processes and metabolic reactions in various organs and tissues that are important for the understanding of physiological and pathological processes. 2. Explain the conditionality of three-dimensional structure and biological activity on the protein example. 3. Discuss the creation and storage of metabolic energy and the overall strategy of metabolism. 4. Define the basic principles and the importance of the central dogma of molecular biology and the basic concepts related to the formation and structure of nucleic acids in living organisms. 5. Explain the mechanisms of DNA replication, transcription of DNA and translation of RNA.	1. Explain and discuss essential facts, concepts, principles and theories relating to chemistry and chemical engineering. 2. Evaluate, interpret and synthesize chemical information and data. 3. Apply acquired knowledge in practice, in particular problem-solving competences, relating to both qualitative and quantitative information. 4. Present chemical and chemical engineering related material and arguments in writing and orally form to expertly audience. 5. Recognize the need for continuing professional development.

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. The conformation and dynamics. Conditionality of three-dimensional structure and biological activity on the protein example. Myoglobin and	1. Recognize the relationship between the natural and biomedical knowledge 2. Compare the diversity of functions of proteins and	1. Interpret a structure of 20 amino acids. 2. Define the structure of proteins, from primary to quaternary.

hemoglobin. Enzymes. Collagen and elastin.	peptides. 3. Determine the amino acid structure of the protein, peptide bond, conformation, dynamic aspects of the structure and function of proteins. 4. Distinguish proteins with special functions, hemoglobin, a model globular protein and hemoglobin interaction with ligands, and myoglobin. 5. Explain conditionality of the structure and function fibril proteins collagen and elastin 6. Explain the basics of enzyme catalysis, allosteric regulation of enzyme activity, activators and inhibitors, coenzymes and prosthetic groups	3. Apply the knowledge of the structure and function of proteins in the hemoglobin and myoglobin, and fibrillar proteins collagen and elastin, as well as proteins with specific functions. 4. Explain the regulation of metabolic activities of important enzymes, coenzymes and prosthetic groups
2. The creation and storage of metabolic energy. The overall strategy of metabolism.	1. Explain the basic concepts and metabolic properties. 2. Explain the metabolic degradation of glucose - the flow pathway, control and regulation, allosteric regulated enzymes, ATP production, the importance of NADH oxidation. 3. Sketch cycle gluconeogenesis, citric acid cycle, Cori cycle. 4. Explain the cellular bioenergetics, ATP cycle, respiratory chain and oxidative phosphorylation, oxidation cascade coenzyme NADH and $FADH_2$. 5. Write the basic levels of	1. Notice the differences in the levels of certain metabolic cycles. 2. Define the common precursors over the cycle, and the input and output components. 3. Apply knowledge of the overall strategy of metabolism in each cycle.

	fat metabolism: decomposition of triacylglycerols and b-oxidation of fatty acids. 6. Compare the urea cycle, different ways of excretion of nitrogen from the body, alanine and glutamine cycle transfer of nitrogen from various tissues to the liver, oxidative deamination of glutamate, the flow of urea cycle, and the mechanism of toxicity of NH4 + ions in the brain.	
3. The central dogma of molecular biology.	1. Define the basic principles and the importance of the central dogma of molecular biology. 2. Explain the formation of nucleic acids in living organisms. 3. Define the higher structural forms of DNA in prokaryotes and eukaryotes. 4. Explain the mechanisms of DNA replication, transcription of DNA and translation of RNA.	1. Explain the concept and importance of the central dogma of molecular biology by own way. 2. Explain the way in which the nucleic acids are created in living organisms. 3. Explain the way for the formation of higher structural forms of DNA in prokaryotes and eukaryotes. 4. Explain the mechanisms of DNA replication, transcription of DNA and RNA translation. 5. Distinguish the replication of DNA, transcription of DNA and translation of RNA.

FORM 2

1) Course teacher: Prof. Irena Škorić, Ph.D.	
2) Name of the course: Chemical Technology Laboratory	
3) Study programme (undergraduate, graduate):Applied Chemistry, undergraduate	
4) Status of the course: mandatory	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. to be able to explain the basic principles of work of each of the instrumental methods of analysis; 2. to be able to choose an appropriate analytic method for a specific problem 3. to be able to understand advantages, disadvantages and limitations of each method 4. to be able to analyze data obtained at specific instruments	**6) Learning outcomes at the level of the study programme:** 1. to apply specific instrumental technique in the analysis of given substrate; 2. to use the knowledge gained in the production process and quality control; 3. to apply the knowledge gained in research projects; 4. to apply computer skills in data analysis of chemical data and information;

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1.Analytical approach to chemical analysis from preparation of the sample to the interpretation of results - application to the samples from the environment	- obtaining knowledge on the principles of working on instruments for the analysis of the samples from the environment; - determination of inorganic and organic analyt in the samples of water (drinking and waste) by chromatographic methods (HPLC-DAD and IC) and by method of atomic absorption	- differentiate approach to analysis of samples by spectroscopic and chromatographic methods - differentiate the principles of specific methods - the ability of independent choice and application of suitable calibration method and of making an calibration curve - to show independence in

	spectrometry (AAS).	work - numerically express and analyze data based on measurements that were made - to conduct laboratory notebook
2. Introduction to basic principles of work on the GC/MS, UV/VIS spectrophotometer, fluorimeter , HPLC/MS and microwave reactor, especially in the analysis and synthesis of organic compounds	- to get to know the basic principles of work on the system gas chromatograph / mass spectrometer (GC/MS), UV/VIS spectrometer and fluorimeter, HPLC/MS system; - to get to know the application of organic microwave synthesis; - to gain the knowledge to use specific instruments; - to know how to combine all of the techniques in analysis of reaction mixture	- to conclude on the advantages, disadvantages and limitations of work on specific instruments - discuss on the data gained by different techniques - analyze spectra of organic compounds used in different instrumental techniques -judge which of the instrumental methods is more suitable depending on the analysis of the structures
3. Reasearch of chemical systems with electrochemical techniques (cyclic, voltammetry, electrochemical quartz crystal nano-scale, electrochemical impedance spectroscopy, hydrodynamic voltammetry)	- to get to know the basic principles of electrochemical techniques -to interpret the results obtained - to gain the knowledge and skills necessary for the application of the electrochemical techniques in chemical analysis and synthesis	- to show competence in independent work and interpretation of electrochemical results - to link results gained by electrochemical techniques with the mechanism of the corresponding physical-chemical process and reactions - to differ the principles of work with electrochemical techniques
4. Application of ICP-MS	- to get to know the basic principles of work and the possibility of application of	- to differ the principles of work of atom absorption, emission and mass

FORM 2

techniques in the elemental analysis	ICP-MS method in elemental analysis - to get to know the principles of qualitative and quantitative elemental analysis and isotope elemental analysis - to master the basic principles of instrument calibration - to master the basic principles of sample preparation for analysis - to recognize possible interference in elemental analysis	spectrometer -to explain the principles of work by ICP-MS methods -to differ spectrometers of low and high resolution - to explain principles of removing interference by the principle of dynamic reaction chamber - to show the ability of sample preparation for the anaylsis and calculation and interpretation of the results gained.

University of Zagreb
Faculty of Chemical
Engineering and Technology

FKITMCMXIX

FORM 2

1) Course teacher: Marijana Kraljić-Roković, PhD, assistant professor; Sanja Martinez, PhD, full professor

2) Name of the course: Electrochemical and Corrosion Engineering

3) Study programme (undergraduate, graduate): Applied Chemistry, undergraduate

4) Status of the course: obligatory

5) Expected learning outcomes at the level of the course (4-10 learning outcomes):

- apply fundamental knowledge of electrochemistry and chemical engineering to the development of electrochemical reactors
- envision problems that may arise during the conduction of electrochemical processes
- compute the optimal process parameters for various examples
- memorize basic electrochemical processes which are encountered in practice
- apply fundamentals of electrochemistry to solve practical problems of corrosion.
- define the descriptively and mathematically corrosion phenomena and processes.
- conduct and interpret basic corrosion measurements.
- demonstrate use of the electrochemical equipment.

6) Learning outcomes at the level of the study programme:

- memorize the basic facts, concepts, principles and theories related to electrochemical engineering fundamentals,
- identify and solve qualitative and quantitative problems using suitable electrochemical principles and theory
- apply knowledge in practice, especially in solving electrochemical problems on the basis of qualitative or quantitative information
- monitoring, observe and measure electrochemical parameters, record and document them in a systematic manner

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Fundamental concepts of electrochemical engineering	-define energy transformation in electrochemical cell - define equilibrium cell potential and cell voltage	-classify electrochemical cell according to the nature of energy transformation -illustrate voltage components in

	-define technological indicators important for electrochemical production -memorise modes of mass transport in electrochemical systems -describe hydrodynamic boundary layer and Nernst diffusion layer - predict heat generation in electrochemical reactor	electrochemical cell -calculate cell voltage -list and define technological indicators important for electrochemical production -calculate the mass of a substance produced during an electrolysis process -describe three modes of mass transport in electrochemical systems -sketch formation of hydrodynamic boundary layer and Nernst diffusion layer -calculate heat generation in electrochemical cell
2. Current and potential distribution	-identify reasons of non-uniform current and potential distribution -explain influence of non-uniform current and potential distribution on efficiency and energy consumption	-define current and potential distribution -describe reasons of non-uniform current and potential distribution -match current and potential distribution with process efficiency and energy consumption -sketch electrochemical reactors with uniform and non-uniform current and potential distribution

FORM 2

3. Electrochemical cell design	-memorise main parts of electrochemical cell -describe different electrode configuration -memorize and compare the main types of electrochemical reactors	-describe main parts of electrochemical cell -select type of electrochemical reactors for specific process
4. Most important industrial electrochemical processes	-memorise the most important industrial electrochemical processes -describe the most important industrial electrochemical processes	-list the most important industrial electrochemical processes -describe the most important industrial electrochemical processes
5. Introduction to corrosion and corrosion engineering	- explain the cause of electrochemical corrosion - describe equilibrium and non-equilibrium state of a corrosion system - demonstrate the method of corrosion potential measurement - explain the operation of corrosion cell, current flow in the cell and basic corrosion reactions	- sketching energy levels of participants of the corrosion process and explaining the cause of corrosion - setting up the equipment and measuring of the corrosion potential - sketching the corrosion cell, denoting of the direction of current flow - writing of the most common corrosion reactions - calculating the electromotive force of the corrosion cell for selected pairs of corrosion reactions
6. Kinetics of corrosion process	- explain the meaning of corrosion rate - explain the principles of measurement techniques to determine the corrosion rate	- calculate and express the rate of corrosion in different units of measurement - describe and apply the process of corrosion rate

FORM 2

	- apply the knowledge gained from the analysis of electrochemical corrosion measurements	measurement by different techniques - memorize the Wagner-Traud equation and explain the meaning of its parameters - graphically represent and analyse polarization measurements and calculate relevant parameters
7. Thermodynamics of corrosion process	- apply the Pourbaix diagram - explain the theory of mixed potential - measure the corrosion potential	- construct and apply the Pourbaixovog diagrams - derive the connection between the Butler-Volmer and Wagner-Traud equations - sketch polarization curves in different coordinate systems - sketch and analyse the Evans diagrams
8. Localized corrosion	- explain the difference between the uniform and localized corrosion - explain the mechanisms of different types of localized corrosion -recognize the appearance of various types of corrosion	- graphically and trough chemical equations, describe the mechanisms of various forms of corrosion - recognize various type of corrosion from photographs
9. Corrosion protection techniques	- describe the phenomenon of passivity and explain the mechanism of growth and breakdown of the passive layer - give examples of use of particular types of corrosion resistant alloys - explain the functioning of	- state causes of passivity and passivity breakdown - give some examples of technologically significant passivating metals and alloys - recognize anodic polarization curves obtained under various conditions - sketch cathodic/anodic

	electrochemical protection techniques, of corrosion inhibitors, inorganic and organic protective coatings - perform laboratory measurements related to corrosion protection techniques	protection system and denote the electrochemical reactions, direction of current flow and polarity of electrodes - graphically represent current and potential distributions in the cathodic protection system of a pipeline - specify the parameters and criteria of cathodic /anodic protection - define corrosion inhibitors and write down the expression inhibitor efficiency - explain simple and complex mechanisms of inhibitor action - explain the mechanisms of action of inorganic coatings - sketch mechanism of protection by zinc and chromium coatings on steel - enumerate basic components of organic coatings and basic types of coatings - name properties of the organic coating system relevant for corrosion protection - apply measuring instruments for coating inspection and assess the efficiency of protection

FORM 2

1) Course teacher: Silvana Raić-Malić, Šime Ukić

2) Name of the course: Introduction to Environmental Chemistry

3) Study programme (undergraduate, graduate): undergraduate study – Applied Chemistry

4) Status of the course: optional

5) Expected learning outcomes at the level of the course (4-10 learning outcomes):	**6) Learning outcomes at the level of the study programme:**
1. To classify organic species from environment according to their chemical structure. 2. To define organic pollutants of water, air, and soil and to explain biodegradation of organic substances. 3. To define "green" organic chemistry and to explain its application in basic organic reactions. 4. To define approach to environmental chemical analysis. 5. To identify environmental sample (water, soil, air) and to select appropriate analysis method according to examined pollutant. 6. To differentiate approaches when traces of environmental pollutants should be analysed from macro-constituent analysis. 7. To prepare and show (in oral and written form) presentation of a topic related to the course.	1. To demonstrate knowledge and understanding of basic facts, principles and theories related to chemistry and chemical reactions. 2. To apply previously accepted knowledge of environmental chemical analysis, especially in problem solving based on quantitative information. 3. To interpret observations and measurements, and connect them with relevant theory. 4. To assess chance of risk incurring related to application of specific chemicals. 5. To manage and plan the time.

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Organic pollutants of water, air, and soil.	- To classify organic species from environment according to their chemical structure. - To define organic pollutants of water, air, and soil and to explain biodegradation of	- To name organic compounds and analyse their influence on environment. - To differentiate chemical, photochemical and

	organic substances.	biodegradation of organic material - To explain scheme of humification.
2. „Green“ organic chemistry	- To define “green” organic chemistry and to explain its application in basic organic reactions.	- To illustrate through examples the application of catalysis, biocatalysis, and photocatalytic reactions. - To list the examples of alternative reaction media and conditions. - To illustrate through examples “green” approaches in preparing of products in laboratory and industry.
3. Approach to chemical analysis of environmental samples	- To define analytical process according to previous knowledge. - To differentiate application of classical and instrumental methods in chemical analysis of environmental samples. - To differentiate sampling methods depending on type of medium.	- To recognize the importance of each step of analytical process. - To recognize the basic principle of certain methods of analysis.
4. Samples from environment (water, soil, air)	- To define water quality indicators. - To explain water pollution by heavy metals and other inorganic compounds. - To explain reactions of metals with organic compounds. - To explain mechanisms of mobility and bounding for soil pollutants. - To list indicators of air pollution. - To define reactions of atmospheric ozone.	- To differentiate approaches for chemical analysis of soil, water, and air. - To demonstrate ability of approaching independently to chemical analysis of environmental samples. - To use measured parameters for numerically solving of the problems.
5. Laboratory practice	- To apply microwaves in product synthesis – green approach *versus* classical one. - To apply obtained knowledge	- To analyse synthesis of aspirin by using microwaves and the classical approach. - To analyse certain

	about the environmental chemical analysis approach. - To apply principles of good laboratory practice. - To collect measured data correctly and elaborate it. - To write adequate laboratory report.	environmental sample by applying obtained knowledge. - To express numerically and elaborate the results from the performed measurements. - To show independency in laboratory work. - To write a personal laboratory diary.

FORM 2

1) Course teacher: Lidija Furač, Felicita Briški, Tomislav Bolanča	
2) Name of the course: Chemistry in environment protection	
3) Study programme (undergraduate, graduate): undergraduate study – Applied Chemistry	
4) Status of the course: obligatory	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. To define chemical and microbiological pollutants in environment. 2. To apply analysis methods for determination of pollutants in environment. 3. To apply methods of waste treatment in environment protection. 4. To define aspects of sustainable development related to environment protection. 5. To apply principles of chemical analysis quality system and environmental system management.	**6) Learning outcomes at the level of the study programme:** 1. To demonstrate competence in recognizing and solving qualitative and quantitative problems by applying appropriate chemical principles and theories. 2. To demonstrate competence in evaluation and interpretation of chemical data and information. 3. To apply tracking and monitoring of chemical parameters and properties and their systematic documentation. 4. To interpret laboratory observations and obtained measurements. 5. To assess risk of using chemical reagents and performing chemical procedures.

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	**Learning outcomes**	**Evaluation criteria**
5. Chemical pollutants of environment	- To define chemical and microbiological pollutants in environment. - To apply analysis methods for determination of pollutants in	- To define and explain chemical pollutants in water. - To explain influence of heavy metals (mercury, zinc, cadmium, nickel, lead, manganese, iron,

	environment. - To define aspects of sustainable development related to environment protection.	arsenic and selenium). - To define and explain chemical pollutants in air. - To explain formation of photo-chemical smog, acidification of environment, ozone holes, and global warming. - To explain influence of chemical pollutants in soil. - To explain mechanisms of dissolution of sulphide, hydroxide, carbonate and silicate materials and mobility of pollutants through soil to the underground waters. - To define and explain basic methods of chemical treatment of wastewater and emissions of hazard gasses.
6. Microbiological pollutants of environment	- To define chemical and microbiological pollutants in environment. - To apply analysis methods for determination of pollutants in environment. - To define aspects of sustainable development related to environment protection.	- To define eco-systems and physical environment. - To define microbiological pollutants in water, air and soil and to explain their influence on eco-system. - To demonstrate knowledge of environmental legislations and to define principles of environment protection.

FORM 2

		- To demonstrate knowledge of principles of deposing hazard waste and the related legislative. - To explain carbon, sulphurs, nitrogen and phosphorus cycles in nature considering both: aerobic and anaerobic processes. - To define and explain basic methods of biological treatment of wastewater.
7. Analysis of pollutants in environment	- To define chemical and microbiological pollutants in environment. - To apply analysis methods for determination of pollutants in environment. - To define aspects of sustainable development related to environment protection.	- To relate principles of chemical reactions and equilibrium with methodology of water analysis. - To apply analytical methods for defining acid-base and ion-exchange properties of soil. - To apply analytical methods for analysis of greenhouse gasses. - To apply analytical methods in processes of industrial ecology and green chemistry. - To define significant aspects of quality control system.

FORM 2

1) Course teacher: Prof. dr. sc. Stanislav Kurajica and prof. dr. sc. Sanja Lučić Blagojević

2) Name of the course: Introduction to nanotechnology

3) Study programme (undergraduate, graduate): Applied Chemistry (undergraduate)

4) Status of the course: Electional

5) Expected learning outcomes at the level of the course (4-10 learning outcomes):	**6) Learning outcomes at the level of the study programme:**
1. The ability to explain certain properties of materials and to understand the reasons for change of properties occurring on nano-scale. 2. The understanding of ideas, concepts and techniques in the field of nanotechnology and the ability of their critical judgment. 3. Distinguishing of top-down and bottom-up methods of nanofabrication, the understanding of these methods and being able to perceive their advantages and disadvantages. 4. The ability to analyze the purpose and to apply knowledge of materials science and engineering in nanotechnology 5. To explain connection between structure and properties of nano-objects and integrated nano-systems. 6. To describe different methods of characterization on nano-scale and to know principles of these methods and perceive their advantages and idsadvantages. 7. To perceive momentary limitations in the development of nanomaterials and ethical doubts appearing in the field of nanotechnology. 8. To demonstrate communication skills, ability of critical thinking and cognition of the need for further learning.	1. Competence in the evaluation, interpretation and synthesis of chemical information and data. 2. Competence in presenting chemical and chemical engineering related material and arguments in writing and orally, to an informed audience. 3. Capacity to apply knowledge in practice, in particular problem-solving competences, relating to both qualitative and quantitative information. 4. Carry out standard laboratory procedures and use instrumentation involved in synthetic and analytical work, in relation to both organic and inorganic systems. 5. Monitoring, by observation and measurement, of chemical properties, events or changes, and the systematic and reliable recording and documentation thereof. 6. Interpret data derived from laboratory observations and measurements in terms of their significance and relate them to appropriate theory. 7. Conduct risk assessments concerning the use of chemical substances and laboratory procedures. 8. Study skills and competences needed for continuing professional development.

7) Teaching units with the corresponding learning outcomes and evaluation

FORM 2

criteria		
Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. The properties and characterization of nanomaterials	- Knowing of terms in the field of nanoscience and nanotechnology. - The understanding of the properties of materials (especially physical, mechanical, chemical, optical, electrical and magnetic) and causes for the change of properties on nano-scale. - Knowing of the principles of typical methods for the characterization of nanomaterials (especially transmission and scanning electron microscope as well as scanning tunneling microscope and atomic force microscope. - The combination of knowledge on structure and properties on nano-scale with the aim of perceiving of application potential of nanomaterials and nanoproducts.	- The listing of typical characteristics of nanotechnology. - Explaining terms typical for nanomaterials and nanotechnologies - Explaining terms connected to various properties of materials and connection between structure and properties of materials. - Explaining reasons for changing of certain properties on nano-scale - Describing operating principles of typical methods of nanomaterials characterization. - The listing of constrains, advantages and disanvantages of certain methods. - Describing preparation of samples for certain methods of characterization.
2. Nanofabrication, manufacturing, trends and applications of nanomaterials	- The differentiation between top-down and bottom-up methods of nanofabrication. - Understanding of principles of these methods, controlling factors and limitations (especially lithography, dip-pen nanolithography, crystallization, sol-gel method, chemical vapor deposition, self-assembly and nanomanipulation. - Understanding of ideas, concepts, techniques and trends in the field of	- List the methods of manufacturing - List and explain classification of nanomanufacturing methods - List most important nanomanufacturing methods from each category. - Describe the most important methods, advantages, disadvantages, limitations, controlling factors. - List some nanoproducts already at the market. - List main areas of investigation in

FORM 2

	nanotechnology (especially in electronics, medicine, materials engineering and environmental protection) and the ability of their critical judgment. - Perceiving of ethical doubts appearing in the field of nanotechnology and the ability to discuss on them.	nanotechnology, aims of these investigation, assumtions they are based on and the purpose of aimed nanoproducts. - List some of the potential risks associated with nanotechnology.
3. Nanoobjekti	- Recognition of the role of materials science and engineering in synthesis of nanoobjects. - Connection between structure and properties of nanoobjects. - Understanding of principles of chemical and physical modifications of nanoobjects surfaces.	- Describe synthesis processes of certain nanoobjects. - Explain connection between structure and properties of nanoobjects and specificities in relation to bulk materials. - Explain and analyse the manners of sertain nanoobjects modification.
4. Selected nanotechnologies (nanobiotechnology, nanoelectronics, polymer nanocomposites)	- The recognition of scientific and technological acheivements realised in the area of nanotechnology. - The insight in realized and potential acheivements in certain areas of nanotechnology. - The analysis of the purpose of nanoobjects for certain applications in integrated systems.	- Explain the purpose and define contribution of certain areas of nanotechnology and give examples from literature. - Describe examples in certain areas of nanotechnology. - Explain the purpose of nanoobjects and other components of integrated systems.

FORM 2

1) Course teacher: Hrvoje Ivanković	
2) Name of the course: Structure and properties of materials	
3) Study programme (undergraduate, graduate): undergraduate and graduate	
4) Status of the course: free elective	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. An ability to apply fundamental science and engineering principles relevant to structure and properties of materials. 2. An ability to understand 3D form and nature of minerals and amorphous materials. 3. Be able to calculate parameters relevant for structure, physical properties and chemical stability of materials. 4. An ability to use the techniques, skills, and modern engineering tools necessary for precious description the structure and properties of materials.	**6) Learning outcomes at the level of the study programme:** 1. Be able to apply general math, science and engineering skills to understand the relationship between structure and properties of materials. 2. Be able to design and conduct experiments, and to analyze data. 3. Be able to organize and rationaly use time. 4. Be able to analyze and present (in written, spoken and graphical form) research results applying suitable computer.

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	Learning outcomes	Evaluation criteria
1.Introduction to Crystallography	-To describe the connection among composition, structure, properties and processing of materials. -To describe crystal and amorphous state -To describe 3D periodic building of crystals -Using models be able to recognise crystal systems, 14	- To analyze and interpret connection between structure and properties of materials. -On the models, to show skills in observing 3D periodic building of crystals. - To understand and describe the relationship between external and internal shape of minerals.

	Bravais crystal lattices and symmetry elements - To calculate and interpret crystal planes, Millers indices, interplanar spacing, d.	
2. X-ray crystallography	-To describe the nature of X-ray and its forming -To describe X-ray diffraction from crystal lattice -To distinguish Laue and Bragg approach to x-ray diffraction on crystal lattice. - To describe and define reciprocal lattice and Ewalds sphere. -To prepare and perform the laboratory experiment of x-ray diffraction on unknown powder sample and analyse obtained results	-To explain behaviour of x-ray on crystal lattice -To explain and mathematically describe Braggs approach to x-ray diffraction on crystal lattice. - To apply experimentally x-ray diffraction on polycrystalline materials -To calculate crystallographic parameters from experimental data.
3. Introduction to crystal chemistry	-To describe and distinguish different crystal structures (compact packaging, coordination polyhedra, metallic, ionic and covalent structures). -To describe and draw some typical structures -To define and describe defects in crystal and thermodynamics of defects forming. - To define and distinguish	- To analyze and interpret simple crystal structures -To explain and thermodynamically interpret defects forming in crystal structures. -To calculate equilibrium concentration of defects at assigned temperature. -To calculate and analyze from experimental data some

4.Materials properties and method of characterisations	properties of materials (mechanical, thermal, optical and electromagnetically). -To describe and apply methods of characterisation (thermal and microscopic). - To prepare and perform laboratory testing and write the reports – To define thermodynamic parameters and to describe equilibrium in one- and two-component systems.	mechanical and thermal characteristics of material. -To know choose the right testing method. -To analyze and interpret one- and two-component phase diagram. -To calculate phase composition from phase diagram.

FORM 2

1) Course teacher: Dr. Marijana Hranjec, associate professor
2) Name of the course: Planning of Organic Synthesis
3) Study programme (undergraduate, graduate): Undergraduate
4) Status of the course: Optional

5) Expected learning outcomes at the level of the course (4-10 learning outcomes):	**6) Learning outcomes at the level of the study programme:**
1. Define the basic principles and problems associated with simple and multistep organic synthesis. 2. Understand and present retrosynthetically analysis of targeted organic molecules. 3. Identify and present possible synthetic pathways of target molecules. 4. Select and identify the most appropriate synthetic route to the synthesis of target molecules according to the available starting chemicals. 5. Critical thinking when choosing a particular synthetic pathway with respect to existing laboratory conditions for the synthesis of target molecules. 6. Synthesize selected target molecules.	1. To recognise and solve qualitative and quantitative problems using the appropriate chemical principles and theories 2. To evaluate, interpretate and synthesize chemical information and data . 3. To present chemical and chemical engineering related material and arguments in writing and orally, to an informed audience. 4. To engage in interdisciplinary team-working . 5. To carry out standard laboratory procedures and use instrumentation involved in synthetic and analytical work, in relation to both organic and inorganic systems . 6. To conduct risk assessments concerning the use of chemical substances and laboratory procedures.

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Planning of organic synthesis: a synthetic plan, strategy and retrosynthesis	- define the basic principles and the importance of planningof organic synthesis - become familiar with the concepts of synthetic plan and strategy of organic synthesis - define the	- understand the importance of planning organic synthesis in the synthesis of new molecular targets - implement strategy and synthetic plan in the planning of synthesis of target molecules - apply rethrosynthesis in the synthesis of target molecules

FORM 2

	rethrosynthesis - explain the concept of synthons and their importance in organic synthesis	- use adequate synthons while proposing synthetic pathways for target molecule
2. Chemoselectivity; Regioselectivity; Stereoselectivity	- define chemoselectivity and its role in organic synthesis - define regioselectivity and its role in organic synthesis - define stereoselectivity and its role in organic synthesis - explain individual roles of mentioned selectivity in the synthesis of target molecules	- understand the terms of chemoselectivity, regioselectivity and stereoselectivity - to notice the difference between the above mentioned selectivities - understand the role of the aforementioned selectivities, and their use in the synthesis of target molecules - apply mentioned selectivities in the synthesis of target molecules
3. Creating a new C-C and C = C bonds which lead to the new molecular structure	- define the basic methods for synthesis of C-C bond - define the basic methods for synthesis of C = C bond - assume the most appropriate synthetic pathways with regard to the desired increase in molecular structure - explain the difference between the individual synthetic manner in the given examples of target molecules synthesis	- know the common ways for synthesis of C-C bond - know the common ways for synthesis of C=C bond - know how to critical choose the most convenient method for synthesis of C-C or C = C bond considering the desired increase in molecular structure - apply the aforementioned synthetic methods for the synthesis of target molecules
4. Asymmetric synthesis and catalysis in the formation of C-C, C-H, CN and CO bonds	- define the concept of asymmetric synthesis and asymmetric catalysis - to be familiar with the ways of asymmetric synthesis for formation of C-C and C-H bond - to be familiar with the ways of asymmetric synthesis for formation of CN and CO bond (C-heteroatom bonds)	- understood the asymmetric synthesis and catalysis and their use in organic synthesis - to know the ways of asymmetric synthesis for formation of C-C and C-H bond - to know the ways of asymmetric synthesis for formation of CN and CO bond (C-heteroatom bonds) - apply the mentioned methods

FORM 2

	- assume the most convenient synthetic routes for the formation of appropriate linkages	of asymmetric synthesis in the planning of synthesis of target molecules
5. The strategy of functional groups, and the synthesis of azole heterocycles having two or more heteroatoms	- define the most important functional groups for planning organic synthesis - define the role of the functional groups in organic synthesis - to be familiar with the ways of synthesis for azole and nitrogen heterocycles - to be familiar with the methods of synthesis for heterocycles with two or more heteroatoms	- know the most important functional groups, especially for the synthesis of heterocycles - understand the ways for azole and nitrogen heterocycles synthesis - understand the ways for synthesis of heterocycles with two or more heteroatoms - apply the mentioned methods of heterocycles synthesis in the planning of target molecules synthesis

FORM 2

1) Course teacher: Tatjana Gazivoda Kraljević, assistant professor	
2) Name of the course: Heterocyclic Chemistry	
3) Study programme (undergraduate, graduate): undergraduate	
4) Status of the course: Optional	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. Recognize and be able to designate certain heterocyclic compounds 2. Understand the impact of heteroatoms in the ring structures 3. Think critically and discuss aromaticity in heteroaromatic compounds 4. Propose synthetic route of target heterocyclic structure 5. Explain the factors that influence on the reactivity of functional groups in ring structures	**6) Learning outcomes at the level of the study programme:** 1. Explain and discuss essential facts, concepts, principles and theories relating to chemistry and chemical engineering. 2. Evaluate, interpret and synthesize chemical information and data. 3. Apply knowledge in practice, in particular problem-solving competences, relating to both qualitative and quantitative information. 4. Present chemical and chemical engineering related material and arguments in writing and orally form to expertly audience. 5. Recognize the need for continuing professional development.

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	Learning outcomes	Evaluation criteria

FORM 2

1.Introduction to structure , properties and reactivity of heterocyclic compounds. Classification and Hantzsch-Widman nomenclature of monocyclic and bicyclic compounds, macrocyclic polyethers and annulenes	- distinguish main classes of heterocyclic compounds - determine aromatic and nonaromatic compounds - connect and use the terms of heterocyclic chemistry. - apply the Hantzsch-Widman rules for naming heterocyclic compounds depending of the size of the heterocyclic compound and the number of heteroatoms	- analyze the structure of heterocyclic compounds, aromaticity and reactivity - designate the different classes of organic compounds and reproduce their structures - explain how factors affect the reactivity of functional groups in the heterocyclic structures
2. Heterocyclic compounds according to the size of the ring and the number of heteroatoms (oxirane, thiirane, aziridine, oxetane, thietane, azetidine, furan, thiophene, pyrrole, benzofuran, benzothiophene, indole, azoles, benzoazoles, pyridine, pyridinones, aminopyridines, alkylpyridines, pyridine N-oxides, pyrazine; aziridine, azepine, azocine, triazoles, thiazoles, benzopyridines , pyran, pyrilium salts, pyrones, coumarins, flavonoids,chromones, macrocycles): structures, properties, reactivity, reaction and synthesis	-apply the Hantz-Widman rules for naming heterocyclic compounds -define and explain the basic types of heterocycles reactions and their mechanisms -explain the influence of heteroatoms in the heterocyclic structures - present given topic in oral form independently or in a team - prepare, isolate, purify and identify some representatives of heterocyclic compounds	- apply the Hantz-Widman nomenclature - analyse and apply the chemical transformations and mechanisms for heterocyclic compounds - plan a synthetic route to a given heterocyclic system - present the results of work in oral and written form in a clear and understandable way

FORM 2

1) Course teacher: Full Prof. Ante Jukić, PhD., Assoc. Prof. Elvira Vidović, PhD	
2) Name of the course: Petrochemistry	
3) Study programme (undergraduate, graduate): undergraduate	
4) Status of the course: elected	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. to memorize the knowledge on pathways for the feedstocks (petroleum, natural gas) conversion in a range of products (syngas, fuels, monomers, polymers, solvents). 2. to relate the previous knowledge (organic, physical chemistry) and others (thermodynamics, transport phenomena) with the processes of hydrocarbons conversion by parameters selection. 3. to recognize the basic technological settlements in petrochemical industry 4. to outline the simple scheme of main processes in petrochemical industry.	**6) Learning outcomes at the level of the study programme:** 1. knowledge and understanding of essential facts, concepts, principles and theories relating to chemistry and chemical engineering 2. competence in the evaluation, interpretation and synthesis of chemical information and data 3. carry out standard laboratory procedures and use instrumentation involved in synthetic and analytical work, in relation to both organic and inorganic systems 4. safe handling of chemical materials, taking into account their physical and chemical properties, including any specific hazards associated with their use

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Natural gas and synthesis gas.	- to compare the processes of syn gas production	- to distinguish processes of syn gas production
2. Pyrolysis – the primary process in petrochemical industry.	- to describe the reaction conditions of pyrolysis of hydrocarbons	- to explain the importance of hydrocarbons pyrolysis process and its products

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FORM 2

1) Course teacher: Tomislav Bolanča

2) Name of the course: Chemometrics

3) Study programme (undergraduate, graduate): graduate study – Applied Chemistry

4) Status of the course: obligatory

5) Expected learning outcomes at the level of the course (4-10 learning outcomes):

6. To define data distributions.
7. To apply statistical hypothesis tests in chemistry.
8. To use methods of exploration of data in real chemical systems.
9. To apply methods of modelling and optimization
10. To extract useful information.
11. To calibrate analytical system, to process measured signal in order to obtain useful information.

6) Learning outcomes at the level of the study programme:

6. To demonstrate competence in evaluation, interpretation and synthesis of chemical information and data.
7. To develop computational skills in processing chemical data and information.
8. To develop ability of numerical thinking and computational skills including error analysis, evaluation of order of magnitude, and correct use of units.
9. To interpret laboratory observations and obtained measurements, their meaning and connection with appropriate theory.
10. To demonstrate skills of time-planning and managing, as well as being standalone in work.

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	**Learning outcomes**	**Evaluation criteria**
8. Basic statistics in chemometrics.	- To define data distributions. - To apply statistical hypothesis tests in chemistry.	- To relate experimental data, information and knowledge. - To define data by using different distributions.

		- To operate with *t*-, *F*-, Dixon, Grubbs and Cochran tests. - To use single and multi-factor analysis of variance.
9. Exploration chemometric methods	- To apply methods of exploration of data on real chemical systems.	- To apply principles of filling-in, scaling, and rotating of data. - To define principles of recognizing samples. - To apply hierarchical cluster analysis.
10. Experimental design, modelling and optimization	- To design experimental procedure. - To apply modelling and optimization methods - To extract useful information	- To define basic principles of design of experiments. - To distinguish methods of random blocks, Latin squares and full factorial design. - To apply methods of linear regression. - To define methods of non-linear regression. - To apply artificial neural network methods.
11. Signal processing	- To calibrate analytical system and process measured signal in order to obtain useful information	- To apply calibration procedures. - To define decision threshold, and limits of detection and quantification. - To distinguish filtering, modulation, smoothing and deconvolution of signal. - To apply and explain Fourier transformations.

FORM 2

1) Course teacher: Krešimir Košutić (Full Professor)
2) Name of the course: Molecular separation
3) Study programme (undergraduate, graduate): The graduate study of Applied chemistry
4) Status of the course: mandatory

5) Expected learning outcomes at the level of the course (4-10 learning outcomes):	**6) Learning outcomes at the level of the study programme:**
1. A depper knowledge of theoretical principles of adsorption, ion exchange and membrane separations and they application in practice, particulary in water treatment 2. To apply knowledge of mathematics and chemistry, derive and apply equation (that clearly define the principles of separation) 3. Individually and independently prepare (set up) and make complex laboratory experiments 4. Analyze, synthesize, and interpret the results of experiments 5. Prepare laboratory reports	- a deeper knowledge and understanding of chemistry built upon the foundations of the Bachelors degree, which provides a basis for originality in developing and applying ideas within a research context; - ability to demonstrate knowledge and understand essential facts, concepts, and chemical principles and theories relating to the advanced chemistry areas studied during the Masters programme; - ability to apply knowledge and understanding, and problem solving abilities, in new or unfamiliar environments within broader (or multidisciplinary) contexts related to the chemical sciences - ability to interact with scientists from other disciplines on inter- or multidisciplinary problems; - ability to assimilate, evaluate and present research results objectively - skills required for the conduct of advanced laboratory procedures and use of instrumentation in synthetic and analytical work - ability to plan and carry out experiments independently and be self-critical in the evaluation of experimental procedures and outcomes - ability to team work and to work autonomously with minimal supervision

7) Teaching units with the corresponding learning outcomes and evaluation

FORM 2

criteria		
Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. -5. Adsorption	- Define the concept of adsorption, to know the properties of the adsorbent, recognize the importance of factors affecting the adsorption, identify the types of adsorption - Mathematical describe the main types of adsorption isotherms - Freundlich, Langmuir, Brunauer-Emmett-Teller, Dubinin-Polanyi, extended and other theories; - Define the adsorption equilibrium of single-component and multicomponent systems - Describe the adsorption kinetics and dynamics of the adsorption columns - Describe the adsorption processes- batch, semi-continuous and continuous - breakthrough curve, regeneration methods - Prepare and make a laboratory exercise and computational process measurement data and interpret the Freundlich adsorption isotherm; write a lab report	-List the major types of porous adsorbents and their most significant properties - Explain the importance of experimental conditions for determining adsorption isotherms, interpret parameters isotherms -Compare three major expressions (so-called isotherms) used for correlating single-component adsorption equilibria -List step involved in adsorption of a solute, and which steps may control rate of adsorption -Describe major methods for regenerating adsorbent -Explain the concept of breakthrough in fixed-bed adsorption -Demonstrate skill computation and application Freundlich, Langmuir and BET isotherms -Demonstrate skill computing conditions of batch, semi-continuous and continuous performance adsorption -Demonstrate importance of the experimental parameters for determining Freundlich adsorption isotherms
6.-10. Ion Exchange	-Describe ion exchange resins types - Describe the structure of ion exchange resins	- Explain the basic principles of ion exchange - List the types and properties of ion exchange resins - Explain the ion exchange equilibrium

FORM 2

	- Define the ion exchange equilibrium - Define ion exchange cycle and ion exchange systems which are applied in practice	- List the examples of ion exchange system in the processing of water
11.-15- Membrane separation	-Know to classify membranes and membrane processes - Define the performance of membrane modules - Define and describe the mass transfer through the membrane - Define the principles of retention and separation models - Describe membrane permeation: gas permation, gas diffusion, pervaporation, membrane distillation - Define the pressure membrane separation: reverse osmosis, nanofiltration, ultrafiltration and microfiltration and their practical application - Recognize the causes and consequences of fouling and biofouling in practice - Describe electric membrane separation (electrodialysis, membrane electrolysis, bipolar membrane) - Prepare and make a laboratory exercise: RO / NF separation saline solution, process measurement data and write a lab report	- Select membranes for various separation tasks - Identify criteria of application of membrane separation - Experimental check nominal properties of commercial membranes - Identify and explain the mechanisms of action of membrane separation - Recognize the difference between the concentration polarization and fouling phenomena in membrane processes - Explain the structure of anionic ad cationic membrane, explain how to work electrodialyzer - Explain desalination of sea water and brackish water by reverse osmosis and nanofiltration

FORM 2

1) Course teacher: Dr Ivana Steinberg, Assistant Professor	
2) Name of the course: Integrated Chemical Systems	
3) Study programme (undergraduate, graduate): graduate	
4) Status of the course: compulsory	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes):	**6) Learning outcomes at the level of the study programme:**
1. Define function, forms and applications of nano- and micro-integrated chemical systems (ICS) in the context of modern science and technology 2. Identify main parts of real integrated chemical systems using hierarchical approach and analyse their chemical function 3. Recognise the role of miniaturisation concepts and define the consequences of miniaturisation on the function and application of an ICS 4. Create a virtual ICS with proposed function using predetermined building blocks 5. Evaluate the potential of proposed ICS for real application in the context of existing scientific knowledge	1. Knowledge and understanding of chemistry built upon the foundations of the Bachelor’s degree, which provides a basis for originality in developing and applying ideas within a research context 2. Ability to demonstrate knowledge and understand essential facts, concepts, and chemical principles and theories relating to the advanced chemistry areas studied during the Masters programme 3. Ability to apply knowledge and understanding, and problem solving abilities, in new or unfamiliar environments within broader (or multidisciplinary) contexts related to the chemical sciences 4. Adopt and develop competences and transferable skills suitable for employment as professional chemists in chemical and related industries in the public or private sector 5. Attain academic standards appropriate for access to third cycle course units or degree programs 6. Ability to assimilate and integrate knowledge, to handle complex ideas, and to formulate judgments with incomplete or limited information 7. Ability to clearly and unambiguously communicate scientific or technical concepts, data, and conclusions with the knowledge and rationale underpinning them to both specialist and non-specialist audiences in written and

	oral form 8. Ability to interact with scientists from other disciplines on inter- or multidisciplinary problems 9. Ability to engage in team and autonomous work with minimal supervision

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. **Integrated chemical systems**: definition, examples, hierarchical approach	The student will be able to: 1. Define an ICS and select some real examples of ICSs 2. Explain the relationship between chemical interaction and the function of an ICS 3. Describe and identify the similarities between artificial (synthetic) and natural (bio)chemical systems 4. Recognise the function, structure and application of an ICS applied on chemical sensors and biosensors (with an emphasis on glucose sensing) 5. Explain and illustrate the main driving forces for development of new ICSs especially in the field of diagnostic, biomedical and analytical applications	1. Analyse a given real example of ICS in terms of its application and function 2. Define building blocks of a chosen ICS 3. Identify and analyse the chemical (and other) interactions responsible for the final function of an ICS
2. **Building blocks and ICS fabrication techniques**: Functional materials – examples, Self-assembly of	The student will be able to: 1. Define the meaning of a term *building block* in the	1. Identify necessary building blocks needed to develop an ICSs with the specified function

molecules and materials; Microsystem technologies; Chemical methods of nano- and micro-functionalization of ICSs	context of an ICS 2. Identify main types of building blocks of an ICS 3. Define the phenomenon of self-assembly of molecules and materials and relate it to processes relevant for fabrication and and function of an ICS 4. Distinguish *top-down* and *bottom-up* approaches applied for fabrication of nano- and micro-integrated chemical systems 5. Describe and identify the main processes involved in microsystem fabrication 6. Explain the role of microsystem technologies in development of ICSs 7. Define the main approaches to (nano)chemical functionalization of ICSs	2. Recognise the type of building block (molecule, supermolecule, nanostructure) 3. Define the interactions responsible for the building block's functional properties 4. Recognise and define structure- property relationship of selected examples of materials 5. Categorise the self-assembly process in terms of interactions involved, and illustrate its potential application in the area of ICSs 6. Demonstrate with examples the *top-down* and *bottom-up* approaches to development of ICSs 7. Analyse given examples of ICSs in terms of their building block and fabrication techniques
3. **Miniaturization and microfluidic platforms in analytical and synthetic integrated chemical systems:** Introduction to microfluidics as enabling technology for ICAS; Miniaturisation of analytical systems: Lab-on-a-chip; Integrated chemical analytical systems (ICAS); Integrated chemical synthetic systems (microreactors); Microfluidic chemical synthesis (Plant-on-a-chip)	The student will be able to: 1. Explain the concepts of miniaturisation as applied to ICSs 2. Recognise the meaning and interpret the term *information density* in the context of miniaturisation 3. Identify the scaling laws relevant to microfluidics 4. Identify the consequences of laminar flow on mixing in microfluidic channels 5 Compare analytical and synthetic microfluidic	1. Analyse and discuss working principles of microfluidic H-filter and T – sensor devices 2. Illustrate and discuss concepts of miniaturisation using different microfluidic platforms in real application (e.g. DNA chips, micro-TAS, Lab-on-a-chip) 3. Analyse a given example of an ICS (reported in a scientific paper) using generic approach adopted at the course 4. Apply knowledge gained

	platforms and define advantages of miniaturisation respectively.	at the course to analyse the ICS presented in a paper and summarise it in a form of written and oral presentation

FORM 2

1) Course teacher: **(by alphabetical order)** Assistant Prof. Lucija Foglar, and Associate Prof. Dragana Mutavdžić Pavlović

2) Name of the course: Chemical and biochemical processes in soil and sediment

3) Study programme (undergraduate, graduate): graduate, 1st year

4) Status of the course: optional

5) Expected learning outcomes at the level of the course (4-10 learning outcomes):	**6) Learning outcomes at the level of the study programme:**
1. Define the physical and chemical properties of the soil. 2. Explain the importance of soil organic matter. 3. Distinguish anthropogenic changes in soil. 4. Explain the biochemical processes of carbon, nitrogen, phosphorus and sulphur compounds in soil and sediment. 5. Demonstrate the role of microorganisms in the biochemical processes in soil and sediment.	1. Deeper knowledge and understanding of essential facts, concepts, principles and theories relating to chemistry and chemical and biochemical reactions. 2. Apply previously acquired knowledge in environmental analysis, especially in solving the problem on the basis of quantitative information. 3. Interpret observations and measurements, and connect them with the appropriate theory. 4. Assess the possibility of risks associated with the use of certain chemical substances. 5. Appraise and evaluate the biochemical processes for environmental protection. 6. Interpreter and predict the role of microorganisms in the process of soil and sediment protection. 7. Ability of time management and project planning skills.

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Soil as part of the environment and access to chemical analysis of soil samples	- define the analytical process - define the importance of soil in the environment - distinguish the ways of	- recognize the importance of each step of the analytical process - distinguish pedogenetic

FORM 2

	origin of soils	factors and processes
2. Composition of the soil	- define the chemical and physical properties of soil - explain the importance of soil organic matter - distinguish anthropogenic changes in soil - provide the indicators of soil contamination	- ability to independently access to chemical analysis of soil samples - distinguish the physical from the chemical properties of soil - define chemically the most active part of the soil - define procedures for cleaning polluted soil
3. Laboratory exercises in Part 1 (Chemical part of course)	- apply the approach to chemical analysis of the soil and sediment - apply the principles of good laboratory practice - properly collect and process the measurement data - write the appropriate laboratory report	- analyze the obtained soil and sediment sample on the basis of the acquired knowledge - numerically express and process the results on the basis of the measurements - show independence in laboratory work - write the laboratory notebook
4. Fundamentals of biochemical processes in soil and sediment.	- classify and analyze different biochemical processes in soil and sediment - summarize the importance of nutrients, micronutrients and environmental factors in the transformation process	- distinguish and select appropriate process among given examples - recognize crucial environmental factors in different biotransformation process
5. The biochemical processes of nitrogen compounds conversion in soil and sediment.	- distinguish the processes of nitrification, assimilation, ammonification, denitrification and nitrogen fixation	- select and propose suitable process for given compounds
6. The transformation of the organic matter in the soil	- classify and analyze transformation of organic and inorganic carbon compounds	- select suitable process and interpret assimilative and dissimilative redox reactions

		of carbon compounds
7. Laboratory exercise Part 2 (Biochemical part of course)	- determine number of different microorganisms in soil and sediment sample - monitor the nitrification and denitrification process and analyze microbial degradation of organic matter in soil and sediment samples	- apply selected microorganisms for given environmental processes in order to decrease pollution of soil and sediments

FORM 2

1) Course teacher: Lidija Furač, Šime Ukić

2) Name of the course: Water Chemistry

3) Study programme (undergraduate, graduate): graduate study – Applied Chemistry

4) Status of the course: optional

5) Expected learning outcomes at the level of the course (4-10 learning outcomes):

1. To differentiate factors that regulates chemical composition of water considering cycles of elements through water, soil, and air.
2. To explain coordination chemistry in water medium in relation to chemical separation, bioavailability and metal toxicity.
3. To describe redox processes in water media with special overview on electron-transfer mechanisms, linear free energy relationships, and photochemical processes.
4. To explain interactions of water media and solid surface, adsorption phenomena, and chemistry of colloids.
5. To develop ability for perception and solving of real complex problems from the environment.

6) Learning outcomes at the level of the study programme:

1. To demonstrate competence in assessment, interpretation and synthesis of chemical information.
2. To demonstrate competence in presentation of the course related materials (written and oral) to the relevant auditorium.
3. To practice standard laboratory procedures and application of instrumentation those are used for preparative or analytical purposes for inorganic or organic systems.
4. To use software package Visual Minteq for simulation and description of element release processes into environment, and for precipitation and dissolution of minerals.

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Cycle of regulation of chemical composition of water.	- To differentiate factors that regulates chemical composition of water considering cycles of elements through water, soil, and air.	- To explain hydrological cycle and water-air interactions. - To define sources and transfer of atmospheric pollutants. - To explain processes of

		minerals and rocks dissolution. - To explain isothermal evaporation of natural waters that causes precipitation of calcium carbonate. - To explain carbonate equilibrium, acidity, alkalinity and buffer capacity of water. - To explain characteristics, composition and diversities of surface water, ground water, and sea
2. Coordination chemistry in water media.	- To explain coordination chemistry in water medium in relation to chemical separation, bioavailability and metal toxicity.	- To explain hydrolysis of metal ions in water, formation of polynuclear hydroxy complexes and to interpret their stability - To explain formation of chelate complexes and their stability - To explain carbonate complex compounds that origins in natural waters, and their interaction with organic compounds - To explain complexation of humic acids - To illustrate distribution of polynuclear, chelate and carbonate species.
3. Redox processes in water media.	- To describe redox processes in water media with special overview on electron-transfer mechanisms, linear free energy relationships, and photochemical processes.	- To define electron activity in water medium and create analogy with pH. - To formulate redox equations and for given real system with redox equilibrium compute

		electron activity (including partial pressures of dissolved gasses also), to illustrate distribution of equilibrium redox-species graphically and to interpret the graph. - To define electrode potential and explain thermodynamic connection of potential and solution composition according to Nernst equation. - To define redox conditions in natural waters and their influence on photosynthesis and biochemical cycle (cycle of carbon, sulphur, and nitrogen). - To explain mechanisms of redox transformation in aerobic and anaerobic conditions. - To explain the influence of complex formation on redox potential - To demonstrate measurement of redox potential in natural waters. - To explain oxidation kinetics in natural waters.
4. Interactions of water media and solid surface	- To explain interactions of water media and solid surface, adsorption phenomena, and chemistry of colloids.	- To differentiate specific from physical adsorption; to interpret mechanistic model approach - To demonstrate knowledge of surface complexation theory - To formulate adsorption

		equations for reactions that occur on solid phase/liquid phase boundary (surface adsorption of water molecules, protonation and deprotonation , surface hydrolysis, formation of surface complexes by metal bounding or ligand exchange), to differentiate outer- from inner-sphere surface complexes. - to define terms and demonstrate how to compute surface charge, total charge, point of zero charge, and intrinsic constant of reaction equilibrium, to use specific surface data for computing density of surface adsorption-sites in case of surface complexation. - to propose models of surface complexation based on electrochemical double-layer model (diffuse layer model, constant capacitance model, triple-layer model). - to apply Visual Minteq software for simulation of environmental process and to interpret the obtained results and their meaning.

FORM 2

1) Course teacher: Prof. dr. sc. Sanja Lučić Blagojević and Prof. dr. sc. Stanislav Kurajica	
2) Name of the course: Introduction to nanotechnology	
3) Study programme (undergraduate, graduate): Applied chemistry (graduate)	
4) Status of the course: Electional	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. The ability to explain certain properties of materials and to understand the reasons for change of properties occurring on nano-scale. 2. The understanding of ideas, concepts and techniques in the field of nanotechnology and the ability of their critical judgment. 3. Distinguishing of top-down and bottom-up methods of nanofabrication, the understanding of these methods and being able to perceive their advantages and disadvantages. 4. The ability to analyze the purpose and to apply knowledge of materials science and engineering in nanotechnology 5. To explain connection between structure and properties of nano-objects and integrated nano-systems. 6. To describe different methods of characterization on nano-scale and to know principles of these methods and perceive their advantages and idsadvantages. 7. To perceive momentary limitations in the development of nanomaterials and ethical doubts appearing in the field of nanotechnology. 8. To demonstrate communication skills, ability of critical thinking and cognition of the need for further learning.	**6) Learning outcomes at the level of the study programme:** 1. Competence in the evaluation, interpretation and synthesis of chemical information and data. 2. Competence in presenting chemical and chemical engineering related material and arguments in writing and orally, to an informed audience. 3. Capacity to apply knowledge in practice, in particular problem-solving competences, relating to both qualitative and quantitative information. 4. Carry out standard laboratory procedures and use instrumentation involved in synthetic and analytical work, in relation to both organic and inorganic systems. 5. Monitoring, by observation and measurement, of chemical properties, events or changes, and the systematic and reliable recording and documentation thereof. 6. Interpret data derived from laboratory observations and measurements in terms of their significance and relate them to appropriate theory. 7. Conduct risk assessments concerning the use of chemical substances and laboratory procedures. 8. Study skills and competences needed for continuing professional development.
7) Teaching units with the corresponding learning outcomes and evaluation	

FORM 2

criteria		
Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. The properties and characterization of nanomaterials	- Knowing of terms in the field of nanoscience and nanotechnology. - The understanding of the properties of materials (especially physical, mechanical, chemical, optical, electrical and magnetic) and causes for the change of properties on nano-scale. - Knowing of the principles of typical methods for the characterization of nanomaterials (especially transmission and scanning electron microscope as well as scanning tunneling microscope and atomic force microscope. - The combination of knowledge on structure and properties on nano-scale with the aim of perceiving of application potential of nanomaterials and nanoproducts.	- The listing of typical characteristics of nanotechnology. - Explaining terms typical for nanomaterials and nanotechnologies - Explaining terms connected to various properties of materials and connection between structure and properties of materials. - Explaining reasons for changing of certain properties on nano-scale - Describing operating principles of typical methods of nanomaterials characterization. - The listing of constrains, advantages and disanvantages of certain methods. - Describing preparation of samples for certain methods of characterization.
2. Nanofabrication, manufacturing, trends and applications of nanomaterials	- The differentiation between top-down and bottom-up methods of nanofabrication. - Understanding of principles of these methods, controlling factors and limitations (especially lithography, dip-pen nanolithography, crystallization, sol-gel method, chemical vapor deposition, self-assembly and nanomanipulation. - Understanding of ideas, concepts, techniques and trends in the field of	- List the methods of manufacturing - List and explain classification of nanomanufacturing methods - List most important nanomanufacturing methods from each category. - Describe the most important methods, advantages, disadvantages, limitations, controlling factors. - List some nanoproducts already at the market. - List main areas of investigation in

	nanotechnology (especially in electronics, medicine, materials engineering and environmental protection) and the ability of their critical judgment. - Perceiving of ethical doubts appearing in the field of nanotechnology and the ability to discuss on them.	nanotechnology, aims of these investigation, assumtions they are based on and the purpose of aimed nanoproducts. - List some of the potential risks associated with nanotechnology.
3. Nanoobjekti	- Recognition of the role of materials science and engineering in synthesis of nanoobjects. - Connection between structure and properties of nanoobjects. - Understanding of principles of chemical and physical modifications of nanoobjects surfaces.	- Describe synthesis processes of certain nanoobjects. - Explain connection between structure and properties of nanoobjects and specificities in relation to bulk materials. - Explain and analyse the manners of sertain nanoobjects modification.
4. Selected nanotechnologies (nanobiotechnology, nanoelectronics, polymer nanocomposites)	- The recognition of scientific and technological acheivements realised in the area of nanotechnology. - The insight in realized and potential acheivements in certain areas of nanotechnology. - The analysis of the purpose of nanoobjects for certain applications in integrated systems.	- Explain the purpose and define contribution of certain areas of nanotechnology and give examples from literature. - Describe examples in certain areas of nanotechnology. - Explain the purpose of nanoobjects and other components of integrated systems.

University of Zagreb
Faculty of Chemical
Engineering and Technology

FKITMCMXIX

FORM 2

1) Course teacher:

Professor Ante Jukić, PhD

2) Name of the course: Fuel Cells

3) Study programme: Graduate

4) Status of the course: Elected

5) Expected learning outcomes at the level of the course:	**6) Learning outcomes at the level of the study programme:**
- to describe operating principle of the fuel cell. - to define mechanism and kinetics od electrode reactions as well as thermodynamics of the fuel cell. - to define chemical reactions in different types of fuel cells. - to explain design of different types of fuel cells. - to idetify critical challenges, major R&D needs and key benefits for the main types of fuel cells.	1. Ability to demonstrate knowledge and understand essential facts, concepts, and chemical principles and theories relating to the advanced chemistry areas. 2. Ability to apply knowledge and understanding, and problem solving abilities, in new or unfamiliar environments within broader (or multidisciplinary) contexts related to the chemical sciences. 3. Ability to assimilate and integrate knowledge, to handle complex ideas, and to formulate judgments with incomplete or limited information. 4. Ability to clearly and unambiguously communicate scientific or technical concepts, data, and conclusions with the knowledge and rationale underpinning them to both specialist and non-specialist audiences in written and oral form. 5. Ability to interact with scientists from other disciplines on inter- or multidisciplinary problems.

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Fuell cell – operating principle and technology description, mechanisms and kinetics of electrode reactions, thermodynamics, design.	- to describe operating principle of the fuel cell. - to define mechanism and kinetics od electrode reactions as well as thermodynamics of the fuel cell.	- to draw chemical reactions in the fuel cell. - to outline design of the fuel cell. - to idetify and explain the most important kinetic and

		thermodinamic aspects of electrode reactions and fuel cell.
2. Types of fuel cells: PEMFC, AFC, PAFC, DMFC, MCFC, SOFC. Application of fuel cells; examples.	- to define chemical reactions in different types of fuel cells. - to explain design of different types of fuel cells. - to idetify critical challenges, major R&D needs and key benefits for the main types of fuel cells.	- to draw appropriate reaction routes. - to outline design of the different types of fuel cells. - to evaluate advantages and disadvatages and to compare different types of fuel cells.

FORM 2

1) Course teacher: Veljko Filipan, PhD, full professor; Marijana Kraljić Roković, PhD, assistant professor	
2) Name of the course: Alternative energy sources	
3) Study programme (undergraduate, graduate): graduated	
4) Status of the course: elected	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. -memorise general energetic theory that facilitate to understand and overcome the issues in the field of energy sustainability 2. -distinguish different alternative forms of energy 3.explain main principle of energy transformation from one form to another, efficiency of the process, economical factors and influence of energy transformation on environment 4. distinguish direct and indirect energy transformation 5. explain roll and importance of different energy sources 6. define legal framework for application of alternative power sources 7. define global energy strategy and energy strategy of EU and Croatia	**6) Learning outcomes at the level of the study programme:** 1.- ability to interact with scientists from other disciplines on inter- or multidisciplinary problems 2. -ability to assimilate, evaluate and present research results objectively

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	Learning outcomes	Evaluation criteria
1. Solar energy and	-explain basic principles of	-describe basic principles of

FORM 2

photovoltaic cell	how to utilise solar energy -explain electrical properties of semiconductors and p-n junction -list materials that can be used for the production of photovoltaic cells	solar energy utilisation -sketch energy bands of metals, semiconductors and insulators -outline main principle of p-n junction -list materials that can be used for the production of photovoltaic cells
2.Electrochemical power sources	-describe different electrochemical power sources (batteries, fuel cells, supercapacitors) -explain working principles and list main characteristic of electrochemical power sources	-predict appropriate electrochemical power source for specific application -calculate power density and energy density of an electrochemical power source -compare discharging characteristics of battery and supercapacitor -compare different type of fuel cells
3. Biomass, biogas, liquid bioufuels	-define biomass and biofuels -explain basic principle of energy production from biomass -distinguish first-, second- and third generation of biofuels -memorise disadvantages advantages and of biofuels	-describe Life Cycle Analysis (LCA) -define biomass and biofuel -list advantages and disadvantages of biofuels -compare first-, second- and third generation of biofuels
4. Renewable energy in industrial application. Energy storage. Smart grids. Legal	-describe possibility for renewable power sources application in industrial process	-give an example for renewable power sources application in industrial process

framework for application of alternative power sources.	-list different energy storage systems -explain basic principles of smart grid -define global energy strategy and energy strategy of EU and Croatia	-list different energy storage systems -state basic principles of smart grid -recognise global energy strategy and energy strategy of EU and Croatia

FORM 2

1) Course teacher: prof. dr. sc. Stanislav Kurajica
2) Name of the course: Natural silicate materials
3) Study programme (undergraduate, graduate): Applied chemistry (graduate)
4) Status of the course: Electional

5) Expected learning outcomes at the level of the course (4-10 learning outcomes):	**6) Learning outcomes at the level of the study programme:**
1. Knowing of basic terms connected to natural and synthetic silicate materials. 2. The ability to apply the principles of materials science and engineering for understanding the properties of silicates and processes occurring in the course of production and use of silicates. 3. Capability of connecting knowledge of chemistry, chemical engineering and structure and properties of materials in order to identify, formulate and solve problems in the area of silicate chemistry. 4. The ability of analyzing the behavior of silicates on macro-level having in mind structure and microstructure of material and phenomenon on micro-level. 5. The development of critical way of thinking on structure, properties, manufacturing and applications of silicates. 6. Recognition of professional standards and improvement of work ethics as well as gain motivation for further education and intellectual development. 7. Improvement of capabilities of analythical thinking and synthesis of knowledge, communication skills, criticism and ability to draw conclusions. 8. The capability to use instrumental techniques of materials analysis and to enhance computer skills, analysis and synthesis of data.	1. Application of scientific principles underlying chemistry, physics and chemical engineering on materials, their structure, properties, processing and performance. 2. Understanding and integration of four major elements of materials science and engineering: structure, properties, processing, and performance of materials, and application of this knowledge on practical issues. 3. Knowledge of various kinds of materials and technologies for their production, including novel materials (nanomaterials, biomaterials). 4. The ability to choose and apply appropriate analytical methods and models for computational problem solving, including the use of commercial databases and analytical and modeling programs. 5. Capability for further learning. 6. Ability to apply gained knowledge in materials production processes and quality control, and in their improvement. 7. Skills necessary for running chemical and physical laboratories, selection and preparation of adequate laboratory equipment and organization of laboratory work according to standards. 8. The ability to create solutions and independently solve problems (including the identification and formulation of the problem) in materials science and engineering.

FORM 2

7) Teaching units with the corresponding learning outcomes and evaluation criteria		
Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Silicij, [SiO_4]-tetraedar, silikati, klasifikacija silikata	- Knowing of basic terms of silicate chemistry. - Understanding of silicate minerals genesis. - Perceiving of the importance of silicates and the reasons of existance of numerous and versatile silicates. - Notation of similarities and differences of silicon and carbon chemical behavior. - Knowing of properties of silicon. - Interpretation of processes of obtaining technical and semiconductor silicon, CVD process, Czochralski process and floating zone process. - Distinguishing of various types of solar cells. - Interpretation of polycrystalline cells manufacturing process. - Explaining the nature of a chemical bond between silicon and oxigen as well as ways of connecting of [SiO_4]-tetrahedrons. - Applying of Pauling rules for building of ionic crystals on silicates. - Classifying of silicates and recognizing in which group certain silicate could be categorized. - Reproduction of concepts of dimension number, multiplicity, periodicity, branchedness and to determine these parameters	To define: - silikates, - segregation coefficient. To distinguish - dimensional number, multiplicity, periodicity. To explain: - similarities and differences of chemistry of silicon and carbon, - differences of silicon reactivity in bulk form and in melt, - the nature of Si-O bond, - the ways of connecting of [SiO_4] tetrahedral. To state: - four basic reasons of silicates diversity, - forms of Si on the market and approximate purity, - types of solar cells, - coordination polihedra pf usual ions in silicates, - three common ways of classification of silicates and what are they based on, - kinds of silicates according to structural classification. To describe: - process of manufacturing of technical silicon, - process of manufacturing of ultra-pure polycrystalline silicon, - method of conversion of polycrystalline silicon to monocrystal.

	for simple silicates.	
2. Island, group, ring and chain silicates	- Knowing of most important groups of island silicates. - Understanding of the olivine structure - Understanding of the connection between structure and properties of island silicates. - The ability to explain the differences in structure, especially the coordination of aluminum in silimanite group minerals. - perceiving of role and importance of mullite in chemical industry. - Understanding of beryl structure. - The ability to explain chain silicates structures trough T-O-T units conformance. - perceiving similarities and differences between structures of pyroxenes and amphyboles. - Perceiving the reasons why some minerals are used as a gemstones or semiprecious stones. - Knowing of basic terms of gemstones processing and assesment.	Define olivine. State: -coordination numbers of aluminum in silimanite andalusite and kyanite, - how is defined periodicity of chain silicates. Describe: -the importance and role of mullite in porcelain microstructure and properties that it is meritorious in porcelain, - beryl structure, - basic structure of piroxenes and amphyboles. Explain - how are $[SiO_4]$-tetrahedra connected in olivine and how Mg^{2+} ions are coordinated with O^{2-} ions and vice versa, - how is 2nd Pauling rule on the strength of valence in ionic structure is applied to olivine, - the influence of kation in polihedra on mechanical properties of silicates, - the influence of chain silicates structure to their properties. Distinguish ortopyroxenes and clinopyroxenes.
3. Layered silicates	- Knowing of important groups of layered silicates. - Understanding of the structure of layered silicates. - Ability to describe tetraherral and octahedral layer. - Ability to differentiate T-O and T-O-T layers. - Ability to explain terms of dioktahedral and trioktahedral structure.	To state: -which types of structures have kaolinite and serpentine, - what are typical properties of vermiculite and montmorillonite, which are characteristics of their structures and what are the differences between them. - few uses of kaoline. - what factors influence sedimentation and

	- Ability to differentiate various layer connection manners. - Interpretation of classification of layered silicates. - The ability to describe structures of kaolinite, serpentine, pyrophylite, talc, mica, chlorite, vermiculite, montmorillonite and illite. - The ability to explain the genesis of layered silicates. - Interpretation of clays classification. - Knowing of methods of bentonite modifications. - Understanding of colloid properties of clay and the ability to control the stability of suspension, plasticity, viscosity and flow properties. - Understanding of terms of exchange equilibria, selectivity coefficient, cation exchange capacity and ability to use them for the control og ion exchange process.	coagulation stability of clay suspensions. Describe: - the connection between layers in kaolinite, talc and muscovite, - the reasons of ion exchange property in clays, Explain: - the difference between trioctahedral and ioctahedral structure of layered silicates, - in what way will be changed the diffraction pattern of montmorillonite after addition of ethylene-glycole, or after heating to 400°C? - will it be any changes after the same treatment of kaolinite and why. - what is zeta-potential, on what it depends and how it can be influenced, explain with details both ways of influence. To differentiate clays of primary and secondary deposits.
4. Framework silicates and synthetic silica	- Knowing of important groups of framework silicates. - Ability to explain various factors on ordering of feldspars structures. - Understanding of zeolite structures. - Interpretation of zeolite classification. - Understanding of the mechanisms underlying zeolite application for drying, separation and catalysis. - Interpretation of zeolite manufacturing process. - Knowing of SiO_2 polymorphs and the variety	To define: - factors influencing compatibility in the course of formation of the solid solution between two feldspars. - hydrogel, xerogel, aerogel To state: - most important feldspars and factors influencing ordering of their structure, - professional diseases connected with the work with crystalline silica, - classification of synthetic silica. Describe: Aerosil process

	of quartz. - Interpretation of Fenner's diagram. - Knowing of quartz raw materials. - Consciousness of SiO_2 influence to health. - Differentiation of various kinds of fine synthetic silica. - Interpretation of manufacturing procesess of pirogeneous silica, silica-sol, silica-gel, precipitated silica and post-processed silica.	Processes of obtaining silica-sol, silica-gel and precipitated silica. Explain: - the role of feldspars in porcelain firing process, - why zeolites are called molecular sieves and why are they good ion exschangers. Describe structure of zeolites through hierarchy of structural elements. List modifications of silica depicted in Fenner's diagram. Differentiate stabile and metastabile modifications of silica, reconstructive and displacive phase transformations of silica.
5. Other inorganic silicate compounds and organosilicon compounds	To list, describe and differentiate other inorganic compounds of silicon. Interpretation of the manufacturing process of soluble alkali metal silicates. Describing and differentiation of silanes, halogen silanes, siloxanes, silanoles and alkoxysilanes and knowing their properties. Interpretation of silane manufacturing process. Knowing of organosilicon compounds, especially organohalogen silanes i organoalkoksi silanes and their chemical properties. Interpretation of manufacturing processes of organosilicon compounds. Knowing silicone properties. Interpretation of manufacturing processes of silicones. Differentiation of industrial silicone products, especially silicon oils, silicone rubbers,	To define: - water glass To state: - classification of industrial silicon products, - most important properties of silicon-carbide, silanes, siloxanes, silanoles, and alkoxysilanes. To describe: - methods of obtaining of networked silicone polymers. - ways of environment endangerment with the processes of exploitation and manufacturing of silicates and to perceive methods of environmental protection - important solid-state reactions of silicates. To list and to describe various methods of silicate characterization.

	silicone resins. Perceiving need and methods for environmental protection in processes of exploitation and manufacturing of silicates. Interpretation of thermal processes in silicate chemistry and important solid-state processes of silicates. To apply methods of structural characterisation, thermal analysis, electron microscopy and microanalysis for characterization of silicates.	

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FORM 2

1) Course teacher: Assoc. Prof. Elvira Vidović, PhD

2) Name of the course: Polymer Biomaterials

3) Study programme (undergraduate, graduate): graduate

4) Status of the course: elected

5) Expected learning outcomes at the level of the course (4-10 learning outcomes):

- to contrast characteristics of polymer materials to other materials regarding physico-mechanical, chemical and biological properties
- to describe reaction mechanisms, synthesis and preparation procedure of polymer biomaterials
- to analyze polymer biomaterials regarding their application
- to define the processes of bioresorption and biodegradation of material
- to describe the application of biomaterials in medicine
- to explain implementation of *in-vivo* and *in-vitro* tests

6) Learning outcomes at the level of the study programme:

1. a deeper knowledge and understanding of chemistry built upon the foundations of the Bachelors degree, which provides a basis for originality in developing and applying ideas within a research context

2. adopt and develop competences and transferable skills suitable for employment as professional chemists in chemical and related industries in the public or private sector

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	Learning outcomes	Evaluation criteria
1. Properties of biomaterials	- to describe characteristic properties of biomaterials: physico-mechanical, chemical, biological, surface	- to name characteristic properties of biomaterials: physico-mechanical, chemical and biological, surface
2. Degradation of biomaterial	- to identify materials regarding their bioresorption and biodegradation	- to classify materials regarding their bioresorption and biodegradation

FORM 2

1) Course teacher: Dr. Marijana Hranjec, associate professor
2) Name of the course: Planning of Organic Synthesis
3) Study programme (undergraduate, graduate): Graduate
4) Status of the course: Optional

5) Expected learning outcomes at the level of the course (4-10 learning outcomes):	**6) Learning outcomes at the level of the study programme:**
1. Define the basic principles and problems associated with simple and multistep organic synthesis. 2. Understand and present retrosynthetically analysis of targeted organic molecules. 3. Identify and present possible synthetic pathways of target molecules. 4. Select and identify the most appropriate synthetic route to the synthesis of target molecules according to the available starting chemicals. 5. Critical thinking when choosing a particular synthetic pathway with respect to existing laboratory conditions for the synthesis of target molecules. 6. Synthesize selected target molecules.	1. Identify, understand and apply complex chemical principles that build on basic knowledge of chemistry acquired in undergraduate studies; creatively develop and apply the ideas in the context of scientific research. 2. To apply acquired knowledge to solve qualitative and quantitative problems in a new context, including the selection and implementation of appropriate methodology. 3. Independently and self-directed acquire of new knowledge. 4. Sum up objectively, evaluate and present the results of the work. 5. Perform advanced laboratory procedures and use of instrumentation in the context of chemical synthesis and analysis. 6. Independently plan and conduct the experiments, self-critically evaluate the experimental procedures and results. 7. To acquire competencies and skills relevant to employment in the chemical or allied industries, in public or private sector.

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Planning of organic synthesis: a synthetic plan, strategy and retrosynthesis	- define the basic principles and the importance of planningof	- understand the importance of planning organic synthesis in the synthesis of new molecular targets

	organic synthesis - become familiar with the concepts of synthetic plan and strategy of organic synthesis - define the rethrosynthesis - explain the concept of synthons and their importance in organic synthesis	- implement strategy and synthetic plan in the planning of synthesis of target molecules - apply rethrosynthesis in the synthesis of target molecules - use adequate synthons while proposing synthetic pathways for target molecule
2. Chemoselectivity; Regioselectivity; Stereoselectivity	- define chemoselectivity and its role in organic synthesis - define regioselectivity and its role in organic synthesis - define stereoselectivity and its role in organic synthesis - explain individual roles of mentioned selectivity in the synthesis of target molecules	- understand the terms of chemoselectivity, regioselectivity and stereoselectivity - to notice the difference between the above mentioned selectivities - understand the role of the aforementioned selectivities, and their use in the synthesis of target molecules - apply mentioned selectivities in the synthesis of target molecules
3. Creating a new C-C and C = C bonds which lead to the new molecular structure	- define the basic methods for synthesis of C-C bond - define the basic methods for synthesis of C = C bond - assume the most appropriate synthetic pathways with regard to the desired increase in molecular structure - explain the difference between the individual synthetic manner in the given examples of target molecules synthesis	- know the common ways for synthesis of C-C bond - know the common ways for synthesis of C=C bond - know how to critical choose the most convenient method for synthesis of C-C or C = C bond considering the desired increase in molecular structure - apply the aforementioned synthetic methods for the synthesis of target molecules
4. Asymmetric synthesis and catalysis in the formation of C-C, C-H, CN and CO bonds	- define the concept of asymmetric synthesis and asymmetric catalysis - to be familiar with the ways of asymmetric synthesis for formation	- understood the asymmetric synthesis and catalysis and their use in organic synthesis - to know the ways of asymmetric synthesis for formation of C-C and C-H bond

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	of C-C and C-H bond - to be familiar with the ways of asymmetric synthesis for formation of CN and CO bond (C-heteroatom bonds) - assume the most convenient synthetic routes for the formation of appropriate linkages	- to know the ways of asymmetric synthesis for formation of CN and CO bond (C-heteroatom bonds) - apply the mentioned methods of asymmetric synthesis in the planning of synthesis of target molecules
5. The strategy of functional groups, and the synthesis of azole heterocycles having two or more heteroatoms	- define the most important functional groups for planning organic synthesis - define the role of the functional groups in organic synthesis - to be familiar with the ways of synthesis for azole and nitrogen heterocycles - to be familiar with the methods of synthesis for heterocycles with two or more heteroatoms	- know the most important functional groups, especially for the synthesis of heterocycles - understand the ways for azole and nitrogen heterocycles synthesis - understand the ways for synthesis of heterocycles with two or more heteroatoms - apply the mentioned methods of heterocycles synthesis in the planning of target molecules synthesis

FORM 2

1) Course teacher: Full Prof. Ante Jukić, PhD, Assoc. Prof. Elvira Vidović, PhD	
2) Name of the course: Petrochemistry	
3) Study programme (undergraduate, graduate): graduate	
4) Status of the course: elected	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. to identify transformation processes in petrochemical production (alkylation (de)hydrogenation, isomerization). 2. to distinguish reaction mechanisms and parameters in the processes of hydrocarbons oxydation. 3. to compare the technological settlements in petrochemical industry 4. to outline the schemes of main processes in petrochemical industry.	**6) Learning outcomes at the level of the study programme:** 1. a deeper knowledge and understanding of chemistry built upon the foundations of the Bachelors degree, which provides a basis for originality in developing and applying ideas within a research context 2. adopt and develop competences and transferable skills suitable for employment as professional chemists in chemical and related industries in the public or private sector

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	Learning outcomes	Evaluation criteria
1. Thermal decomposition of hydrocarbons	- to describe the reaction mechanism and importance of process parameters	- to explain the importance of process parameters
2. Heterogenous reactions of olephines and aromatic hydrocarbons	- to write the reaction pathways including reaction conditions	- to interpret the requirements in particular reaction phase

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FORM 2

1) Course teacher: Dr. Tatjana Gazivoda Kraljević, assisstant professor	
2) Name of the course: Structure Determination of Organic Compounds	
3) Study programme (undergraduate, graduate): graduate	
4) Status of the course: optional	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. Analyse and interpret the spectra of known organic compounds by spectroscopic methods, UV / Vis, IR, 1H and 13C NMR as well as mass spectrometry 2**.** Determine the structure of novel compounds based on data obtained by spectroscopic methods 3. Explain the impact of factors on the chemical shift in 1H and 13C NMR spectra 4. Determine and interpret the spin systems in the 1H and 13C NMR spectra	**6) Learning outcomes at the level of the study programme:** 1. Demonstrate knowledge and understand essential facts, concepts, and chemical principles and theories relating to the advanced chemistry areas studied during the Masters programme; 2. Creatively develop and apply the ideas in the context of scientific research 3. Apply knowledge and understanding to the solution of qualitative and quantitative problems which may be formulated in an unfamiliar way, and to adopt and apply appropriate methodology to solving such problems 4. Self-directed and acquire new knowledge 5. Assimilate, evaluate and present research results objectively

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	**Learning outcomes**	**Evaluation criteria**
Ultraviolet - visible spectroscopy (UV / VIS): electronic transitions, basic photophysical processes, the absorbance (Lambert-Beer's law), chromophores, examples of the UV / Vis spectra.	1. Identify organic compounds that absorb UV / VIS radiation 2. Analyze and interpret the UV / VIS spectra of organic compounds on the basis of absorption bands responsible for the structural groups in the molecule 3. Determine how certain	Analyze and interpret the UV/Vis spectra and determine structure of known organic compounds.

	factors (solvent, increasing the conjugation) affect the absorption spectrum	
Infrared spectroscopy (IR): vibrations of covalent bonds in molecules (stretching and bending) functional group area and the fingerprint area, examples of IR spectra .	1. Recognize and identify the type of molecular vibrations 2. Analyze and interpret the IR spectra of organic compounds	Analyze and interpret the IR spectra to determine the structure of organic compounds on examples from the literature.
Nuclear magnetic resonance (1H and 13C NMR): spin coupling (1H 1H), multiplets, splitting scheme, spin systems of the first and second order in 1H NMR. 13C NMR spectroscopy: coupled and decoupled spectra, APT, DEPT. Two-dimensional (2D) NMR spectroscopy: Homonuclear correlation methods 1H-1H and heteronuclear correlation methods 1H-13C; Correlation methods through space 1H-1H	1. Analyze and interpret one- and two- dimensional 1H and 13C NMR spectra of organic compounds 2. Analyze how certain factors affect the chemical shift in 1H and 13C NMR spectra 3. Analyze and interpret the spin systems in the 1H and 13C NMR spectra. 4. Determine the configuration or conformation of organic compounds using 2D NMR techniques 5. Apply complementary information obtained from various spectroscopic methods in determining of structure of organic molecules	Apply spectroscopic methods to determine the structure of organic compounds on examples from the literature and own experimental data. Analyze and interpret the spectra and determine the structure of organic compounds on the basis of complementary information obtained using various spectroscopic methods.
Mass spectrometry (MS): ionization methods, mass spectrometry of high resolution, the basic processes of organic compounds fragmentation; gas chromatography and mass spectrometry (GC / MS) system, liquid chromatography and mass spectrometry (LC / MS)	1. Apply rules to predict fragmentation 2. Analyze and interpret mass spectra of known and novel compounds 3. Determine the structure of organic compounds on the basis of anticipated mass fragments of synthesized compounds	Analyze the mass spectrum and determine the structure of known or novel compounds

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system		
Chirooptical methods: optical activity and rotation of linearly polarized light; Optical rotatory dispersion (ORD) and circular dichroism (CD).	1. Analyze and interpret ORD- and CD spectra 2. Apply chirooptical methods in determining of stereochemical properties of organic molecules (drugs, natural compounds, biomolecules)	Analyze and interpret ORD- and CD spectra

FORM 2

1) Course teacher: Dr. Marijana Hranjec, associate professor	
2) Name of the course: Heterocyclic Chemistry	
3) Study programme (undergraduate, graduate): Graduate	
4) Status of the course: Optional	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. Recognize and be able to designate certain heterocyclic compounds 2. Understand the impact of heteroatoms in the ring structures 3. Think critically and discuss aromaticity in heteroaromatic compounds 4. Propose synthetic route of target heterocyclic structure 5. Explain the factors that influence on the reactivity of functional groups in ring structures	**6) Learning outcomes at the level of the study programme:** 1. Identify, understand and apply complex chemical principles that build on basic knowledge of chemistry acquired in undergraduate studies; creatively develop and apply the ideas in the context of scientific research. 2. To apply acquired knowledge to solve qualitative and quantitative problems in a new context, including the selection and implementation of appropriate methodology. 3. Independently and self-directed acquire of new knowledge. 4. Perform advanced laboratory procedures and use of instrumentation in the context of chemical synthesis and analysis. 5. Independently plan and conduct the experiments, self-critically evaluate the experimental procedures and results. 6. Sum up objectively, evaluate and present the results of the work.

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	Learning outcomes	Evaluation criteria

FORM 2

1. Introduction to structure , properties and reactivity of heterocyclic compounds. Classification and Hantzsch-Widman nomenclature of monocyclic and bicyclic compounds, macrocyclic polyethers and annulenes	- distinguish main classes of heterocyclic compounds - determine aromatic and nonaromatic compounds - connect and use the terms of heterocyclic chemistry - apply the Hantzsch-Widman rules for naming heterocyclic compounds depending of the size of the heterocyclic compound and the number of heteroatoms	- analyze the structure of heterocyclic compounds, aromaticity and reactivity - designate the different classes of organic compounds and reproduce their structures - explain how factors affect the reactivity of functional groups in the heterocyclic structures
2. Heterocyclic compounds according to the size of the ring and the number of heteroatoms (oxirane, thiirane, aziridine, oxetane, thietane, azetidine, furan, thiophene, pyrrole, benzofuran, benzothiophene, indole, azoles, benzoazoles, pyridine, pyridinones, aminopyridines, alkylpyridines, pyridine N-oxides, pyrazine; aziridine, azepine, azocine, triazoles, thiazoles, benzopyridines , pyran, pyrilium salts, pyrones, coumarins, flavonoids,chromones, macrocycles): structures, properties, reactivity, reaction and synthesis	-apply the Hantz-Widman rules for naming heterocyclic compounds -define and explain the basic types of heterocycles reactions and their mechanisms -explain the influence of heteroatoms in the heterocyclic structures - present given topic in oral form independently or in a team - prepare, isolate, purify and identify some representatives of heterocyclic compounds	- designate heterocyclic compounds using the Hantzsch-Widman's rules - analyse and apply the chemical transformations and mechanisms for heterocyclic compounds - plan a synthetic route to a given heterocyclic system - present the results of work in oral and written form in a clear and understandable way

FORM 2

1) Course teacher: Dr. Marijana Hranjec, assoc. prof.; Dr. Tatjana Gazivoda Kraljević, assis. prof.
2) Name of the course: Organic Chemistry in Drug Development
3) Study programme (undergraduate, graduate): Graduate
4) Status of the course: Optional

5) Expected learning outcomes at the level of the course (4-10 learning outcomes):	**6) Learning outcomes at the level of the study programme:**
1. Define and explain the facts and concepts and apply complex principles related to medical chemistry and rational approach to drug design. 2. Recognize some of the targets of drug action and apply basic knowledge of organic chemistry and biochemistry in the understanding of the structure and mechanisms of biological action of main classes of drugs. 3. Analyze the targets of drug action and apply basic strategies of medicinal chemistry in the development of pharmacologically active compounds. 4. Use of modern laboratory methods and procedures in the synthesis of potential biologically active compounds, and analyze and present the results. 5. Interpret and present some types of drugs from selected therapeutic groups.	1. Identify, understand and apply complex chemical principles that build on basic knowledge of chemistry acquired in undergraduate studies. 2. Creatively develop and apply the ideas in the context of scientific research. 3. To apply acquired knowledge to solve qualitative and quantitative problems in a new context, including the selection and implementation of appropriate methodology. 4. Independently and self-directed acquire of new knowledge. 5. Perform advanced laboratory procedures and use of instrumentation in the context of chemical synthesis and analysis. 6. Independently plan and conduct the experiments, self-critically evaluate the experimental procedures and results. 7. Sum up objectively, evaluate and present the results of the work.

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Rational approach and medicinal chemistry strategies to drug design	1. Define the goals of research in medicinal chemistry and strategies for development of leading	1. Explain the rational approach to drug design 2. Define the goals of research in medicinal

	compounds 2. Apply strategies in a rational approach to drug design (bioisostery, prodrugs) 3. Identify and define the main targets of drug action 4. Interpret the function and importance of enzymes	chemistry and strategies for development of leading compounds and SAR 3. Explain the differences in mechanisms of action between different therapeutic classes of drugs 4. Explain the function and importance of enzymes 5. Explain the function of prodrugs
2. Classification of drugs according to the selected therapy groups (general and local anesthetics, sedatives and hypnotics, anticonvulsants and muscle relaxants, narcotic analgesics and antipyretic, cardiovascular drugs, antihistamines, non-steroidal anti-inflammatory drugs (NSAIDs), sulfonamides, anthelmintics and antimalarials, antibiotics, anticancer drugs, antiviral drugs)	1. Enumerate, identify and interpret types of drugs, their preparation, and the ways and mechanisms of their biological activity. 2. Classify drugs according to the selected therapeutic groups. 3. Analyze the mechanisms of the biological activity of certain types of drugs. 4. Synthesize choosen representatives of drugs by using some modern synthetic methods, and analyze, interpret and present the results.	1. Identify the types of drugs and explain ways and mechanisms of their biological activity. 2. Identify the types of drugs according to the selected therapeutic groups. 3. Explain the mechanisms of the biological activity of certain types of drugs. 4. Plan the synthesis of representatives of choosen drugs.

FORM 2

1) Course teacher: Prof. Silvana Raić-Malić, PhD
2) Name of the course: Chemistry of Natural Compounds
3) Study programme (undergraduate, graduate): Graduate
4) Status of the course: Optional

5) Expected learning outcomes at the level of the course (4-10 learning outcomes):	**6) Learning outcomes at the level of the study programme:**
1. To classify natural compounds according to their structures, physiological activity, natural source and biosynthetic pathway, 2. To identify structures of natural compounds and recognize their building blocks, 3. To explain physiological and biological (pharmacological and toxicological) properties of natural compounds involved in secondary metabolism, 4. To design total synthesis of representatives of selected natural compounds, 5. To create biosynthesis of some representatives of natural compounds.	1. A deeper knowledge and understanding of chemistry built upon the foundations of the Bachelors degree, which provides a basis for originality in developing and applying ideas within a research context, 2. Ability to demonstrate knowledge and understand essential facts, concepts, and chemical principles and theories relating to the advanced chemistry areas studied during the Masters programme, 3. Skills required for the conduct of advanced laboratory procedures and use of instrumentation in synthetic and analytical work, 4. Ability to plan and carry out experiments independently and be self-critical in the evaluation of experimental procedures and outcomes.

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Lipids	- to define structural characteristics and properties of fatty acids, triacylglyceroles and waxes, - to define complex lipids (phospholipids, sphingophospholipids and glycosphingolipids), - to explain basis of biosynthesis of fatty acids, - to relate structures with biological properties of	- to draw structures of representatives of saturated and unsaturated fatty acids and triacylglycerols (simple and mixed), - to distinguish building blocks of complex lipids and their biological importance, - to explain nomenclature of prostaglandins,

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	prostaglandins,	
2. Steroids	- to define structure and importance of steroids as sex hormones and corticoids,	- to illustrate by examples steroids as sex hormones, mineralocorticoids and glucocorticoids,
3. Terpenes	- to explain isoprene rules according to number of isoprene units, - to describe biosynthesis of terpenoids,	- to identify terpene type according to number of isoprene units, - to list and draw representatives of monocyclic, bicyclic monoterpenes, sesquiterpenes, diterpenes and triterpenes,
4. Alkaloids	- to classify alkaloids according to nitrogen contents and biosynthetic origin, - to explain physical properties and function of alkaloids in plants, - to subdivide alkaloids according to chemical structure, pharmacological action and biological origin,	- to illustrate representatives of following classes of alkaloids: protoalkaloids, alkaloids with pyrimidine, piperidine, pyrrolidine, quinoline, isoquinoline and indole ring, tropane and purine alkaloids, and to distinguish their biological properties,
5. Natural dyes and pigments	- to define structural characteristics of flavonoids, quinonoids, anthraquinones, anthocyanins, tannins and carotenoids,	- to draw the chemical structures of representatives of mentioned natural dyes and pigments classes and to design total synthesis of selected compound,
6. Vitamins	- to classify vitamins, explain their biological activities and identify natural source of vitamins,	- to draw the structure of vitamins soluble in water and fats, - to distinguish biologically active intermediates of vitamins,
7. Natural antibiotics	- to classify natural antibiotics according to their chemical structure,	- to identify and distinguish structural characteristics of β-lactams, tetracyclines, macrolides, polyenes, anthracyclines, aminoglycosides, polypeptide antibiotics,
8. Regulators of plant and insect	- to identify regulators of plant and insect growth, their biological properties and natural	- to define basic structural characteristics of regulators for growth, sex pheromones, plan

growth	source.	hormones, - to give an example of total synthesis of pheromones.

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1) Course teacher: Helena Otmačić Ćurković	
2) Name of the course: Corrosion and environment	
3) Study programme (undergraduate, graduate):graduate	
4) Status of the course:	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. identify hazards that corrosion and inadequate corrosion protection present to environment and human health; 2. identify how some of the corrosion protection methods may endanger environment and human health due to the release of toxic compounds; 3. estimate which corrosion protection method is the most adequate for given corrosion issue; 4. relate presence of pollution and climatic parameters to the corrosion level of various structural materials.	**6) Learning outcomes at the level of the study programme:** 1. adopt and develop competences and transferable skills suitable for employment as professional chemists in chemical and related industries in the public or private sector; 2. ability to clearly and unambiguously communicate scientific or technical concepts, data, and conclusions with the knowledge and rationale underpinning them to both specialist and non-specialist audiences in written and oral form; 3. skills required for the conduct of advanced laboratory procedures and use of instrumentation in synthetic and analytical work;

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	Learning outcomes	Evaluation criteria
1. Environment pollution	- indentify common sources of pollution -discuss different approaches towards reduction of pollution caused by industry	- student should indentify the most common sources of pollution -student should explain the principles of sustainable development
2. Corrosion processes	-explain causes of corrosion -distinguish various types of corrosion processes	- identify causes of corrosion and possible type of corrosion that will occur for specific material in given environment.

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		-write corrosion reactions for selected combination metal-environment
3. Harmful substances released to environment due to the corrosion or in corrosion protection	-explain which harmful substances can be released to environment due to the corrosion or in corrosion protection - explain the influence on environment and human health of the most common pollutants related to the corrosion processes	-name harmful compound that can be released from particular construction or process related to corrosion protection and explain its influence on environment and human health
4. Corrosion damage	-analyze the importance of corrosion protection for safe operation of various industrial processes and stability of metallic constructions, - identify the critical parts of metallic constructions or technological processes where inadequate corrosion protection may cause serious damage	-explain the causes of known corrosion failure -experimentally determine the corrosion rate of metallic materials used in medicine as implants.
5. Influence of environment parameters on corrosion type and rate	-correlate changes in environment with corrosion stability of metallic materials - relate presence of pollution and climatic parameters to the corrosion level of various structural materials	- explain key factors that lead to damage of cultural heritage and other constructions in polluted environment - experimentally determine corrosion rate of bronze in different environments
6. Corrosion protection methods	- identify potential hazards of application of various corrosion protection methods -explain which modifications in existing corrosion protection methods are	-explain potential hazards of some corrosion protection method and how they can be overcome

	needed to comply with recent environmental regulation	

FORM 2

1) Course teacher: prof.dr.sc. Emi Govorčin Basjić	
2) Name of the course: Polymer engineering materials	
3) Study programme (graduate): Chemical Engineering (1st and 2nd year) ; Applied Chemistry (1st and 2nd year)	
4) Status of the course:Elective	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. Distinguish molecular structure and super molecular structure of polymers and static structure and dynamic structure of polymers 2. Distinguish dynamic structure and properties of thermoplasts, duromers and elastomers at oscillating strain 3. Explain different types of degradation and process of flammability 4. Define of structure and properties of multiphase polymer systems 5.Choose the methods of processing of polymer materials into a finished product	**6) Learning outcomes at the level of the study programme:** 1. Recognise the specificities in behaviour of viscoelastic materials in regard to elastic solid and viscous liquid 2. Ability to analyse the durability of materials in production processes and in application 3. Ability to apply gained knowledge from structure and properties of polymers for production of new polymer materials 4. Ability to select and application of corresponding process in processing of polymer materials

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	Learning outcomes	Evaluation criteria
1. Static and dynamic structure of polymers	Distinguish the static and dynamic structure of polymers	
2. Deformation states of polymers	Distinguish the dynamic structure and properties of polymers in heating process	Report of laboratory exercise on DSC and MDSC instruments
3. Viscoelasticity	Distinguish the dynamic structure and properties of polymers at oscillating strain	Report of laboratory exercise on DMA instrument and rotational viscometer
4. Stability of polymer	Explain the process of	Report of laboratory exercise

materials	degradation and ageing of polymer materials	of photooxidative degradation of polymer materials
5. Polymer blends	Ability to define correlations of composition, structure and properties of multiphase polymer systems	Analysis of morphological structure of polymer blends by DSC, DMA, TGA i SEM technique Exercise and report
6. Procedures of polymer materials processing	Distinguish the basic procedures of polymer materials processing	
7. Extrusion	Analyse extrusion as a most common procedure in polymer processing	Report of laboratory exercise of preparation of polymer materials by extrusion
8. Moulding	Analyse of the moulding process of polymer materials	Report of laboratory exercise of moulding of polymer materials

FORM 2

1) Course teacher: Associated professor Danijela Ašperger, Ph.D.
2) Name of the course: Nondestructive methods of chemical analysis in art and archaeology, Applied Chemistry
3) Study programme (undergraduate, graduate): undergraduate (1st year, 1st semester, mag. appl. chem.)
4) Status of the course: optional

5) Expected learning outcomes at the level of the course (4-10 learning outcomes):	**6) Learning outcomes at the level of the study programme:**
1. Proper interpretation adopted theoretical knowledge related to methods of instrumental analysis and principles of instruments and procedural knowledge and skills related to practical performance measurement. 2. Explain the connection between basic knowledge in the application of instrumental analysis of artistic artifacts and artifacts of historical importance. 3. The ability for autonomously practice on the analysis of real samples (from sampling to interpretation of results) in the laboratory for instrumental analysis of non-destructive methods and further autonomously study having a positive attitude about the need for the development of professional competencies. 4. Integrate the acquired knowledge and apply them in problem solving and decision making in the restoration and conservation practice.	1. Ability to apply basic knowledge of the natural sciences in practice, especially in solving problems based on qualitative or quantitative information. 2. Numerical reasoning, numeracy and calculation skills, including such aspects as error analysis, order-of-magnitude estimations, and correct use of units. 3. Competence presentation materials related to the case study (oral and written) professional audience. 4. Monitoring, by observation and measurement, of chemical properties, events or changes, and the systematic and reliable recording and documentation there of. 5. Interpret data derived from laboratory observations and measurements in terms of their significance and relate them to appropriate theory. 6. Conduct risk assessments concerning the use of chemical substances and laboratory procedures. 7 Skills in planning and time management, and the ability to work autonomously. 8. Study skills and competences needed for continuing professional development.

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7) Teaching units with the corresponding learning outcomes and evaluation criteria		
Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Introduction to the role of analytical chemistry and the role of the analyst with the scientific and technical aspects in education of restorers-conservators. Tasks of laboratories, laboratory techniques and methods of sampling and sample preparation in the restoration and conservation purposes. Introducing approach artifacts of artistic and historical importance made of different materials	- Use, combine and compare different methods of sampling, micro-sampling, non-destructive sampling *in situ* for different artifacts. - Use, implement and choose different methods of transport, preparation and storage of samples for different artifacts to the analysis in the laboratory and/or *in situ*.	- Define, describe, classify and apply methods of sampling and sample preparation for different artifacts.
2. Instrumental methods of analysis with a focus on micro-destructive and non-destructive methods	- Adopt and define theoretical knowledge related to methods of instrumental analysis (spectrometry (PIXE, PIGE, RBS, FTIR, etc.), electroanalytical, thermochemical, instrumental separation methods, photographic and microbiological methods), and the principles of individual methods, and procedural knowledge and skills related to practical performance measurement, connect basic knowledge and newly acquired knowledge in the course of instrumental methods, identify the strengths and limitations of individual methods.	- Define, describe, classify, apply, identify and choose adequate instrumental analytical method for analysis different artifact.
3. Laboratory exercises	- Practice on the instruments (alone or in a small group) according to the curriculum of exercises on real samples. - Operate/use programs	- Concisely describe the experimental work - aim, methods, and results. - Autonomously interpretation the results in

	related to the work of the instrument. - Apply the statistical processing of numerical data and their graphical presentation. - Ability to record experimental data and write reports autonomously.	laboratory report.

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FORM 2

1) Course teachers: Associate. prof. Ana Lončarić Božić PhD, **Assistant prof. Hrvoje Kušić PhD**	
2) Name of the course: Environmental Engineering and Management	
3) Study programme: graduate	
4) Status of the course: elective	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. the ability to understand the concept of sustainable development within the environmental engineering and management practice. 2. the ability to correlate the characteristics of pollution sources and the opportunities for their reduction with the features of sustainable technologies 3.the ability to understand the main requirements of national Environmental protection law, IPPC directive and Environmental impact assessment study 4.the ability to apply instruments of sustainable environmental engineering and management practice	**6) Learning outcomes at the level of the study programme:** 1. the ability to apply fundamentals of chemical engineering in identifying and solving problems within the environmental engineering and management practice 2. the ability to understand the role of chemical engineering in proactive approach within the environmental engineering and management practice. 3. the ability to apply fundamental knowledge and methodological competences for solving environmental problems within the environmental engineering and management practice.

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1.Introduction to environmental engineering and management; Principles of proactive approach in integrated environmental management	- be acquainted with the key requirements of national Environmental protection law -adopt main terms in environmental engineering and management -understand the concept of sustainable development as a pillar of environmental management -adopt basic principles and elements of preventive	- explain the main terms in environmental engineering and management - identify sources of environmental pollution i.e. emission in soil, air and water -explain the principles of noise, light and odour pollution control -explain and apply proactive approach in waste management based on Cleaner production

FORM 2

	approach in environmental engineering and management - understand the role of chemical engineering in environmental protection and management	methodology - specify and apply the main principles in environmental management based on presented case study
2. Instruments of sustainable environmental management	-be acquainted with technologies of waste minimization and management - understand the risk assessment and management methodology -understand the basic principles of Environmental management systems -adopt instruments of sustainable environmental management (EMS,CP, RC) - be acquainted with the main features of IPPC directive -understand principles of EMAS and its integration in requirements national Environmental protection legislation	- specify the correlation between Environmental management systems (EMS) and other management systems such as QMS and OHSAS - explain the term Best available technology as a key component of IPPC directive - explain the concept and advantages of Integrated environmental management systems (IMS)

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FORM 2

1) Course teacher: Prof. Sanja Papić, PhD
Assoc. Prof. Ana Lončarić Božić, PhD

2) Name of the course: Risk Assessment

3) Study programme: graduate

4) Status of the course: elective

5) Expected learning outcomes at the level of the course (4-10 learning outcomes):	**6) Learning outcomes at the level of the study programme:**
1. Define risk and explain the categories of risk, the way of expressing risk, the risk assessment procedure and risk management. 2. Describe and classify the test methods as a vital component of the environmental risk assessment of chemicals. 3. Define the main factors in making an environmental risk assessment of chemicals and explain the assessment procedure. 4. Define and explain the major components of risk assessment to human health from chemicals. 5. Recognise legal requirements and basic elements of major accident hazards control for the operators of Seveso industrial sites 6. Identify the correlation of waste management activities with specific health and safety, and environmental risks. 7. Understand the risk assessment frameworks for household waste landfills and correlate specific activities and exposure paths with the corresponding risks. 8.Understand the methodology of data collection and analysis within the process of risk assessment 9.Adopt and apply qualitative and quantitative methods in risk assessment process	1. Basic professional knowledge of risk assessment and management in order to protect human health and the environment. 2. Involvement in the team work on the study on environmental protection. 3. The analysis and the interpretation of information about the process. 4. Critical analysis of problems in the field of environmental protection.

FORM 2

7) Teaching units with the corresponding learning outcomes and evaluation criteria		
Teaching unit	**Learning outcomes**	**Evaluation criteria**
1) Introduction to risk assessment Test methods: a vital component of the environmental risk assessment of chemicals	- define risk and explain the categories of risk, the way of expressing risk, the risk assessment procedure and risk management - describe and classify the test methods as a vital component of the environmental risk assessment of chemicals	- define risk - know the categories of risk - know the way of expressing risk - understand what includes risk assessment and risk management - know the standard testing methods of chemical substances used in the assessment of environmental risk - know the purpose, indicators and possible limitations of the testing methods (physico-chemical, biodegradation, bacterial toxicity, aquatic toxicity, soil, sediment and avian toxicity test methods)
2) Application of risk assessment methods to evaluate human health and ecological impacts of chemicals releases to the environment	- define the main factors in making an environmental risk assessment of chemicals and explain the assessment procedure - define and explain the major components of risk assessment to human health from chemicals	- know the procedures of environmental risk assessment according to EU Directives and know the assessment factors: aquatic, STP microorganism, sediment, terrestrial – define the main factors (predicted environmental concentration – PEC and predicted no effect concentration - PNEC) in making an environmental risk assessment of chemicals and show examples of

		calculations - in general describe the procedure of environmental risk assessment of chemicals - know the principles of some EU Directives or international agreements which control directly or indirectly the quantities of specific chemicals or chemical classes which may be used in or discharged to the environment (EQU-Environmental Quality Objectives; BATNEEC-Best Available Techniques not Entailing Excessive Cost, Precautionary principle) - know and understand the tools of the major components of risk assessment to human health from chemicals (hazard assessment, dose-response, exposure assessment, risk characterization)
3. Risk assessment for industrial sites and waste landfills	- Recognise and understand specify the legal requirements for risk control at industrial sites - Adopt the basic elements of major accident hazards control for the Seveso industrial sites - Understand the correlation of waste management activities with specific health and safety, and environmental risks. - Understand and the risk assessment frameworks for	- specify the main goals and requirements of Seveso II directive and their transposition into national legislation - explain the correlation between risk assessment elements and define their role in control of major accident hazards - define hazards according to Seveso II directive and explain the methodology of hazard identification. - demonstrate of the risk matrix and explain the

	household waste landfills - Correlate specific activities and exposure paths with the corresponding risks.	importance of its' application in risk management -list and explain the risk mitigation measures proposed within the national Waste management strategy -specify the sources, transportation and exposure paths for landfill gas and leachate with the risk assessment of landfill sites.
4. Qualitative and quantitative methods in risk assessment	- understand the methodology of data collection and analysis within the process of risk assessment - adopt and apply qualitative and quantitative methods in risk assessment process -	- list and explain the categories of scientific evidences i.e. information in risk assessment - demonstrate the application of Bayes' law in quantitative risk assessment - outline and explain the conceptual model of location in risk assessment - specify and describe types of logic trees and their application in risk assessment - outline event/decision tree based on the given example -describe the risk analysis procedure based on fault tree – demonstrate qualitative and quantitative analysis in risk assessment based on the given example using the fault tree

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FORM 2

1) Course teacher: Krešimir Košutić (Full Professor)

2) Name of the course: Membrane technology of water treatment

3) Study programme (undergraduate, graduate): The graduate study of Environmental engineering and Applied chemistry

4) Status of the course: optional

5) Expected learning outcomes at the level of the course (4-10 learning outcomes):

-Knowledge of materials for membrane preparation, preparation methods and the methods of characterization
- Classify membrane processes according to the driving force,

- Knowledge of membrane systems design
- Define mass transfer through the membrane, flux, define separation mechanisms
- Knowledge of the application of membrane technology in the water treatment: microfiltration, ultrafiltration, nanofiltration and reverse osmosis, HERO processes, electrodialysis
- Prepare and make laboratory experiments, analyze and interpret the results of experiments
- Prepare laboratory reports

- Get acquainted with the industrial RO desalination plant of brackish water through field-education

6) Learning outcomes at the level of the study programme:

1. advanced knowledge of mathematics, physics, chemistry and biology;
2. advanced knowledge of elementary engineering subjects;
3. professional knowledge of protecting the local and global environment, the enhancement and management of the environment, the legislation related to the protection of the environment;
4. professional knowledge from the field of water, air and ground management, waste and energy management;
5. independence and reliability in independent work;
6. efficiency, reliability and adaptability in team work;
7. the conducting of experiments and explaining the data retrieved during the experiment;
8. active participation in creative, synthetic and integrative activities related to the ecological and sustainability processes;
9. understanding of engineering processes and their design

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	Learning outcomes	Evaluation criteria

FORM 2

1.-2.The membrane; Membrane processes; membrane modules	- Define the concept of membranes, knowledge of various kinds materials for preparation membranes and membrane classify, - Define performance membranes, their selectivity and other physical and chemical characteristics - Classification of membrane operations by the driving force - Classify basic types of membrane modules that are applied in practice, recognize their strengths and weaknesses	Explain membrane processes in terms of the membrane, feed, retentate, permeate List types of industrial membrane processes Discuss membrane shapes and membrane modules
3.-6. Membrane systems-design	- Define dead-end and cross-flow - Describe single and multi-stage process, and batch system for smaller applications - Define dead-end and hybrid / cross-systems - Identify advantages cascading operations	Explain use of dead-end and crosss-flow membrane operation Explain use and advantages/disadvantages of cascades operations Calculate and estimate of conversion in spiral modul
7.-8. Mass transfer through the membrane, mass transport models	- Define and describe the mass transfer through the membrane (water transport, salt transport, specific flux) - Define the principles of retention and separation mechanism -Describe and distinguish of concentration polarization and membrane fouling-causes and ways of preventing in practice - Explain membrane permeation- permeation of gas, gas diffusion, pervaporation, membrane	Explain mass transfer of water and salt through membrane List membrane separation mechanism Explain concentration plarization List and explain causes of membrane fouling

	distillation -list and describe the electrical membrane processes (electrodialysis, membrane electrolysis, bipolar membrane) - Prepare and make a laboratory exercise RO / NF separation saline solution, processing and analysis of measurement data, and write a lab report	
9.-13. Pressure membrane processes: microfiltration, ultrafiltration, nanofiltration reverse osmosis, HERO process	- Describe the application of membrane processes MF, UF, NF and RO in water tretment - argue application: the case of industrial obtaining drinking water from the sea, from brackish water, getting ultrapure water	Explain osmosis and how reverse osmosis can be achived Differentiate between the asymmetric and thin layer composite membranes, and between microporous and dense membranes Explain desalination of sea and brackish water by reverse osmosis and nanofiltration
14. Electric membrane processes	-be able to describe principles of electrodialysis; membrane electrolysis, bipolar membranes and fuel cells	Expalin structure of cationic and anionic ion exchange membranes Explain mass transfer in dialysis and electrodialysis

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FORM 2

1) Course teacher: **Prof. Sanja Lučić Blagojević, Ph.D.**
2) Name of the course: **Polymer nanocomposites**
3) Study programme (undergraduate, graduate): **Graduate programme   Chemical engineering**
4) Status of the course: elective

5) Expected learning outcomes at the level of the course (4-10 learning outcomes):	**6) Learning outcomes at the level of the study programme:**
1. To relate knowledge of polymer materials engineering with surface and interfaces engineering in multiphase polymer systems. 2. To apply knowledge of the structure, properties, production of polymer nanocomposites. 3. To acquire knowledge on the application of polymer nanocomposites as advanced materials. 4. To acquire knowledge on selection techniques and methods for the characterization of multiphase systems and quality control of the product. 5. To analyze and synthesize scientific knowledge about the structure, preparation, properties and application of polymer nanocomposites on the experimental example and present it in oral form.	1. Understanding scientific principles important for chemistry and materials engineering. 2. The ability to identify and solve problems in the design of advanced materials using suitable chemical and engineering principles and theories. 3. Deepening of knowledge about advanced polymer materials. 4. Ability to apply techniques and methods of characterization of materials. 5. Ability of effective work and the presentation of the work in written and oral form.

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Differences between micro and nanocomposites	- to apply knowledge of surfaces and interfaces engineering in polymer	- explain the theory of adhesion (adsorption and chemisorption) at the

	composite systems - to analyze the differences in morphology and properties between micro and nanocomposites	interface of polymer / filler - explain and relate the impact of the filler particles size on the interface size, morphology and fraction of polymer in interphase layer
2. Nanofillers (carbon nanotubes, layered nanofillers, equi-axed nanofillers, quantum dots)	- to analyze and apply the role of chemistry and materials engineering in the synthesis of nanofillers - to choose nanofiller for a particular purpose depending on its structure and morphology - to understand the principles of chemical and physical surface modification of nanofiller	- describe the processes of synthesis of particular nano-filler - explain the relationship between structure and properties of nanofiller - explain surface modification of the nanofillers and define its advantages and disadvantages
3. Preparation of polymer nanocomposites	- to identify the optimal parameters of the preparation processes - to apply knowledge of thermodynamics in nanocomposite preparation processes - to link knowledge about polymer materials and processing	- explain the methodology of specific preparation process and specify their advantages and disadvantages - explain the role of entropy and enthalpy contributions in processes of nanocomposites preparation - identify key factors (structure of polymers and fillers, process parameters) that affect the morphology and structure of nanocomposites
	- to analyze the factors that affect the achievement of the advanced properties - to analyze and apply the mechanisms of nanofiller influence on predicting the properties of the polymeric nanocomposites	- define the impact of the fillers characteristics and surface modifications on the properties of polymer nanocomposites - explain the mechanisms of filler influence on the properties of nanocomposites (mechanical, thermal,

		electrical, optical, dimensional stability, gas permeability)

FORM 2

4) Course teachers: Associate. prof. Ana Lončarić Božić PhD	
5) Name of the course: Environmental management systems	
6) Study programme: graduate KI	
4) Status of the course: elective	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. the ability to apply the methodology of Environmental management systems based on Deming's cycle of continual improvement 2. the ability to analyse processes, activities and corresponding environmental aspects and impacts 3.the ability to propose preventive measure for potential environmental problems related to different processes and activities 4. the ability to recognise and response to the specific environmental issues related to inherent risks of chemical industry	**6) Learning outcomes at the level of the study programme:** 1. the ability to apply basics of professional protection of local and global environment, environmental development and control, and environmental legislation ; 2. the ability to perform critical analysis of environmental problems. 3. the ability to understand and solve environmental issues using environmental management tools

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Basic principles of sustainable development; Introduction to Environmental management system (EMS) based on Demig's cycle; ISO 14001	- adopt the preventive approach in environmental protection and management -understand the role of Demings' cycle in continual improvement - understand the significance of the main elements and their correlation within EMS - understand the requirements of ISO 14001 -analyse processes, activities and corresponding environmental aspects and impacts	- describe and explain the basic principles of preventive approach and EMS as a sustainable development tool -specify the elements of Demings' cycle and describe the concept of continual improvement - explain the requirements for environmental policy according to ISO 14001 -set "smart "EMS objectives based on given examples -define environmental aspects and impacts based on activities described in given

		case study - distinguish types of EMS documentation
2. Cleaner production, Life Cycle Analysis (LCA) and Responsible care	- understand and adopt the methodology of Cleaner production, Life Cycle Analysis (LCA) and Responsible care - correlate sources of waste in Cleaner production with corresponsive preventive measures - understand the importance and main characteristics of programme Responsible care in chemical industry	-describe and explain the basic elements of Cleaner production, Life Cycle Analysis (LCA) and Responsible care methodology -classify types of waste sources in Cleaner production -specify and explain applicability of preventive measures in Cleaner production -describe inherent environmental and health risks in chemical industry -explain principles of Responsible care their correlation with the EMS methodology

FORM 2

1) Course teacher: prof. dr. sc. Stanislav Kurajica	
2) Name of the course: X-ray diffraction in materials engineering	
3) Study programme (undergraduate, graduate): Applied chemistry (graduate)	
4) Status of the course: Electional	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. Understanding of the characteristics of the crystalline state, the importance of crystal structure for mechanical, physical and other properties of material, and the application of knowledge on understanding of structure and behavior of various materials. 2. Understanding the principles of emergence of X-rays, diffraction and working of diffractometer. 3. Accepting the skills necessary for work with diffractometer, conducting of experiment and for analysis of data obtained by measurement. 4. Ability for identification of crystal phases in powder sample, conducting of qualitative analysis, characterization of solid solution and microstructure. 5. Ability for critical thinking and capability for cognition and solving of problems in the area of X-ray diffraction and structural characterization. 6. Ability of applying the knowledge of mathematics and structure and properties of materials. 7. Ability to work in multidisciplinary team and communication skills.	**6) Learning outcomes at the level of the study programme:** 1. Application of scientific principles underlying chemistry, physics and chemical engineering on materials, their structure, properties, processing and performance. 2. Understanding and integration of four major elements of materials science and engineering: structure, properties, processing, and performance of materials, and application of this knowledge on practical issues. 3. The ability to choose and apply appropriate analytical methods and models for computational problem solving, including the use of commercial databases and analytical and modeling programs. 4. The ability to choose and apply appropriate analytical methods and models for computational problem solving, including the use of commercial databases and analytical and modeling programs. 5. Ability to apply gained knowledge in materials production processes and quality control, and in their improvement. 6. The ability to create solutions and independently solve problems (including the identification and formulation of the problem) in materials science and engineering. 7. Capability for further learning.

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	**Learning outcomes**	**Evaluation criteria**

FORM 2

1. Theoretical basis of crystallography and X-ray diffraction	Knowledge of damaging effects of ionizing radiation to humans. Understanding of principles of radiation protection. Knowledge of measurement units used for ionizing radiation. Application of safety rules for work with ionizing radiation. Understanding of crystalline nature of matter. Distinguishing between chemical bonds and knowing principles of arrangement of atoms, ions or molecules into crystal lattice. Understanding of the terms unit cell and crystal structure. Distinguishing between crystal systems and Bravais lattices. Knowing, recognizing and distinguishing of symmetry elements. Perceiving of crystallographic planes. Determination of Miller indices. Understanding of the concept of point and space group. Understanding the principle of X-rays formation. Knowing of nature and properties of X-rays. Distinguishing between continuous and characteristic spectrum. Knowing of X-rays detection methods. Knowing and understanding of phenomena occurring in interaction of X-rays diffraction with material. Interpretation of diffraction geometry.	Describe biological effect of ionizing radiation. List principles of radiation protection. Define important measurement units used dor ionizing radiation and dose limits. List security rules for work with ionizing radiation. Distinguish between crystal and amorphous state. Describe characteristics of crystalline state. List chemical bonds and the differences between them. Describe principles of arrangements of atoms, ions or molecules in crystal lattice. Define unit cell. List and describe crystal systems and Bravais latices. Distinguish, perceive and describe symmetry elements. Describe and perceive crystallographic planes and state corresponding Miller indices. Distinguish and explain terms point group and space group. Explain principle of X-rays Describe the nature and properties of X-rays. Distinguishing between continuous and characteristic spectrum. Describe X-ray detection methods. Describe phenomena occurring in interaction of X-rays with material. Define diffraction. Describe the geometry of diffraction. Define terms connected with

	Interpretation and application of Braggs law. Understanding of term reciprocal lattice. Understanding of dependence of diffraction lines intensity on crystal structure. Interpretation of scattering on electron, atom, unit cell and crystal. Understanding of the term structure factor.	X-ray diffraction. Describe Von Laue's approach. Specify and explain Bragg's law. Explain term reciprocal lattice. Explain the dependence of diffraction lines intensity on crystal structure. Describe scattering of radiation at electron, atom, unit cell and crystall. Define and describe structure factor.
2. Practical applications of diffraction methods	Distinguishing between different methods of X-ray diffraction analysis. Interpretation of diffraction on single crystal. Knowing of the parts of apparatus for powder X-ray diffraction. Application of the apparatus for powder X-ray diffraction. Knowing and application of sample preparation methods. Knowing and understanding of kinds and sorces of error in the diffraction data. Interpretation of data for the identification of crystal phases using ICDD database. The application of computer analysis for the interpretation of data, methods of atomatic identification of crystal phases. Interpretation of data for the determination of lattice parameters, solid solution characterization, determination of crystallite size and microstrain measurements. Interpretation of data for	Differentiate and explain different methods of conducting of X-ray diffraction experiment. Interpretation of measurement data obtained uding X-ray diffraction on single crystal. Description of working principle of powder X-ray diffraction apparatus. List and description of parts of powder X-ray diffraction apparatus. Describe and apply methods of sample preparation. State and explain most common sorces of measurement errors. Conduct measurement and interpret measurement data of qualitative analysis of single- and multi-component system using ICDD database. Apply computer analysis for interpretation of data and identification of crystal phases. Conduct measurement and interpret measurement data for the determination of

FORM 2

	quantitative analysis. The application of methods of outer and internal standards, addition, reference intensity ratio method. Knowing of the basics of structure solving and indexing of reflexes Understanding of Rietveld refinement method. Perceiving of factors influencing diffraction pattern. Application of Rietveld refinement on simple example. Perceiving of wide applicability of X-ray diffraction in materials engineering. Reproduction of various areas of application.	lattice parameters and characterization of solid solution. Conduct measurement and interpret measurement data for the determination of crystallite size and micro-strain measurement. Conduct measurement and interpret measurement data for the qualitative analysis. Discern, apply and analyze data obtained using various quantitative analysis methods. Conduct measurement and interpret measurement data for the determination of crystal structure and indexing. Describe Rietveld method Define factors influencing the appearance of diffraction pattern. Apply Rietveld refinement for simple sample. State the areas of application of X-ray diffraction in materials engineering. Describe important areas of application.

FORM 2

1) Course teacher: prof. dr. sc. Sandra Babić	
2) Name of the course: Quality management	
3) Study programme (undergraduate, graduate): graduate	
4) Status of the course: core	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. Ability to explain the role, development and application of quality management system. 2. Ability to explain the role, development and application of quality assurance system in analytical laboratory. 3. Ability to apply the proper numerical method in solving of quality problems. 4. Ability to describe norm and normisation.	**6) Learning outcomes at the level of the study programme:** 1. Ability to clearly and unambiguously communicate scientific or technical concepts, data, and conclusions with the knowledge and rationale underpinning them to both specialist and non-specialist audiences in written and oral form. 2. Ability to apply such knowledge and understanding to the solution of qualitative and quantitative problems which may be formulated in an unfamiliar way, and to adopt and apply appropriate methodology to solving such problems 3. Ability to apply knowledge and understanding, and problem solving abilities, in new or unfamiliar environments within broader (or multidisciplinary) contexts related to the chemical sciences 4. Ability to assimilate and integrate knowledge, to handle complex ideas, and to formulate judgments within complete or limited information. 5. Ability to assimilate, evaluate and present research results objectively. 6. Ability to use an understanding of the limits of accuracy of experimental data to inform the planning of future work.

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	Learning outcomes	Evaluation criteria

FORM 2

1.Quality management system	- describe the role of quality system - apply the acquired knowledge in the development of quality system	- define the quality - enumerate the basic principles of quality management system - explain the process approach to quality management - explain the planning, establishment and documentation of quality management - explain the quality control - explain the independent quality evaluation - explain quality improvement - explain quality assurance
2. Quality assurance in analytical laboratory	- explain the role, development and application of quality assurance system in analytical laboratory	- enumerate the sources of errors - explain validation of sampling, method validation and validation of data - define the measurement uncertainty - explain the evaluation of measurement uncertainty - distinguish between internal and external quality evaluation - define the reference materials - explain the role of reference materials - define the traceability - explain the ways of proving the traceability in the measurement
3. Statistical methods in	- apply the proper numerical	- define the normal

FORM 2

quality management system	method in the solving of quality problems	distribution - explain and apply the statistical tests - explain and apply Ishikawa chart - explain and apply Pareto analysis - explain and apply control charts
4. Norm and normisation	- explain the role of normisation	- define the norm - explain the normisation procedure - identify aims of normisation - enumerate norms for quality system and laboratory accreditation

FORM 2

1) Course teacher: Dr Ivana Steinberg, Assistant Professor	
2) Name of the course: Technology management and Innovation	
3) Study programme (undergraduate, graduate): graduate	
4) Status of the course: compulsory	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. Recognise and explain the role of innovation in the context of research and development in public and private institutions 2. Identify and distinguish: intellectual property (IP) and intellectual property rights (IPRs) and illustrate them by practical examples 3. Describe and define *transfer of technology* and strategic exploitation of IPR 4. Define new product development process and identify its steps 5. Apply methodology of project management 6. Create and prepare a business plan for a new high-tech start-up company based on a chosen patent	**6) Learning outcomes at the level of the study programme:** 1. Adopt and develop competences and transferable skills suitable for employment as professional chemists in chemical and related industries in the public or private sector 2. Apply knowledge and understanding, and problem solving abilities, in new or unfamiliar environments within broader (or multidisciplinary) contexts related to the chemical sciences 3. Attain academic standards appropriate for access to third cycle course units or degree programs 4. Assimilate and integrate knowledge, to handle complex ideas, and to formulate judgments with incomplete or limited information 5. Clearly and unambiguously communicate scientific or technical concepts, data, and conclusions with the knowledge and rationale underpinning them to both specialist and non-specialist audiences in written and oral form 6. Adopt learning skills that allow them to continue to study in a manner that may be largely self-directed or autonomous 7. Acquire study skills necessary for continuing professional development 8. Interact with scientists from other disciplines on inter- or multidisciplinary problems 9. Time management and project planning skills

	10. Team work and autonomous work with minimal supervision

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Innovation and R&D (research and development)	The student will be able to: 1.Recognise importance of innovation in general and describe its relevance to R&D 2. Relate investments in R&D to social environment and potential impacts on society 3. Describe the term *technology waves* and relate it to government investment to R&D.	1. Analyse an example of a company with R&D unit in terms of business sector, its revenue and investment in R&D) 2. Identify and analyse real examples of government investment in R&D
2. Intellectual property (IP)	The student will be able to: 1. Define and distinguish intellectual property (IP) and intellectual property rights (IPRs) and illustrate them by practical examples 2. Identify and describe different forms of IP 3. Define and analyse a patent 4. Apply on-line patent research methodology to identify suitable patents	1. Classify forms of intellectual property and select appropriate IP form for a given example 2. Demonstrate advantages of chosen IP form 3. Use an on-line patent database to search and select a patent using given keywords 4. Choose a patent related to the given chemistry area appropriate for high-tech applications (innovative product or service) 5. Analyse main parts of a patent application
3. Technology transfer and exploitation of IPR	The student will be able to: 1. Describe and define different forms of IPR	1. Identify potential patents for licencing to the chosen company on the global

FORM 2

	exploitation 2.Recognise main parts of a licence agreement 3.Expalin and illustrate terms related to exploitation of IPR: transfer of technology; seed financing, joint venture company 4. Identify sources of financing for start-up companies and specify and compare their advantages or disadvantages	market 2. Decide and justify choice of real companies appropriate for licencing to a given patent 3. Sketch a simple patent licence agreement
4. Project management and new product development (NPD)	The student will be able to: 1. Describe and interpret steps in the process of new product development (NPD) 2. Distinguish traditional and integrated approach to NPD 3. Analyse a typical life cycle curve of a product and identify its parts 4. Identify and explain basic methods and tools of project management and project planning	1. Apply *brainstorming* technique to generate ideas for development of an innovative product or service based on a patent 2. Plan and present a project using *Gantt* chart 3. Predict and present a *cash-flow* chart as a part of the business plan
5. Technology start-up companies and business plans	The student will be able to: 1. Recognise the meaning of a business plan (BP) in relation to technology start-up companies 2. Define and explain the main parts of a business plan 3. Summarize and combine knowledge gained in previous units (innovation, IP, patents, project management, new product development, technology	1. Create a business plan for a technology start-up company based on a selected real patent as a form of IP 2. Present a part of BP as a member of a company team and discuss it with “potential investors”

	transfer) and prepare a business plan for a technology start-up company	

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FORM 2

1) Course teacher: prof. dr. sc. Sandra Babić **prof. dr. sc. Tomislav Bolanča**
2) Name of the course: Advanced separation techniques in environmental chemistry
3) Study programme (graduate): Applied chemistry
4) Status of the course: optional

5) Expected learning outcomes at the level of the course (4-10 learning outcomes):	**6) Learning outcomes at the level of the study programme:**
1. Ability to interpret theoretical knowledge about separation methods 2. Explain the basic principles underlying modern separation techniques. 3. Ability to explain the role of separation techniques in chemical analysis and environmental protection. 4. Ability to classify and discuss different sampling procedures, extraction procedure, and separation techniques in quantitative analysis of complex environmental samples. 5. Ability to work independently in analytical laboratory and understand the necessity of continual professional development. 6. Ability to synthesized the acquired knowledge and applied in problem solving and decision making in analysis of complex environmental samples. 7. Ability to define and applied rules of safety laboratory work and good laboratory practice (GLP). …..	1. Ability to apply basic knowledge and understanding to the solution of qualitative and quantitative problems which may be formulated in an unfamiliar way, and to adopt and apply appropriate methodology to solving such problems. 2. Ability to assimilate, evaluate and present research results objectively. 3. Ability to plan and carry out experiments independently and be self-critical in the evaluation of experimental procedures and outcomes. 4. Ability to clearly and unambiguously communicate scientific or technical concepts, data, and conclusions with the knowledge and rationale underpinning them to both specialist and non-specialist audiences in written and oral form. 5. Skills required for the conduct of advanced laboratory procedures and use of instrumentation in synthetic and analytical work. 6. To have acquired study skills necessary for continuing professional development.

FORM 2

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	Learning outcomes	Evaluation criteria
1. The role of separation techniques in chemical analysis and environmental protection	- explain the role of separation techniques in chemical analysis - explain the role of separation techniques in environmental protection	- enumerate the separation techniques - state the aims of sample preparation for chemical analysis
2. Sample and sampling	- explain and discus the sampling procedures for environmental samples	- explain the representative sample - enumerate and explain sampling techniques - discus and compare the different sampling plans
3. Advanced separation techniques for sample preparation	- discus the development of sample preparation techniques for quantitative analysis of environmental samples - explain and discus advanced extraction procedures including liquid-liquid extraction and extraction from solid samples	- plan the sample preparation procedure based on analite and sample matrix - state the procedures that precede and follow extraction procedure - explain the liquid-liquid extraction, define and distinguish between partition coefficient and partition ratio - explain the effects that influence the extraction of solid samples - explain and discus the extraction of weak acids and meal ions
4. Advanced separation techniques for quantitative analysis (chromatography, electrophoresis, mass spectrometry)	- demonstrate the theoretical knowledge on separation instrumental analysis (chromatography, electrophoresis and mass spectrometry) - explain the principles of	- demonstrate theoretical knowledge and understanding of the basic of instrumental analytical separation methods

	instrumental analysis - collect basic knowledge and new knowledge acquired on the course Advanced separation techniques in environmental chemistry - discuss the advantages and disadvantages of each method	
5. Laboratory exercises	- apply chemical lows in identification and separation of analites form real environmental samples - understanding and application of principles of good laboratory practice (GLP) and safe laboratory work	- practical work on analytical instruments - analite separation from real environmental samples (solid phase extraction) - quantitative instrumental analysis (high performance liquid chromatography) - writing the laboratory notes, data analysis, graphical presentation and interpretation of obtained results - apply the GLP principles

FORM 2

1) Course teacher: Associated professor Danijela Ašperger, Ph.D.
2) Name of the course: Nondestructive methods of chemical analysis in art and archaeology, Applied Chemistry
3) Study programme (undergraduate, graduate): undergraduate (2nd year, 3rd semester, mag. appl. chem.)
4) Status of the course: optional

5) Expected learning outcomes at the level of the course (4-10 learning outcomes):	**6) Learning outcomes at the level of the study programme:**
1. Proper interpretation adopted theoretical knowledge related to methods of instrumental analysis and principles of instruments and procedural knowledge and skills related to practical performance measurement. 2. Explain the connection between basic knowledge in the application of instrumental analysis of artistic artifacts and artifacts of historical importance. 3. The ability for autonomously practice on the analysis of real samples (from sampling to interpretation of results) in the laboratory for instrumental analysis of non-destructive methods and further autonomously study having a positive attitude about the need for the development of professional competencies. 4. Integrate the acquired knowledge and apply them in problem solving and decision making in the restoration and conservation practice.	1. Ability to apply basic knowledge of the natural sciences in practice, especially in solving problems based on qualitative or quantitative information. 2. Numerical reasoning, numeracy and calculation skills, including such aspects as error analysis, order-of-magnitude estimations, and correct use of units. 3. Competence presentation materials related to the case study (oral and written) professional audience. 4. Monitoring, by observation and measurement, of chemical properties, events or changes, and the systematic and reliable recording and documentation there of. 5. Interpret data derived from laboratory observations and measurements in terms of their significance and relate them to appropriate theory. 6. Conduct risk assessments concerning the use of chemical substances and laboratory procedures. 7 Skills in planning and time management, and the ability to work autonomously. 8. Study skills and competences needed for continuing professional development.

7) Teaching units with the corresponding learning outcomes and evaluation criteria		
Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Introduction to the role of analytical chemistry and the role of the analyst with the scientific and technical aspects in education of restorers-conservators. Tasks of laboratories, laboratory techniques and methods of sampling and sample preparation in the restoration and conservation purposes. Introducing approach artifacts of artistic and historical importance made of different materials	- Use, combine and compare different methods of sampling, micro-sampling, non-destructive sampling *in situ* for different artifacts. - Use, implement and choose different methods of transport, preparation and storage of samples for different artifacts to the analysis in the laboratory and/or *in situ*.	- Define, describe, classify and apply methods of sampling and sample preparation for different artifacts.
2. Instrumental methods of analysis with a focus on micro-destructive and non-destructive methods	- Adopt and define theoretical knowledge related to methods of instrumental analysis (spectrometry (PIXE, PIGE, RBS, FTIR, etc.), electroanalytical, thermochemical, instrumental separation methods, photographic and microbiological methods), and the principles of individual methods, and procedural knowledge and skills related to practical performance measurement, connect basic knowledge and newly acquired knowledge in the course of instrumental methods, identify the strengths and limitations of individual methods.	- Define, describe, classify, apply, identify and choose adequate instrumental analytical method for analysis different artifact.
3. Laboratory exercises	- Practice on the instruments (alone or in a small group) according to the curriculum of exercises on real samples. - Operate/use programs	- Concisely describe the experimental work - aim, methods, and results. - Autonomously interpretation the results in

	related to the work of the instrument. - Apply the statistical processing of numerical data and their graphical presentation. - Ability to record experimental data and write reports autonomously.	laboratory report.

FORM 2

1) Course teacher: Mandić Zoran, PhD, associate professor
2) Name of the course: Conducting polymers-synthetic metals
3) Study programme (undergraduate, graduate): graduated
4) Status of the course: elected

5) Expected learning outcomes at the level of the course (4-10 learning outcomes):	**6) Learning outcomes at the level of the study programme:**
1. recognise scientific and technological role and importance of electrically conducting polymers 2. apply modern analytical and physico-chemical methods in the development and application of conducting polymers 3. define principles of conductivity in order to prepare and improve conducting polymer properties 4. distinguish polymer structures that belong to the group of conducting polymers	1. the ability to create solutions and independently solve problems (including the identification and formulation of the problem) in materials science and engineering; 2. ability to solve problems in production and performance of materials with the aid of chemical and physical techniques and instrumental methods of materials analysis; 3. ability to function effectively as an individual or as a member of a multi-disciplinary team, and to present the work in both written and oral form;

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	Learning outcomes	Evaluation criteria
1. Electrical conductivity	-give an example of conducting polymers -distinguish the difference between conventional polymer and conducting polymer -describe intrinsic conductivity and doping process of conducting polymers	-sketch conducting polymer structure -explain intrinsic conductivity mechanism and doping process of conducting polymers -recognise structure of electronically and ionically conducting polymer -demonstrate the method that

	-distinguish the difference between electronically conducting polymers and ionically conducting polymers -explain the method that can be used to determine electrical conductivity of conducting polymers	can be used to determine electrical conductivity of conducting polymers
2. Synthesis of conducting polymers	-explain synthesis mechanism of conducting polymers -memorise the most important synthesis procedures and monomers -explain nucleation mechanism of conducting polymer at metal support	-illustrate synthesis mechanism of conducting polymers -state the most important synthesis procedures and monomers -illustrate nucleation mechanism of conducting polymer at metal support
3. Properties and application of conducting polymers	-relate structure, properties, processing, and performance of conducting polymers and apply this knowledge on practical issues -explain influence of counter-ion and substituent on conducting polymer properties -outline morphological properties of conductive polymers -explain electrochromic properties of conducting polymers -predict applications of conducting polymers in	-give an example of counter-ion and substituent influence on conducting polymer properties -relate morphological properties and application of conducting polymers -relate electrochromic properties and application of conducting properties -select appropriate techniques for investigations of conducting polymers

	various fields of technologies -describe techniques used in the field of conducting polymers -describe methods of preparation and properties of nanostructurised conductng polymers	

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FORM 2

1) Course teacher: Sanja Martinez, PhD, full professor	
2) Name of the course: Corrosion Stability of Materials	
3) Study programme (undergraduate, graduate): graduate	
4) Status of the course: optional	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): After learning students will be able to: 1. Apply the acquired knowledge to identify and solve practical problems of corrosion stability of materials. 2. Apply and monitor corrosion measurements and interpret their results. 3. Use the relevant literature and standards and apply good engineering practice in the field of corrosion.	**6) Learning outcomes at the level of the study programme:** After learning students will be able to: 1. Identify corrosion engineering problems and formulate and propose the solutions. 2. Apply techniques, skills and engineering tools necessary in modern corrosion engineering and corrosion management practice. 3. Design and conduct corrosion measurements and interpret the measured data.

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	Learning outcomes	Evaluation criteria
1. Identification of the causes of corrosion and assessment of the corrosion rate.	After learning students will be able to: - identify the most probable corrosion cause and calculate or estimate the corrosion rate in a particular corrosion system	After learning students will be able to: - draw a conclusion on the cause of corrosion on the basis of the appearance of corrosion damage, corrosion history and / or laboratory measurements - calculate the corrosion rate from measurements or assesse it on the basis of literature data - reach conclusions about the consequences that corrosion has on the durability of the

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		system
2. Corrosion stability of materials and corrosion management	- show basic knowledge of corrosion management and risk analysis in corrosion - describe indirect measurement techniques and the direct techniques of corrosion monitoring applied in the context of corrosion management	- define the basic concepts and use the basic terminology in the field of corrosion management - analyse the results of various indirect measurement techniques and demonstrate knowledge of the principles of their functioning - analyse the results of different techniques of corrosion monitoring and demonstrate knowledge of the principles of their functioning

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FORM 2

1) Course teacher:

Professor Ante Jukić, PhD

2) Name of the course: Hydrogen Energy and Economy

3) Study programme: Graduate

4) Status of the course: Elected

5) Expected learning outcomes at the level of the course:	**6) Learning outcomes at the level of the study programme:**
- to analyze structure of the energy sector from the primary sources diversibility, energy efficiency and environmental impact view. - to define and describe fossil and renewable fuels. - to recognize and describe advantages and disadvatages of hydrogen use as energy carrier. - to define and describe the main hydrogen production technologies. - to idetify reaction mechanisms and chemical reaction routes of the processes. - to explain and arrange process flow diagrams. - to idetify critical challenges, major R&D needs and key benefits for the main hydrogen production technologies.	1. Ability to demonstrate knowledge and understand essential facts, concepts, and chemical principles and theories relating to the advanced chemistry areas. 2. Ability to apply knowledge and understanding, and problem solving abilities, in new or unfamiliar environments within broader (or multidisciplinary) contexts related to the chemical sciences. 3. Ability to assimilate and integrate knowledge, to handle complex ideas, and to formulate judgments with incomplete or limited information. 4. Ability to clearly and unambiguously communicate scientific or technical concepts, data, and conclusions with the knowledge and rationale underpinning them to both specialist and non-specialist audiences in written and oral form. 5. Ability to interact with scientists from other disciplines on inter- or multidisciplinary problems.

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Structure of the energy sector, motivation for an additional energy carrier.	- to analyze structure of the energy sector from the primary sources diversibility, energy efficiency and environmental impact view. - to define and describe fossil	- to define ideal energy source, energy carrier and conversion devices. - to evaluate and compare fossil and renewable fuels. - to indicate and explain

	and renewable fuels. - to recognize and describe advantages and disadvatages of hydrogen use as energy carrier.	advantages and disadvatages of hydrogen use as energy carrier.
2. Hydrogen production processes: steam reforming, partial oxidation, gasification, water electrolysis, thermochemical (high-temperature) water splitting.	- to define and describe the main hydrogen production technologies. - to idetify reaction mechanisms and routes of the processes. - to explain and arrange process flow diagrams. - to idetify critical challenges, major R&D needs and key benefits for the main hydrogen production technologies.	- to draw appropriate reaction routes. - to outline process flow diagrams for the main hydrogen production technologies. - to evaluate the main hydrogen production technologies.

FORM 2

1) Course teacher: Dr. Marijana Hranjec, associate professor

2) Name of the course: Heterocyclic Antitumor Drugs

3) Study programme (undergraduate, graduate): Graduate

4) Status of the course: Optional

5) Expected learning outcomes at the level of the course (4-10 learning outcomes):

1. Identify and differentiate groups of heterocyclic anticancer drugs according to mechanism of their biological activity.
2. To understand and interpret some of the important biological processes in the body associated with the occurrence of tumor cells.
3. Identify the function of certain highly selective enzymes whose activities are associated with the development of tumor cells.
4. Become familiar with the latest principles of anticancer chemotherapy.
5. Apply acquired knowledge and synthesize potential anticancer drugs.

6) Learning outcomes at the level of the study programme:

1. To identify, understand and apply complex chemical principles that build on basic knowledge of chemistry acquired in undergraduate studies; creatively develop and apply the ideas in the context of scientific research.
2. To apply acquired knowledge to solve qualitative and quantitative problems in a new context, including the selection and implementation of appropriate methodology.
3. Independently and self-directed acquire new knowledge.
4. Sum up objectively, evaluate and present the results of the work.
5. Perform advanced laboratory procedures and use of instrumentation in the context of chemical synthesis and analysis.
6. Independently plan and conduct the experiments, self-critically evaluate the experimental procedures and results.

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Anticancer drugs whose biological activity is associated with metabolic processes, hormones and radical mehanizmina in the human body.	- to define groups of heterocyclic anticancer drugs under the said teaching unit - to recognize the characteristic drugs from	- to regognize the group of an antitumor drug to a given structure of the drug - determine the structural characteristics of a particular group of anticancer drugs

FORM 2

	each group listed - identify and analyze the mechanisms of action of the mentioned group of anticancer drugs	- understand the differences in mechanisms of action among various groups of drugs
2. Antitumor drugs whose biological activity is associated with biomakromolekulama DNA / RNA.	- define and enumerate groups of anticancer drugs with respect to their interaction with DNA / RNA - know the mechanism of biological action of intercalators, groove binders and alkylating agents - identify the best-known drugs from the above group of anticancer drugs	- to regognize a group of an antitumor drug according to a given structure of the drug - to interpret the structural characteristics of intercalators, groove binders and alkylating agents - understand the difference between the mechanisms of action of groove binders, the intercalators and alkylating agents
3. Antitumor drugs whose biological activity associated with highly selective inhibition of the enzyme.	- to learn about the function of certain enzymes whose activities are associated with the development of tumor cells - define the group of anticancer drugs with regard to inhibition of highly specific enzymes - identify and analyze the mechanism of action of some groups of drugs in this group	- to know all highly selective enzymes whose activities are associated with the development of tumor cells - to regognize a group of anti-tumor drug according to a given characteristic structure - to understand the main differences between the way the biological activity of a group from this group of anticancer drugs
4. Latest principles of antitumor chemotherapy.	- be familiar with the basics of the latest principles of anticancer chemotherapy - to identify and analyze groups of anticancer drugs in this group - be familiar with the differences of modern principles of anticancer chemotherapy in relation to the aforementioned mechanisms of heterocyclic anticancer	- to know the group of drugs whose mechanism is based on the latest principles of anticancer chemotherapy - understand the differences between the latest principles of anticancer chemotherapy - to define the structural characteristics of individual groups in this group of anticancer drugs - to be familiar with the importance and differences of modern principles of

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	drugs	anticancer chemotherapy in comparison to the aforementioned heterocyclic group of anticancer drugs

FORM 2

1) Course teacher: Dr. Marijana Hranjec, associate professor	
2) Name of the course: Microwave Assisted Chemistry	
3) Study programme (undergraduate, graduate): Graduate	
4) Status of the course: Optional	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. Define and analyze the basic and the principles of microwave irradiation and microwaves. 2. Become familiar with the principles and methods of performance microwave synthesis. 3. Identify differences of classical organic synthesis with respect to the microwave assisted synthesis. 4. Present and interpret the synthesis review of the suitable heterocyclic compounds prepared by using microwave synthesis. 5. Become familiar with the application of microwave synthesis in green chemistry. 6. Synthesize organic compounds by using microwave assisted synthesis.	**6) Learning outcomes at the level of the study programme:** 1.To identify, understand and apply complex chemical principles that build on basic knowledge of chemistry acquired in undergraduate studies; creatively develop and apply the ideas in the context of scientific research. 2. To apply acquired knowledge to solve qualitative and quantitative problems in a new context, including the selection and implementation of appropriate methodology. 3. Independently and self-directed acquire new knowledge. 4. Sum up objectively, evaluate and present the results of the work. 5. Independently plan and conduct the experiments, self-critically evaluate the experimental procedures and results. 6. To acquire competencies and skills relevant to employment in the chemical or allied industries, in public or private sector.

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	Learning outcomes	Evaluation criteria
1. Introduction to the microwave theory and microwave synthesis and the performance way of organic reactions in a microwave oven.	- define the basic principles of microwave synthesis and microwaves - become familiar with the types of microwave ovens and reactors - get to know and analyze the	- understand the basics of microwave radiation - to know how to perform the microwave synthesis - understand the selection of appropriate techniques for microwave synthesis of

	techniques of microwave synthesis - define the methods of development and its optimization	selected heterocyclic group of compounds - apply and integrate acquired knowledge in the filed for optimizing the various methods of microwave synthesis
2. Microwaves in green chemistry and sustainability of microwave assisted synthesis.	- become familiar with the use of microwaves in green chemistry - compare the effectiveness and benefits of microwave radiation in green chemistry and other fields of application - interpret and present the problems related to the sustainability of microwave assisted synthesis	- based on the acquired knowledge to discuss the importance of microwave irradiation in green chemistry - know the advantages of using microwave irradiation in green chemistry - know to discuss about the sustainability of microwave assisted synthesis
3. Overview of the microwave synthesis of different heterocyclic compounds.	- define and identify appropriate reactions of microwave assisted synthesis of heterocyclic compounds - interpret commonly used microwave synthesis reactions - to spot the problems associated with the synthesis of heterocyclic compounds assisted by microwaves	- to know and analyze the microwave synthesis reactions for the synthesis of the corresponding heterocyclic compounds - to know the most commonly used reactions of microwave synthesis of heterocyclic compounds - recognize and understand the problems associated with the synthesis of heterocyclic compounds assisted by microwaves

FORM 2

1) Course teacher: Prof. Silvana Raić-Malić, PhD
2) Name of the course: Antivirotics and Cytostatics
3) Study programme (undergraduate, graduate): Graduate
4) Status of the course: Optional

5) Expected learning outcomes at the level of the course (4-10 learning outcomes):	**6) Learning outcomes at the level of the study programme:**
1. To classify viruses that cause viral infection and explain their life cycle, 2. To define the most successful antivirotics in the treatment of viral infections and to explain the synthesis of their representatives, 3. To subdivide cytostatics according to their targets and to illustrate retrosynthetic approach and total synthesis of selected example, 4. To point out biochemical mechanism of drug action by defining the target for both antivirotics and cytostatics.	1. A deeper knowledge and understanding of chemistry built upon the foundations of the Bachelors degree, which provides a basis for originality in developing and applying ideas within a research context, 2. Ability to demonstrate knowledge and understand essential facts, concepts, and chemical principles and theories relating to the advanced chemistry areas studied during the Masters programme, 3. Skills required for the conduct of advanced laboratory procedures and use of instrumentation in synthetic and analytical work, 4. Ability to plan and carry out experiments independently and be self-critical in the evaluation of experimental procedures and outcomes.

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	Learning outcomes	Evaluation criteria
1. Antivirotics	- to classify viruses that cause viral infections, - to explain life cycle of virus as basis for selection of drug targets, - to subdivide antivirotics for treatment of viral infections and to explain their synthesis, - to distinguish biochemical targets of drug action: inhibitors of DNA-polymerase, inhibitors of reverse transcriptase, absorption inhibitors, inhibitors of fusion, viral envelope rejection, inhibitors of HIV	- to distinguish DNA and RNA viruses, and antiviral drugs for treatment of corresponding infections, - to explain etiology of viral infections, - to list main representatives of antiviral agents and their structural characteristics, - to draw structures of the most successful antiviral agents, - to illustrate synthetic approach for selected antivirotcs, - to differentiate mechanism of

	protease, inhibitors of ionic channels, - to point out application of prodrug strategy and antisense oligonucleotides in antiviral chemotherapy,	action of compounds against various viruses according to their targets, - to illustrate by examples antisense oligonucleotide therapy and prodrug approach in antiviral chemotherapy,
2. Cytostatics	- to explain molecular mechanism of cancer cell deregulation, - to subdivide cytostatics according to their targets, - to relate antimetabolites with their mechanism of action, - to describe and compare the mechanism of action of alkylating and non-alkylating compounds that interact with the DNA and DNA intercalators, - to describe action of anticancer antibiotics, - to describe and compare activity of anticancer drugs that target tubulin and microtubules, - to explain action of anticancer drugs that inhibit hormone, - to list inhibitors of protein and receptor kinases and to select the most efficient ones, - to define new biological targets and therapeutic strategy: inhibitors of cancer cell resistance to drugs, glycoprotein efflux pump, DNA repair, PARP enzyme, telomerase, heat-shock proteins (HSP 90), epigenetic therapy, antimetastatic agens, antisense therapy.	- to identify important representatives of antimetabolites and their target enzymes, - to distinguish drugs that bind to DNA reversible, by covalent bonds or generate reactive radicals, - to illustrate by example electrostatic binding of drug to DNA, binding to DNA minor groove and DNA intercalating agents, - to explain mechanism of action of glycopeptides, anthracyclines and en-di-yne anticancer antibiotics, - to illustrate by example retrosynthetic analysis and total synthesis of en-di-yne anticancer antibiotic, - to explain biochemical mechanism of microtubules generation, - to clarify the rational approach in the development of inhibitors of fusion gene Bcr-Abl, - to illustrate by example new biological targets that have potential in development of drug candidates in future.

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1) Course teacher: Prof. Zlata Hrnjak-Murgić, PhD
2) Name of the course: Polymer Science and Technology
3) Study programme (undergraduate, graduate): graduate
4) Status of the course: elective

5) Expected learning outcomes at the level of the course (4-10 learning outcomes):	**6) Learning outcomes at the level of the study programme:**
1. to collect the basic knowledge about main polymerization reactions 2. to describe and understand the the types of homogeneous and heterogeneous polymerization processes 3. to understand the relationship structure – properties of polymer materials 4. to learn important technologies for polymer processing 5. to understand the knowledge related the polymer degradation and stability 6. to describe and understand the biopolymers	1. application of scientific principles underlying chemistry and chemical engineering on materials, their structure, properties, processing and performance 2. ability to function effectively as an individual or as a member of a multi-disciplinary team, and to present the work in both written and oral form; 3. skills necessary for running chemical and physical laboratories, selection and preparation of adequate laboratory equipment and organization of laboratory work according to standards; 4. an introductionary knowledge to advanced materials and technologies

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	Learning outcomes	Evaluation criteria
1. The main polymerization reactions	- to define mechanisms of polymerizations: chain, step, ionic polymerisation - to define the main types of synthesized polymers (polyolefines, polyesters, polyamides..) - acquisition of knowledge and understanding influence of catalysts type, temperature and time on formation of	-to interpret polymerization processes -to distinguish different type of polymerizations -to recognize the type of condition and type of structure that is formed

	polymer chain structure and of molecular weight	
2. The homogeneous and heterogeneous polymerization processes	- to indicate the type of polymerizations: in bulk, in solution, emulsion, suspension… - to indicate the different reactors for polymerizations	-to define the polymerization types: advantages and disadvantages - to explain the differences between the reactors
3. the relationship structure – properties of polymer materials	- to explain the importance of the structure – properties relationship - to indicate the importance of creating a different structure of polymer chain	- to define and explain properties of polymers in relations with applications -to distinguish the importance of different polymer chain structures
4. Technologies for polymer processing	- to indicate basic type of polymer processing technologies: extrusion, injection, pressing, blowing… - to indicate the main equipment and conditions for polymer processing	-to define type of polymer processing -to define main processing equipment for polymers - to explain effect of conditions of production on the properties
5. Polymer degradation and stability	- to indicate the properties of polymer materials - acquisition of knowledge about the main types of polymer degradation and their mechanism - to indicate the mechanism of stabilization processes	-to define various properties of polymer: chemical properties, mechanical, physical … - to define degradation processes of polymers: photodegradation, thermodegradation, oxidative degradation… - to explain the importance of polymer stabilization
6. Biopolymers	- acquisition of knowledge about biopolymers -to indicate biodegradation processes	-to define biopolymers and biodegradation - to explain sustainable development: advantages and disadvantages of biopolymers