University of Zagreb

1. GENERAL INFORMATION				
1.1 Course teacher	Prof. Tomislav Bolanča, PhD Assoc. Prof. Šime Ukić, PhD		1.6 Year of the study	1. (1st semester)
1.2 Name of the course	Separation Techniques		1.7 ECTS credits	5
1.3 Associate teachers	Matija Cvetnić, PhD		1.8 Type of instruction (number of hours L + E + S + e-learning)	Total: 60 (L 30, E 15, S 15)
1.4 Study programme (undergraduate, graduate, integrated)	graduate		1.9 Expected enrolment in the course	10
1.5. Status of the course	☐ mandatory	☒ elective	1.10 Level of application of e-learning (level 1, 2, 3), percentage of online instruction (max. 20%)	3

2. COUSE DESCRIPTION	
2.1. Course objectives	Familiarising with standard separation techniques. Selection of different separation techniques in compliance with characteristics of the sample or the analytical problem. Processing and interpretation of analytical signal. Method validation.
2.2. Enrolment requirements and/or entry competences required for the course	-
2.3. Learning outcomes at the level of the programme to which the course contributes	• Compile and apply advanced knowledge of natural and technical sciences, particularly chemical engineering and environmental engineering in solving scientific, professional and general social problems • Solve engineering problems using the scientific method combining expert knowledge from chemistry, environmental, and chemical engineering as well as material science and engineering • Utilise advanced laboratory procedures and instruments for synthesis of new products, create sustainable processes, and solve problems of water, air and soil pollution • Apply different analytical techniques, analytical and numerical methods, as well as software tools in creative problem solving of engineering challenges, proposing sustainable technological solutions • Optimise complete and sustainable technological processes using analysis and modelling aimed at waste minimization utilising the strategy of the closed cycle manufacturing • Apply tools, methods and standards for monitoring and assessing the quality of processes and products, as well as their environmental impact, predict potential risks in working with technological processes and developing products • Identify and discuss advantages, disadvantages and limitations of certain methods for preparation, synthesis, analysis and processing of samples in accordance with sustainable development and life cycle of products and processes

	• Develop work ethic, personal responsibility and tendency for further skill and knowledge acquisition, according to standards of engineering practice
2.4. Expected learning outcomes at the level of the course (3 to 10 learning outcomes)	1. To define basic principles of common separation techniques. 2. To connect parts of chromatographic systems into functional order. 3. To select appropriate separation technique in compliance with characteristics of the sample. 4. To explain the selection of stationary phase, mobile phase and detector for various chromatographic analysis. 5. To apply computing tools in processing of the analytical signal. 6. To demonstrate method validation. 7. To identify the sources of measurement uncertainty and to calculate the uncertainty.
2.5. Course content (syllabus)	Lectures: **WEEK 1.** Introduction to separation techniques. Membrane separations. Electrophoresis and chromatography. Basic concepts and control of the separation. Isocratic elution. Gradient elution. **WEEK 2.** Types of samples. General Considerations in Sampling. Solid samples. Liquid samples. Volatile organic compounds. Biological samples. Sample preparation. **WEEK 3.** Sample preparation. Filtration. Solid phase extraction. Soxhlet extraction and accelerated solvent extraction. Membrane techniques. Derivatization. Headspace extraction. **WEEK 4.** Chromatographic equipment. Pumps. Injectors. Degassers. Trap columns. Specific requirements of different chromatographic techniques. **WEEK 5.** Chromatographic columns. Types of stationary phases. Column selectivity. Chromatographic theories: rate theory, plate theory. Chromatographic zone. Column efficiency. Van Deemter equation. Guard columns. **WEEK 6.** Chromatographic detectors. Classification. Detector performance criteria. Limit of detection. Limit of quantification. **WEEK 7.** Partial exam **WEEK 8.** Liquid chromatography. Normal phase chromatography. Reversed phase chromatography. Liquid chromatography. Planar chromatography. Ion chromatography. **WEEK 9.** Liquid chromatography. Size-exclusion chromatography. HPLC. UPLC. **WEEK 10.** Gas chromatography. Temperature effects. GC analysis of nonvolatile compounds. Supercritical fluid chromatography. **WEEK 11.** Multidimensional chromatography. Fundamental principles. Comprehensive mode. Heart-cutting mode. LC-LC coupling. **WEEK 12.** Multidimensional chromatography. GC-GC coupling. HPLC coupled with GC. SFC coupled with other chromatographic techniques. **WEEK 13.** Computer-assisted method development. Linear solvent strength model. Hoover model. Dual eluent species model. MSEA model. Novič's model. Iso-to-grad model. **WEEK 14.** Qualitative and quantitative analysis. Signal processing. Peak detection. Filtering. Smoothing. Peak shape analysis. Peak fronting and tailing. Multivariate signal resolution. Chemometric approach to peak overlap. Deconvolution.Method validation. Determination of chromatographic uncertainty. **WEEK 15.** Partial exam

	Laboratory practice: **WEEK 1.** Selection of relevant chromatographic technique, stationary phase, mobile phase and detector for different sets of analytes. **WEEK 2.** Creation of time-base for LC and GC analysis in chromatographic software. **WEEK 3.** Optimization of chromatographic separation. **WEEK 4.** Validation of chromatographic method. **WEEK 5.** Determination of uncertainty of chromatographic method.

2.6. Format of instruction:	☒ lectures ☐ seminars and workshops ☒ exercises ☐ online in entirety ☒ partial e-learning ☐ field work	☐ independent assignments ☐ multimedia and the internet ☒ laboratory ☐ work with mentor ☐ (other)	2.7. Comments:
2.8. Student responsibilities	Students are obligated to attend lectures (70%), seminars (70%), exercises (100%) as well as exams.		

2.9. Monitoring student work	Class attendance	YES		Research		NO	Oral exam		NO
	Experimental work	YES		Report		NO	(other)		NO
	Essay		NO	Seminar paper	YES		(other)		NO
	Preliminary exam	YES		Practical work	YES		(other)		NO
	Project		NO	Written exam	YES		ECTS credits (total)	5	

2.10. Required literature (available in the library and/or via other media)	**Title**	**Number of copies in the library**	**Availability via other media**
	1. J. M. Miller. Chromatography Concepts and Contrasts, Wiley, 2004.	2	YES
	2. R. W. Rousseau, Handbook of Separation Process Technology, Wiley, 1987.	1	YES

2.11. Optional literature	1. E. Katz, R. Eksteen, P. Schoenmakers, N. Miller, Handbook of HPLC, CRC Press, 1998.
	H. M. McNair, J. M. Miller, Basic Gas Chromatography, Wiley, 2011.
	M. K. Purkait, R. Singh, Membrane Technology in Separation Science, CRC Press, 2018.
2.12. Other (as the proposer wishes to add)	