



**Module Manual**  
**of the Master's Program**  
***Chemistry***

based on the implementation regulations of 14.01.2025

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**1. Module title**

## Modern Concepts of Inorganic Chemistry

**2. Utilisability of the module in degree programs**

M.Sc. Chemistry (mandatory module)

<b>3. Person(s) responsible for module</b> adj. Prof. Dr. M. Gjikaj		<b>4. Relevant faculty</b> Faculty of Natural and Materials Science	<b>5. Module number</b>
<b>6. Language</b> English	<b>7. ECTS</b> 8	<b>8. Duration</b> [ ] 1 semester [X] 2 semesters	<b>9. To be offered</b> [ ] each semester [X] each study year [ ] irregular

**10. Learning/qualification objectives of the module**

Students are able to apply their deepened knowledge of substance and material properties, of chemical bonds in solids, of coordination and molecular compounds, and of chemical-physical methods of characterization methods of inorganic chemistry in a target-oriented manner. They significantly extend their theoretical and practical laboratory knowledge of the synthesis of inorganic compounds and materials.

In this module, students develop not only technical and methodological competences (analytical capability and rhetoric) but also social competence (esp. communication skills).

**Courses**

11. No.	12. Title of the course	13. Lecturer	14. Course -No.	15. Type of Course	16. SWS	17. Workload attendance/ internal study
1	Inorganic Structural Chemistry II	adj. Prof. Dr. M. Gjikaj	S 3030	V/Ü	3	42 h / 78 h
2	Inorganic Synthese II	N.N.	W 3022	V	1	14 h / 46 h
3	Practical Course on Inorganic Chemistry	adj. Prof. Dr. M. Gjikaj Dr. J. Wittrock	W 3034	P	3	42 h / 18 h
<b>Sum:</b>					7	98 h / 142 h

<b>About No. 1:</b>	
<b>18a. Rec. prerequisites</b>	Bachelor in Chemistry or comparable achievements
<b>19a. Contents</b>	<p>Building on the lecture "Inorganic Structural Chemistry" of the Bachelor program, this module is concerned with topics like symmetry as principle of order for crystal structures, energy and chemical bonds; the effective size of atoms and ions; element, ion and molecule structure; MO theory and chemical solid bonds as well as structure-property relations.</p> <p>The contents of the lecture will be deepened in the exercises by solving problems.</p>
<b>20a. Media forms</b>	Board, overhead projector, PowerPoint presentations, lecture notes
<b>21a. Literature</b>	<ul style="list-style-type: none"> <li>• U. Müller „Anorganische Strukturchemie“ 7th edition, Springer-Vieweg (2016)</li> <li>• U. Müller „Anorganische Strukturchemie“ 8th edition, Springer-Vieweg (2015)</li> </ul>
<b>22a. Other</b>	---
<b>About No. 2:</b>	
<b>18b. Rec. prerequisites</b>	Bachelor in Chemistry or comparable achievements
<b>19b. Contents</b>	Building on the lecture "Inorganic Synthesis Chemistry I" of the Bachelor program, this module focuses on inorganic synthesis in non-aqueous solvents.
<b>20b. Media forms</b>	Board, overhead projector, PowerPoint presentations, lecture notes
<b>21b. Literature</b>	<ul style="list-style-type: none"> <li>• J. Jander, Ch. Lafrenz „Wasserähnliche Lösungsmittel“ Verlag Chemie (1968)</li> </ul>
<b>22b. Other</b>	---
<b>About No. 3:</b>	
<b>18c. Rec. prerequisites</b>	Bachelor in Chemistry or comparable achievements
<b>19c. Contents</b>	Inorganic synthesis in non-aqueous solvents, solid state reactions, complex formation reactions, modern crystallization methods; analysis of synthesized substances with instrumental methods of inorganic chemistry.
<b>20c. Media forms</b>	--
<b>21c. Literature</b>	Laboratory script
<b>22c. Other</b>	---

<b>Study/examination performance</b>					
<b>23. No.</b>	<b>24. Assigned courses</b>	<b>25. Exam type</b>	<b>26. ECTS</b>	<b>27. Evaluation</b>	<b>28. Proportion of module grade</b>
<b>1</b>	Inorganic Structural Chemistry II	MTP	4	graded	50 %
<b>2</b>	Inorganic Synthese II	MTP	2	graded	25 %
<b>3</b>	Practical Course on Inorganic Chemistry	MTP	2	graded	25 %
<b>About No. 1:</b>					
<b>29a. Form of examination / prerequisite for the award of credit points</b>		Written examination (K, 60 minutes)			
<b>30a. Responsible examiner</b>		adj. Prof. Dr. M. Gjika			
<b>31a. Preliminary examinations</b>		Participation in the lecture "Inorganic Structural Chemistry II"			
<b>About No. 2:</b>					
<b>29b. Form of examination / prerequisite for the award of credit points</b>		Written examination (K, 60 minutes)			
<b>30b. Responsible examiner</b>		N.N.			
<b>31b. Preliminary examinations</b>		Participation in the lecture "Inorganic Synthese II"			
<b>About No. 3:</b>					
<b>29c. Form of examination / prerequisite for the award of credit points</b>		Practical work / conducting of given experiments incl. precolloquia and independent creation of correct protocols (PrA)			
<b>30c. Responsible examiner</b>		adj. Prof. Dr. M. Gjika, Dr. J. Wittrock			
<b>31c. Preliminary examinations</b>		B.Sc. Chemistry or comparable achievements			

**1. Module title**  
 Instrumental Analysis

**2. Utilisability of the module in degree programs**

M.Sc. Chemistry (mandatory module)

<b>3. Person(s) responsible for module</b> Prof. Dr. U.E.A. Fittschen		<b>4. Relevant faculty</b> Faculty of Natural and Materials Science	<b>5. Module number</b>
<b>6. Language</b> English	<b>7. ECTS</b> 6	<b>8. Duration</b> [ ] 1 semester [X] 2 semesters	<b>9. To be offered</b> [ ] each semester [X] each study year [ ] irregularly

**10. Learning/qualification objectives of the module**

Students have deepened knowledge of chemical analysis of matter, in particular of material analysis and analysis of solids.

They broaden their theoretical and practical knowledge of characterization and analysis of materials and solids.

They are able to communicate and critically discuss their newly developed knowledge of instrumental analysis and modern concepts of inorganic chemistry in a scientific presentation.

In this module, students develop not only technical and methodological competences (analytical capability and rhetoric) but also social competence (esp. communication skills).

<b>Courses</b>						
<b>11. No.</b>	<b>12. Title of the course</b>	<b>13. Lecturer</b>	<b>14. Course- No.</b>	<b>15. Type of course</b>	<b>16. SWS</b>	<b>17. Workload attendance/internal study</b>
<b>1</b>	Instrumental Analysis I	Prof. Dr. U. Fittschen	W 3054	V	1	14 h / 46 h
<b>2</b>	Practical Course on Instrumental Analysis	Prof. Dr. U. Fittschen, Dr. A. Storm	W 3056	P	3	42 h / 48 h
<b>3</b>	Seminar on Inorganic and Analytical Chemistry	Prof. Dr. U. Fittschen	S 3033	S	1	14 h / 16 h
<b>Sum:</b>					5	70 h / 110 h
<b>About. No. 1: Instrumental Analysis I</b>						

<b>18a. Rec. prerequisites</b>	---
<b>19a. Contents</b>	Building on the general fundamentals of analytical chemistry, topics like assay preparation and specific sources of error of material analytics, and analytical figures of merit are deepened. Moreover, topics like speciation, local and time resolution in analytics and non-invasive methods are presented. Selected methods are explained in details and the possibilities of instrument development are discussed. Possible data evaluation and presentation is discussed.
<b>20a. Media forms</b>	Board, PowerPoint presentations, lecture notes
<b>21a. Literature</b>	<ul style="list-style-type: none"> <li>• K. Cammann: Instrumentelle Analytische Chemie, Spektrum Verlag (2010)</li> <li>• D. Harris, Quantitative Chemical Analysis, 9th edition, Freeman (2016)</li> <li>• G. Schwedt, T. Schmidt, O. Schmitz: Analytische Chemie, 3rd edition, Wiley-VCH (2016)</li> <li>• D. A. Skoog, F. J. Holler, S. R. Crouch: Principles of Instrumental Analysis, Brooks/Cole (2006)</li> <li>• R. E. van Grieken: Handbook of X-Ray Spectrometry, Marcel Dekker (2001)</li> <li>• R. Klockenkämper, A. von Bohlen: Total-Reflection X-Ray Fluorescence Analysis and Related Methods, Wiley (2015)</li> </ul>
<b>22a. Other</b>	---
<b>About No. 2: Practical Course on Instrumental Analysis</b>	
<b>18b. Rec. prerequisites</b>	Contents of lecture Instrumental Analysis I
<b>19b. Contents</b>	Sample collection, preparation and conducting of analytical methods especially of methods of atomic spectroscopy, experiment design, discussion of methods
<b>20b. Media forms</b>	--
<b>21b. Literature</b>	<ul style="list-style-type: none"> <li>• K. Cammann: Instrumentelle Analytische Chemie, Spektrum Verlag (2010)</li> <li>• D. Harris, Quantitative Chemical Analysis, 9th edition, Freeman (2016)</li> <li>• G. Schwedt, T. Schmidt, O. Schmitz: Analytische Chemie, 3rd edition, Wiley-VCH (2016)</li> <li>• D. A. Skoog, F. J. Holler, S. R. Crouch: Principles of Instrumental Analysis, Brooks/Cole (2006)</li> <li>• R. E. van Grieken: Handbook of X-Ray Spectrometry, Marcel Dekker (2001)</li> </ul>

	<ul style="list-style-type: none"> <li>R. Klockenkämper, A. von Bohlen: Total-Reflection X-Ray Fluorescence Analysis and Related Methods, Wiley (2015)</li> </ul>
<b>22b. Other</b>	---
<b>About No. 3: Seminar on Inorganic and Analytical Chemistry</b>	
<b>18c. Rec. prerequisites</b>	---
<b>19c. Contents</b>	Students' presentations on advanced topics of inorganic and analytical chemistry.
<b>20c. Media forms</b>	---
<b>21c. Literature</b>	---
<b>22c. Other</b>	---

<b>Study/examination performance</b>					
<b>23. No.</b>	<b>24. Assigned courses</b>	<b>25. Exam type</b>	<b>26. ECTS</b>	<b>27. Evaluation</b>	<b>28. Proportion of module grade</b>
<b>1</b>	Instrumental Analysis I	MTP	2	graded	70 %
<b>2</b>	Practical Course on Instrumental Analysis	MTP	3	graded	30 %
<b>3</b>	Seminar on Inorganic and Analytical Chemistry	LN	1	ungraded	0 % (§ 1 Abs. 6 APO i. V. m. § 13 Abs. 2 APO und § 18 Abs. 7 APO)
<b>About No. 1:</b>					
<b>29a. Form of examination / prerequisite for the award of credit points</b>		Oral examination (30 minutes) or written examination (90 minutes) (M or K)			
<b>30a. Responsible examiner</b>		Prof. Dr. U. Fittschen			
<b>31a. Preliminary examinations</b>		None			
<b>About No. 2:</b>					
<b>29b. Form of examination / prerequisite for the award of credit points</b>		Colloquia for methods, practical work, conducting and analysis with sample preparation and several instrumental methods, preparing protocols (PrA)			

<b>30b. Responsible examiner</b>	Prof. Dr. U. Fittschen
<b>31b. Preliminary examinations</b>	None
<b>About No. 3:</b>	
<b>29c. Form of examination / prerequisite for the award of credit points</b>	Quality of the student´s lecture in terms of content and type of presentation as well as oral participation in scientific discussions. (SL)
<b>30c. Responsible examiner</b>	Prof. Dr. U. Fittschen
<b>31c. Preliminary examinations</b>	None

**1. Module title**

## Design of Organic Synthesis

**2. Utilisability of the module in degree programs**

M.Sc. Chemistry (mandatory module)

**3. Person(s) responsible for module**

Prof. Dr. René Wilhelm

**4. Relevant faculty**Faculty of Natural and Materials  
Science**5. Module number****6. Language**

English

**7. ECTS**

10

**8. Duration**

[ ] 1 semester

[X] 2 semesters

**9. To be offered**

[ ] each semester

[X] each study year

[ ] irregularly

**10. Learning/qualification objectives of the module**

In the seminar students repeat and practice characteristics of different compound classes and the mechanisms of their transformation. Students independently solve simple synthesis problems by using all available sources of information (lecture notes, books, notes, internet, databases...). Students prepare the contents didactically, with the possibility to include similar reactions, side reactions or different theories, and present their results in front of all participants. The aim of this course is to thoroughly repeat knowledge students have developed, for all students to reach the same level of knowledge, to promote the team spirit and integration of new students and for students to apply their knowledge in a creative process of answering scientific questions. By the application of "forward oriented" synthesis steps, this seminar prepares students for the course "Design of Organic Synthesis", in which the focus is placed on retro-analysis, i.e., "backward oriented" synthesis planning.

In the lecture "Design of Organic Syntheses", students will develop, evaluate and discuss synthesis possibilities of more complex organic compositions by retro-synthetic analyses. Applying their knowledge on synthesis methods, students learn to recognize strategically relevant structural components of more complex compositions, and to break them down in synthons and finally starting materials so that a realistic, efficient and economical synthesis can be planned.

Students are also able to conduct organic syntheses from ongoing research and to synthesize more complex substances as well as to isolate complex product mixtures.

They develop the practical knowledge on current fields of work and techniques at the Institute, ranging from the fields of organic chemistry and organic material chemistry to organometallic chemistry, possibly including measurement technology from other institutes.

The module focuses on technical and methodological competences. Retro-analyses highly promote systems competence. In the practical course, self-competence is mainly built by training in time management and a sense of responsibility in academic work as well as the documentation and rational-critical interpretation of scientific findings.

<b>Courses</b>						
<b>11. No.</b>	<b>12. Title of the course</b>	<b>13. Lecturer</b>	<b>14. Course -No.</b>	<b>15. Type of course</b>	<b>16. SWS</b>	<b>17. Workload attendance/ internal study</b>
<b>1</b>	Mandatory Seminar Synthesizing Methods	Prof. Dr. René Wilhelm	W 3178	S	2	28 h / 32 h
<b>2</b>	Design of Organic Synthesis	Prof. Dr. René Wilhelm	S 3106	V/Ü	3	42 h / 48 h
<b>3</b>	Practical Course in Advanced Organic Chemistry	Prof. Dr. A. Schmidt	W/S 3105	P	7	112 h / 38 h
<b>Sum:</b>					12	182 h / 118 h
<b>About No. 1:</b>						
<b>18a. Rec. prerequisites</b>		Knowledge of organic chemistry as conveyed in a Bachelor program.				
<b>19a. Contents</b>		In small groups, students will solve selected synthesis problems of gradually increasing complexity by filling in "gaps" with reagents, reaction products or mechanisms. The results will be presented afterwards.				
<b>20a. Media forms</b>		Mainly board, slides and PowerPoint presentations, if applicable				
<b>21a. Literature</b>		<ul style="list-style-type: none"> <li>All information sources should be available <i>in situ</i>.</li> </ul>				
<b>22a. Other</b>		---				
<b>About No. 2:</b>						
<b>18b. Rec. prerequisites</b>		---				
<b>19b. Contents</b>		Fundamentals of synthesis planning (retrosynthetic analysis) are developed on the basis of typical synthesis problems. Key reactions (cycloaddition, rearrangement reaction, polarity inversion, asymmetric response etc.)				
<b>20b. Media forms</b>		Board, slides, PowerPoint				
<b>21b. Literature</b>		<ul style="list-style-type: none"> <li>Current reviews from research journals</li> <li>J. Clayden, Organic Chemistry, Oxford University Press, 2012.</li> <li>S. Warren, P. Wyatt, Organic Syntheses: The Disconnection Approach, Wiley, 2008.</li> <li>S. Warren, Workbook for Organic Syntheses: The Disconnection Approach, Wiley, 2009.</li> </ul>				
<b>22b. Other</b>		---				
<b>About No. 3:</b>						
<b>18c. Rec. prerequisites</b>		---				

<b>19c. Contents</b>	By the example of 8 synthesis stages from ongoing research, students gain practical insights in the latest fields of work and working techniques of organic chemistry, organic material chemistry and organometallic chemistry. One qualitative micro analysis will be conducted afterwards.
<b>20c. Media forms</b>	---
<b>21c. Literature</b>	<ul style="list-style-type: none"> <li>• Current reviews from research journals</li> </ul>
<b>22c. Other</b>	---

<b>Study/examination performance</b>					
<b>23. No.</b>	<b>24. Assigned courses</b>	<b>25. Exam type</b>	<b>26. ECTS</b>	<b>27. Evaluation</b>	<b>28. Proportion of module grade</b>
<b>1</b>	Mandatory Seminar Synthesizing Methods	MTP	2	graded	30 %
<b>2</b>	Design of Organic Synthesis	MTP	3	graded	70 %
<b>3</b>	Practical Course in Advanced Organic Chemistry	LN	5	ungraded	0 % (§ 1 Abs. 6 APO i. V. m. § 13 Abs. 2 APO und § 18 Abs. 7 APO)
<b>About No. 1:</b>					
<b>29a. Form of examination / prerequisite for the award of credit points</b>		Quality of the student's lecture in terms of content and type of presentation as well as oral participation in scientific discussions (SL)			
<b>30a. Responsible examiner</b>		Prof. Dr. René Wilhelm			
<b>31a. Preliminary examinations</b>		None			
<b>About No. 2:</b>					
<b>29b. Form of examination / prerequisite for the award of credit points</b>		Oral examination (M, 45 minutes)			
<b>30b. Responsible examiner</b>		Prof. Dr. René Wilhelm			
<b>31b. Preliminary examinations</b>		None			
<b>About No. 3:</b>					
<b>29c. Form of examination / prerequisite for the award of credit points</b>		Practical assignment, 8 synthesis stages from ongoing research, 1 qualitative micro analysis, detailed research protocols (PrA)			

<b>30c. Responsible examiner</b>	Prof. Dr. Andreas Schmidt
<b>31c. Preliminary examinations</b>	None

**1. Module title**
**Colloids and Interfaces**
**2. Utilisability of the module in degree programs**

M.Sc. Chemistry (mandatory module)

<b>3. Person(s) responsible for module</b> Prof. Dr. D. Johannsmann		<b>4. Relevant faculty</b> Faculty of Natural and Materials Science	<b>5. Module number</b>
<b>6. Language</b> English	<b>7. ECTS</b> 10	<b>8. Duration</b> [ ] 1 semester [X] 2 semesters	<b>9. To be offered</b> [ ] each semester [X] each study year [ ] irregular

**10. Learning/qualification objectives of the module**

Students have deepened knowledge of the characteristics of thermodynamics and dynamics of interfaces and surfaces. They understand essential phenomena and structures.

They also develop deep understanding of electrochemistry and the double layer model and the Debye-Hückel Theory. They are familiar with dynamic electrochemical processes and methods.

Students are able to apply their knowledge in experiments and to present these in short.

In this module, students develop technical, methodological and social competences (by group works and short presentations in the practical course).

**Courses**

<b>11. No.</b>	<b>12. Title of the course</b>	<b>13. Lecturer</b>	<b>14. Course -No.</b>	<b>15. Type of course</b>	<b>16. SWS</b>	<b>17. Workload attendance/ internal study</b>
<b>1</b>	Physical Chemistry of Colloids and Interfaces	Prof. Dr. D. Johannsmann	W 3222	V	2	28 h / 62 h
<b>2</b>	Interface Analysis	Prof. Dr. F. Endres	W 8041	V	2	28 h / 62 h
<b>3</b>	Practical Course on Physical Chemistry Master	Prof. Dr. D. Johannsmann, adj. Prof. Dr. J. Adams, Dr. A. Langhoff	W/S 3263	P	4	70 h / 50 h
<b>Sum:</b>					8	126 h / 174 h

<b>About No. 1:</b>	
<b>18a. Rec. prerequisites</b>	---
<b>19a. Contents</b>	Capillarity, nature and thermodynamics of interfaces of liquids, monomolecular films, microstructures, micelles, membranes, surfaces of solids, nucleation and condensation, adsorption
<b>20a. Media forms</b>	Board, slides, PowerPoint
<b>21a. Literature</b>	<ul style="list-style-type: none"> <li>Arthur W. Adamson, Alice P. Gast: Physical Chemistry of Surfaces, Wiley-VCH, Weinheim, 1997</li> <li>J.N. Israelachvili: Intermolecular and Surface Forces, Academic Press, 1992</li> </ul>
<b>22a. Other</b>	---
<b>About No. 2:</b>	
<b>18b. Rec. prerequisites</b>	Knowledge in physics, physical chemistry and mathematics
<b>19b. Contents</b>	Introduction to scanning probe microscopy (STM, AFM), REM, electron spectroscopy (XPS, AES), optical spectroscopy of interfaces (IR, Raman) and quartz crystal microbalance technique
<b>20b. Media forms</b>	Board, slides, PowerPoint
<b>21b. Literature</b>	will be announced/handed out with the start of the lectures
<b>22b. Other</b>	---
<b>About No. 3:</b>	
<b>18c. Rec. prerequisites</b>	---
<b>19c. Contents</b>	Project-oriented practical course on topics and methods covered in the lectures
<b>20c. Media forms</b>	Board, PowerPoint
<b>21c. Literature</b>	Independent literature research depending on the topic
<b>22c. Other</b>	---

<b>Study/examination performance</b>					
<b>23. No.</b>	<b>24. Assigned courses</b>	<b>25. Exam type</b>	<b>26. ECTS</b>	<b>27. Evaluation</b>	<b>28. Proportion of module grade</b>
<b>1</b>	Physical Chemistry of Interfaces and Colloids	MTP	3	graded	30 %
<b>2</b>	Interface Analysis	MTP	3	graded	30 %
<b>3</b>	Practical Course on Physical Chemistry Master	MTP	4	graded	40 %

<b>About No. 1:</b>	
<b>29a. Form of examination / prerequisite for the award of credit points</b>	Oral examination (M, 30 minutes)
<b>30a. Responsible examiner</b>	Prof. Dr. D. Johannsmann
<b>31a. Preliminary examinations</b>	None
<b>About No. 2:</b>	
<b>29b. Form of examination / prerequisite for the award of credit points</b>	Oral examination (M, 30 minutes)
<b>30b. Responsible examiner</b>	Prof. Dr. F. Endres
<b>31b. Preliminary examinations</b>	None
<b>About No. 3:</b>	
<b>29c. Form of examination / prerequisite for the award of credit points</b>	Practical assignment (PrA). Practical conduct of experiments (group of 6 - 10 students) incl. collaborative evaluation and interpretation Drawing up and presenting the results in a collaborative manner
<b>30c. Responsible examiner</b>	Prof. Dr. D. Johannsmann, adj. Prof. Dr. J. Adams
<b>31c. Preliminary examinations</b>	None

**1. Module title**

## Chemical Reaction Technology

**2. Utilisability of the module in degree programs**

M.Sc. Chemistry (mandatory module)

<b>3. Person(s) responsible for module</b> Prof. Dr. S. Beuermann		<b>4. Relevant faculty</b> Faculty of Natural and Materials Science	<b>5. Module number</b>
<b>6. Language</b> English	<b>7. ECTS</b> 10	<b>8. Duration</b> [ ] 1 semester [X] 2 semesters	<b>9. To be offered</b> [ ] each semester [X] each study year [ ] irregularly

**10. Learning/qualification objectives of the module**

In the lecture “Chemical Reaction Engineering”, students develop knowledge on the basic concepts of chemical reaction engineering. They are able to understand and apply physicochemical fundamentals of chemical reaction engineering, kinetics of chemical reactions, material transport and chemical reactions of heterogeneous catalysis, as well as principles of technical reaction control and heat balance of chemical reactors individually and in complexes.

In this practical course, students use chosen experiments to theoretically and experimentally apply the knowledge on “Chemical Reaction Engineering” developed in the lecture. Conducting the experiments in groups strengthens the students’ team competence.

The module focuses on technical, social and methodological competences.

**Courses**

11. No.	12. Title of the course	13. Lecturer	14. Course -No.	15. Type of course	16. SWS	17. Workload attendance/ internal study
1	Chemical Reaction Engineering	Prof. Dr. S. Beuermann	W 3332	V	2	28 h / 62 h
2	Practical Master Course ‘Chemical Reaction Engineering’	Dr. M. Drache	W/S 3360	P	6	120 h / 90 h
<b>Sum:</b>					8	112 h / 188 h

<b>About No. 1:</b>	
<b>18a. Rec. prerequisites</b>	---
<b>19a. Contents</b>	<ul style="list-style-type: none"> <li>– Chemical reaction engineering</li> <li>– Fundamentals of chemical reaction engineering</li> <li>– Basic reactor types</li> <li>– Physicochemical fundamentals of chemical reaction engineering</li> <li>– Kinetics of chemical reactions</li> <li>– Material transport and chemical reaction of heterogeneous catalysis</li> <li>– Principles of technical reaction control</li> <li>– Reaction control - Selection of adequate reactor types</li> <li>– Ideal reactors for homogeneous reaction systems</li> <li>– Real reactors for homogeneous and quasi-homogeneous reaction systems</li> <li>– Introduction: Statistical representation and distribution function, residence time distribution functions, simple residence time models (reactor models), complex residence time models (cell models)</li> <li>– Heat balance of chemical reactors</li> <li>– Microreaction technology</li> </ul>
<b>20a. Media forms</b>	Board, PowerPoint (presentations are made available on Stud.IP)
<b>21a. Literature</b>	<ul style="list-style-type: none"> <li>• M. Baerns, A. Behr, A. Brehm, J. Gmehling, H. Hofmann, U. Onken, A. Renken, Technische Chemie, Wiley-VCH</li> <li>• O. Levenspiel: Chemical Reaction Engineering, Wiley &amp; Sons, New York</li> <li>• Current scientific publications</li> </ul>
<b>22a. Other</b>	---
<b>About No. 2:</b>	
<b>18b. Rec. prerequisites</b>	Lecture Chemical Reaction Engineering
<b>19b. Contents</b>	Selected experiments related to “Chemical Reaction Engineering”: discontinuous, semi-continuous and continuous reactors, residence time behavior, reactor stability, heterogeneous catalysis
<b>20b. Media forms</b>	Experiment notes
<b>21b. Literature</b>	<ul style="list-style-type: none"> <li>• M. Baerns, A. Behr, A. Brehm, J. Gmehling, H. Hofmann, U. Onken, A. Renken, Technische Chemie, Wiley-VCH</li> <li>• O. Levenspiel: Chemical Reaction Engineering, Wiley &amp; Sons, New York</li> <li>• W. Reschetilowski, Technisch-Chemisches Praktikum, Wiley VCH Verlag</li> </ul>

<b>22b. Other</b>	The practical course may only be commenced with profound knowledge of chemical reaction engineering.
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<b>Study/examination performance</b>					
<b>23. No.</b>	<b>24. Assigned courses</b>	<b>25. Exam type</b>	<b>26. ECTS</b>	<b>27. Evaluation</b>	<b>28. Proportion of module share</b>
<b>1</b>	Chemical Reaction Engineering	MP	3	graded	100 %
<b>2</b>	Practical Master Course 'Chemical Reaction Engineering'	LN	7	ungraded	0 % (§ 1 Abs. 6 APO i. V. m. § 13 Abs. 2 APO und § 18 Abs. 7 APO)
<b>About No. 1:</b>					
<b>29a. Form of examination / prerequisite for the award of credit points</b>		Oral examination (M, 45 minutes) or written examination (K, 120 minutes)			
<b>30a. Responsible examiner</b>		Prof. Dr. S. Beuermann			
<b>31a. Preliminary examinations</b>		None			
<b>About No. 2:</b>					
<b>29b. Form of examination / prerequisite for the award of credit points</b>		Practical assignment (PrA)			
<b>30b. Responsible examiner</b>		Prof. Dr. S. Beuermann			
<b>31b. Preliminary examinations</b>		None			

**1. Module title**Practical Research Course in the  
Science Pool**2. Utilisability of the module in degree programs**

M.Sc. Chemistry (mandatory module)

<b>3. Persons(s) responsible for module</b> adj. Prof. Dr. J. Adams, Lecturers of chemistry		<b>4. Relevant faculty</b> Faculty of Natural and Materials Science	<b>5. Module number</b>
<b>6. Language</b> English	<b>7. ECTS</b> 4	<b>8. Duration</b> [X] 1 semester [ ] 2 semesters	<b>9. To be offered</b> [X] each semester [ ] each study year [ ] irregular

**10. Learning/qualification objectives of the module**

To realize a group project, students apply their developed general scientific and special chemical knowledge as well as scientific methods and working techniques. In collaboration with others, they are able to develop a working concept, to evaluate the practicability and to practically implement it.

Together with other students, they can critically reflect, evaluate and present their work.

This module promotes technical and methodological competences, and social competence through the participation in a work group.

**Courses**

<b>11. No.</b>	<b>12. Title of the course</b>	<b>13. Lecturer</b>	<b>14. Course -No.</b>	<b>15. Type of course</b>	<b>16. SWS</b>	<b>17. Workload attendance/ internal study</b>
1	Practical Research Course in the Science Pool	adj. Prof. Dr. J. Adams Lecturers of chemistry	W 3950	P	5	60 h / 60 h
<b>Sum:</b>					5	60 h / 60 h
<b>18. Rec. prerequisites</b>		The contents of the shared mandatory modules of both fields of study are prerequisites.				

<b>19. Contents</b>	<p>In team of 6-8 students, students independently work on a research topic, plan experiments and conduct them mostly independently. The results are presented by the group as a whole. The research focuses of at least two work groups are interconnected.</p> <p>This interdisciplinary practical course encourages students to independent scientific group work. Students work on research topics, experiments, their evaluation and interpretation mostly independently while applying their previously developed individual competences (particularly from their Bachelor thesis) in a manner supporting the team.</p>
<b>20. Media forms</b>	---
<b>21. Literature</b>	The choice of literature depends upon the individual research topic. Choosing literature is part of the practical course.
<b>22. Other</b>	---

<b>Study/examination performance</b>					
<b>23. No.</b>	<b>24. Assigned courses</b>	<b>25. Exam type</b>	<b>26. ECTS</b>	<b>27. Evaluation</b>	<b>28. Proportion of module grade</b>
<b>1</b>	Practical Research Course in the Science Pool	MP	4	graded	100 %
<b>29. Form of examination / prerequisite for the award of credit points</b>		Practical assignment (PrA), poster and oral presentation of the results in the group.			
<b>30. Responsible examiner</b>		adj. Prof. Dr. J. Adams, lecturers of chemistry			
<b>31. Preliminary examinations</b>		none			

**1. Module title**  
 Master Thesis

**2. Utilisability of the module in degree programs**

M.Sc. Chemistry (mandatory module)

<b>3. Person(s) responsible for module</b> Lecturers of chemistry		<b>4. Relevant faculty</b> Faculty of Natural and Materials Science	<b>5. Module number</b>
<b>6. Language</b> English	<b>7. ECTS</b> 30	<b>8. Duration</b> [X] 1 semester [ ] 2 semesters	<b>9. To be offered</b> [X] each semester [ ] each study year [ ] irregularly

**10. Learning/qualification objectives of the module**

Students can work on a chemical problem in detail applying scientific methods in a given period of time under supervision by the lecturer. By the topic and question of the final examination, they are familiar with current research topics of the chemical institutes.

Technical, system and methodological competences are developed.

Other developed competences include:

- Detailed literature research
- Development of working concepts
- Daily work planning, team work in a working group
- Summing up results and critical evaluation of results
- Written description of the work

Presentation of the work in front of an academic audience

**Courses**

11. No.	12. Title of the course	13. Lecturer	14. Course -No.	15. Type of course	16. SWS	17. Workload attendance/ internal study
1	Master Thesis + Colloquium	Lecturers of chemistry	---	Ab	6 Monate	
<b>Sum:</b>					6 Monate	

**About No. 1:**

<b>18. Rec. prerequisites</b>	Admission in accordance with § 16 of the Regulatory statutes for the Master program Chemistry (AFB Master Chemistry).
<b>19. Contents</b>	Thesis answering a scientific question from the research fields of the chemical institutes. Upon consultation, the thesis can be completed with external partners (industry, non-university research institutes).
<b>20. Media forms</b>	---
<b>21. Literature</b>	---
<b>22. Other</b>	---

<b>Study/examination performance</b>					
<b>23. No.</b>	<b>24. Assigned courses</b>	<b>25. Exam type</b>	<b>26. ECTS</b>	<b>27. Evaluation</b>	<b>28. Proportion of module grade</b>
<b>1</b>	Master Thesis + Colloquium	MP	30	graded	100 %
<b>29. Form of examination / prerequisite for the award of credit points</b>		The scientific work is presented in a colloquium with subsequent discussion and submitted as a written Master thesis. The written Master thesis is evaluated by two examiners (90 % of the final grade). Details are given in the <i>General Examination Regulations of Clausthal University of Technology</i> and the <i>Regulatory statutes for the Master program Chemistry</i> . The colloquium makes up 10 % of the final grade. The colloquium takes place soon before or after the submission of the written thesis in front of a larger audience (e.g. Institute seminar).			
<b>30. Responsible examiner</b>		Lecturers of chemistry			
<b>31. Preliminary examinations</b>		none			

**1. Module title**

## Computational Chemistry

**2. Utilisability of the module in degree programs**

M.Sc. Chemistry (Mandatory Elective "Cross-Cutting Topics of Modern Chemistry")

**3. Person(s) responsible for module**

Prof. Dr. D. Johannsmann

**4. Relevant faculty**Faculty of Natural and Materials  
Science**5. Module number****6. Language**

English

**7. ECTS**

6

**8. Duration**

[ ] 1 semester

[X] 2 semesters

**9. To be offered**

[ ] each semester

[X] each study year

[ ] irregularly

**10. Learning/qualification objectives of the module**Chemical Bond:

Students understand the concepts of orbitals and their energy levels.

They know the LCAO-MO Theory, the Valence Bond Theory, the VSEPR Theory and the Hückel Theory. Based on the Schrödinger equation, students can determine orbitals and energies for simple homonuclear and heteronuclear molecules; they have reflected upon the necessary approximations. The starting points for computer-aided calculation methods (e.g. the Hartree-Fock method) are also covered in this course.

Computer-Aided Quantum Chemistry:

By using modern quantum chemical software, students are able to calculate the properties of simple molecules. For this, students apply different approximations (Hartree-Fock and Density Functional Theory) yielding different grades of accuracy. They have an overview of current calculation methods, their strengths, limitations and practical advantage. They also know how to interpret the results.

Computer-Aided Molecular Modeling:

Students understand the atomistic fundamentals of Molecular Modeling: Structure generation and visualization of molecules, force fields, molecular mechanics calculation methods and optimization algorithms. Students are able to apply their knowledge using available computer programs.

They can explain and compare interatomic interactions in metals, ceramics and biomolecules. They are able to show the connection of thermodynamic properties (temperature, pressure) and molecular dynamics; they can derive essential material properties from simulations.

In this module, students develop technical and methodological competences.

<b>Courses</b>						
<b>11. No.</b>	<b>12. Title of the course</b>	<b>13. Lecturer</b>	<b>14. Course -No.</b>	<b>15. Type of course</b>	<b>16. SWS</b>	<b>17. Workload attendance/ internal study</b>
<b>1</b>	Chemical Bond	adj. Prof. Dr. J. Adams	S 3227	V	1	14 h / 46 h
<b>2</b>	Computer-Aided Quantum Chemistry	adj. Prof. Dr. E. Hübner	W/S 3180	V/Ü	1	14 h / 46 h
<b>3</b>	Computer-Aided Molecular Modeling	Prof. Dr. D. Johannsmann Dr. Marco Drache Prof. Dr. Nina Gunkelmann	W 3228	V/Ü	2	28 h / 32 h
<b>Sum:</b>					4	56 h / 124 h
<b>About No. 1:</b>						
<b>18a. Rec. prerequisites</b>		---				
<b>19a. Contents</b>		<ul style="list-style-type: none"> <li>• Hydrogen molecule cation</li> <li>• Molecular orbitals</li> <li>• LCAO-MO</li> <li>• H<sub>2</sub> molecule</li> <li>• Valence Bond Theory</li> <li>• Solutions of the Schrödinger equation for polyelectronic systems</li> <li>• Molecular orbital energy diagrams</li> <li>• Heteronuclear molecules</li> <li>• Polyatomic molecules</li> <li>• VSEPR Theory</li> <li>• Hybridization</li> <li>• Hückel Theory</li> <li>• Computational chemistry</li> <li>• Hartree-Fock Method, etc.</li> </ul>				
<b>20a. Media forms</b>		Board, PowerPoint, computer animations				
<b>21a. Literature</b>		Th. Engel, P. Reid: "Quantum Chemistry and Spectroscopy", Pearson, 2013 Additional literature will be announce with the commencement of the lectures.				
<b>22a. Other</b>		---				
<b>About No. 2:</b>						

<b>18b. Rec. prerequisites</b>	---
<b>19b. Contents</b>	Students learn to independently use the quantum chemical calculation software, from creating the structure over selecting options of quantum chemical calculations to the evaluation of results. Students recognize and compare advantages and limitations of quantum chemical methods by calculating simple exemplary molecules (i.a. HF-calculation and DFT-calculation, calculation of excited states, second derivative to test the optimized structures, allocation of IR-oscillations). In addition, students can perform individual calculations in connection with the current (synthetic or analytic) research on site. In a project, students also recognize the use of quantum chemical calculations of applied chemistry.
<b>20b. Media forms</b>	Board, slides, PowerPoint, computer presentations, computer exercises
<b>21b. Literature</b>	T. M. Klapötke, A. Schulz, „Quantum Chemical Methods in Main-Group Chemistry“, WILEY-VCH, Weinheim 1998
<b>22b. Other</b>	---
<b>About No. 3:</b>	
<b>18c. Rec. prerequisites</b>	---
<b>19c. Contents</b>	Model representations of molecule mechanics calculation methods, representation of molecular structures, molecular graphs, visualization of molecules, analysis of molecular geometry, applicability of different force fields, typification of atoms, potential functions, calculation of partial atomic charges, conformity analyses
<b>20c. Media forms</b>	Board, slides, PowerPoint, computer presentations, computer exercises
<b>21c. Literature</b>	R. Hentschke, E.M. Aydt, B. Fodi, E. Stöckelmann „Einführung in die Theorie und Praxis der Computersimulation molekularer Systeme“, Book as PDF-file J. Gasteiger, T. Engel, Chemoinformatics, WILEY-VCH, Weinheim 2003 M. Griebel, S. Knapek, G. Zumbusch, „Numerical Simulation in Molecular Dynamics“, Springer, 2007 A. R. Leach, „Molecular modelling principles and applications“, Pearson Education Ltd., Harlow, 2001, 2nd edition F. Jensen, „Introduction to Computational Chemistry“, Wiley, 2007 D. Frenkel, B. Smit, „Understanding molecular simulation“, Academic, San Diego, 2002, 2nd edition
<b>22c. Other</b>	---

<b>Study/examination performance</b>					
<b>23. No.</b>	<b>24. Assigned courses</b>	<b>25. Exam type</b>	<b>26. ECTS</b>	<b>27. Evaluation</b>	<b>28. Proportion of module grade</b>
<b>1</b>	Chemical Bond	LN	2	ungraded	0 % (§ 1 Abs. 6 APO i. V. m. § 13 Abs. 2 APO und § 18 Abs. 7 APO)
<b>2</b>	Computer-Aided Quantum Chemistry	LN	2	ungraded	0 % (§ 1 Abs. 6 APO i. V. m. § 13 Abs. 2 APO und § 18 Abs. 7 APO)
<b>3</b>	Computer-Aided Molecular Modeling	LN	2	ungraded	0 % (§ 1 Abs. 6 APO i. V. m. § 13 Abs. 2 APO und § 18 Abs. 7 APO)
<b>About No. 1:</b>					
<b>29a. Form of examination / prerequisite for the award of credit points</b>		Theoretical assignment (ThA)			
<b>30a. Responsible examiner</b>		adj. Prof. Dr. J. Adams			
<b>31a. Preliminary examinations</b>		None			
<b>About No. 2:</b>					
<b>29b. Form of examination / prerequisite for the award of credit points</b>		Theoretical assignment (ThA)			
<b>30b. Responsible examiner</b>		adj. Prof. Dr. E. Hübner			
<b>31b. Preliminary examinations</b>		None			
<b>About No. 3:</b>					
<b>29c. Form of examination / prerequisite for the award of credit points</b>		Theoretical assignment (ThA)			
<b>30c. Responsible examiner</b>		Prof. Dr. D. Johannsmann			

<b>31c. Preliminary examinations</b>	None
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<b>1a. Module title (German)</b> Chemie im globalen Umfeld	<b>1b. Module title (English)</b> Chemistry in the Global Environment
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<b>2. Utilisability of the module in degree programs</b> M.Sc. Chemistry (Mandatory Elective “Cross-Cutting Topics of Modern Chemistry”)			
<b>3. Person(s) responsible for module</b> Academic dean		<b>4. Relevant faculty</b> Faculty of Natural and Materials Science	<b>5. Module number</b>
<b>6. Language</b> German and English	<b>7. ECTS</b> 6	<b>8. Duration</b> [ ] 1 semester [X] 2 semesters	<b>9. To be offered</b> [ ] each semester [X] each study year [ ] irregular
<b>10. Learning/qualification objectives of the module</b> <u>Energy Flows, Material Cycles and Global Development:</u> Students know global energy flows and material cycles as well as changes caused by anthropogenic activities as seen by engineers and scientists. They know limitations of industrial energy and material flows and resulting consequences for future developments. <u>Safety and Reliability in Chemistry:</u> Students are familiar with technical, organizational and legal framework conditions for safe chemical work. They know exemplary basic elements of quality assurance in chemistry. They can apply their knowledge to relevant tasks from the professional field. <u>Introduction to Toxicology and Legal Studies on the Hazardous Substances Ordinance</u> The students have basic knowledge of toxicology and the safe and responsible handling of hazardous substances. They have knowledge of the relevant legal bases and can acquire comprehensive expertise in accordance with §5 of the Chemicals Prohibition Ordinance. This course addresses technical and system competence.			

<b>Courses</b>						
<b>11. No.</b>	<b>12. Title of the course</b>	<b>13. Lecturer</b>	<b>14. Course -No.</b>	<b>15. Type of course</b>	<b>16. SWS</b>	<b>17. Workload attendance/ internal study</b>
<b>1</b>	Energieflüsse, Stoffkreisläufe und globale Entwicklung (Energy Flows, Material Cycles and Global Development)	Prof. Dr. T. Turek	S 8413	V	2	28 h / 32 h
<b>2</b>	Sicherheit und Zuverlässigkeit in der Chemie: Die chemisch-technische Infrastruktur (Safety and reliability in the chemical industry: The chemical-technical infrastructure)	Dr. G. Dudek	S 3225	V	1	14 h / 46 h
<b>3</b>	Einführung in die Toxikologie und Rechtskunde zur Gefahrstoffverordnung (GefStoffV) / Introduction to Toxicology and Legal Studies on the Hazardous Substances Ordinance	Dr. A. Saipa	S 3015	V	2	28 h / 32 h
<b>Sum:</b>					5	70 h / 110 h
<b>About No. 1:</b>						
<b>18a. Rec. prerequisites</b>		---				
<b>19a. Contents</b>		<ul style="list-style-type: none"> <li>- Introduction and fundamentals (systems and system balance, thermodynamics and different energy forms)</li> <li>- Bio-geosphere (historical and modern development)</li> <li>- The earth's energy balance (radiation, greenhouse effect, photosynthesis, climate models)</li> <li>- Global materials cycles (i.a. carbon, oxygen, water, nitrogen)</li> <li>- Anthropogenic material and energy flows and their limitations</li> <li>- Scenarios for global development</li> </ul>				
<b>20a. Media forms</b>		Board, slides, PowerPoint				
<b>21a. Literature</b>		<ul style="list-style-type: none"> <li>• Georg Schaub, Thomas Turek, Energy Flows "Material Cycles and Global Development", Springer, Berlin 2011</li> </ul>				
<b>22a. Other</b>		---				

<b>About No. 2:</b>	
<b>18b. Rec. prerequisites</b>	---
<b>19b. Contents</b>	<ol style="list-style-type: none"> <li>1. Introduction Framework conditions, structures, basic concepts (risk, threat, etc.)</li> <li>2. Handling of hazardous substances, chemicals-related regulations Legal bases, hazardous properties, limits</li> <li>3. Chemical safety technology Methods and procedures, plant safety</li> <li>4. Quality assurance in analytical chemistry and test technology Chemical metrology; validation of processes, quality management, GLP, accreditation of laboratories, certification, conformity assessment</li> </ol>
<b>20b. Media forms</b>	Board, slides, PowerPoint
<b>21b. Literature</b>	<ul style="list-style-type: none"> <li>• H. Pohle, „Chemische Industrie Umweltschutz, Arbeitsschutz, Anlagensicherheit; Rechtliche und Technische Normen; Umsetzung in die Praxis.“ Wiley-VCH, Weinheim, 1991</li> <li>• H. Bender, „Sicherer Umgang mit Gefahrstoffen, Sachkunde für Naturwissenschaftler“, Wiley-VCH, Weinheim 1995</li> <li>• J. Steinbach, „Chemische Sicherheitstechnik“ , Wiley-VCH, Weinheim 1995</li> <li>• H. Schäfer, C. Jochum, „Sicherheit in der Chemie, Ein Leitfaden für die Praxis“, Carl Hanser Verlag, Munich Vienna 1997</li> <li>• H. Günzler (Hrsg.), „Akkreditierung und Qualitätssicherung in der Analytischen Chemie“, Springer Verlag Berlin, 1994</li> <li>• C.R. Sunstein, „Gesetze der Angst“, Suhrkamp Verlag, Frankfurt (Main) 2007</li> </ul>
<b>22b. Other</b>	---
<b>About No. 3:</b>	
<b>18c. Rec. prerequisites</b>	---
<b>19c. Contents</b>	<ol style="list-style-type: none"> <li>1. TOXIKOLOGIE <ol style="list-style-type: none"> <li>1.1 Definition und Aufgaben der Toxikologie</li> <li>1.2 Expositionsmöglichkeiten gegenüber Stoffen, <ol style="list-style-type: none"> <li>1.2.1 Arbeitsplatz,</li> <li>1.2.2 Umwelt,</li> <li>1.2.3 Alltag, Haushalt</li> </ol> </li> <li>1.3 Substanz- und zielbezogene Effekte,</li> </ol> </li> </ol>

	<p>1.3.1 Toxikokinetik : Resorption, Metabolismus, Elimination, 1.3.2 Toxikodynamik : Zellaufbau, Körperorgane 1.4 Stoffgruppen mit Intoxikationsrisiken, 1.4.1 Aliphatische und halogenierte aliphatische Verbindungen, 1.4.2 Aromatische Verbindungen (Benzol, Toluol), 1.4.3 Alkohole (Methanol, Ethanol), 1.4.4 Ausgewählte Biozide, 1.4.5 Gase, 1.4.5 Gase, 1.4.6 Schwer- und Übergangsmetalle 1.5 Epidemiologische Erhebungen, Risikoabschätzung</p>
<p><b>20c. Media forms</b></p>	<p>1.6 Untersuchungsmethoden in der Toxikologie, 1.6.1 In vivo akute systemische Verträglichkeit, 1.6.2 In vivo akute lokale Verträglichkeit, 1.6.3 In vivo subakute, subchronische und chronische Verträglichkeit, 1.6.4 In vitro Methoden, 1.6.5 Cancerogene, mutagene, reproduktionstoxische Wirkung; Grenzen der Aussagefähigkeit tierexperimenteller Befunde; Spezies-Spezifität 1.7 Probleme der Bewertung toxikologischer Daten, 1.7.1 Rückschlüsse vom Tierexperiment auf die Verhältnisse beim Menschen, 1.7.2 Prinzip der Festlegung zulässiger Höchstmengen, Sicherheitsfaktor bei Grenzwerten 1.8 Ökotoxikologie, 1.8.1 Untersuchungen in der Ökotoxikologie, 1.8.2 Der Mensch als Teil des Ökosystems, 1.8.3 Gleichgewichte, Eingriffe, Folgen im Ökosystem  2. RECHTSGRUNDLAGEN (Gefahrstoffe) 2.1 Allgemeiner Teil, 2.1.1 Verfassung (Grundgesetz, Bundesstaat, konkurrierende Gesetzgebung) , 2.1.2 Rechtsordnung (Bürgerliches Recht, Öffentliches Recht (Verwaltungsrecht, Strafrecht)), 2.1.3 Rechtliche Vorschriften (Gesetz, Verordnung, Technische Regeln), 2.1.4 Aufbau der staatlichen Ordnung (EU, Bund, Länder)</p>

	2.2 Spezieller Teil: Gefahrstoffrecht, 2.2.1 Verordnungen/Richtlinien der EU, 2.2.2 Rechtsgrundlagen über gefährliche Stoffe nach dem Chemikaliengesetz, Chemikaliengesetz, Chemikalienverbots-verordnung, Gefahrstoffverordnung, Technische Regeln für Gefahrstoffe, 2.2.3 Besondere Rechtsgrundlagen für gefährliche Stoffe außerhalb des Chemikaliengesetzes, wie z.B.: Bundes-Immissionsschutzgesetz, Kennzeichnung gefährlicher Güter nach den Gefahrgutverordnungen, Arbeitsstättenverordnung, Unfallverhütungsvorschriften, 2.2.4 Weitere Rechtsgrundlagen: Abfallrecht, Gentechnikgesetz, Sprengstoffgesetz, Wasserhaushaltsgesetz, Pflanzenschutzgesetz, Arzneimittelgesetz
<b>21c. Literature</b>	Blackboard, overhead projector, PowerPoint presentation, film sequences
<b>22c. Other</b>	Lecture script

<b>Study/examination performance</b>					
<b>23. No.</b>	<b>24. Assigned courses</b>	<b>25. Exam type</b>	<b>26. ECTS</b>	<b>27. Evaluation</b>	<b>28. Proportion of module grade</b>
<b>1</b>	Energy Flows, Material Cycles and Global Development	LN	2	graded	0 % (§ 1 Abs. 6 APO i. V. m. § 13 Abs. 2 APO und § 18 Abs. 7 APO)
<b>2</b>	Safety and reliability in the chemical industry: The chemical-technical infrastructure	LN	2	ungraded	0 % (§ 1 Abs. 6 APO i. V. m. § 13 Abs. 2 APO und § 18 Abs. 7 APO)
<b>3</b>	Introduction to Toxicology and Legal Studies on the Hazardous Substances Ordinance	LN	2	graded	0 % (§ 1 Abs. 6 APO i. V. m. § 13 Abs. 2 APO und § 18 Abs. 7 APO)
<b>About No. 1:</b>					

<b>29a. Form of examination / prerequisite for the award of credit points</b>	Written exam (K, 60 min) or oral exam (M, 30 min)
<b>30a. Responsible examiner</b>	Prof. Dr. T. Turek
<b>31a. Preliminary examinations</b>	None
<b>About No. 2:</b>	
<b>29b. Form of examination / prerequisite for the award of credit points</b>	Theoretical assignment (ThA)
<b>30b. Responsible examiner</b>	Dr. G. Dudek
<b>31b. Preliminary examinations</b>	None
<b>About No. 3:</b>	
<b>29c. Form of examination / prerequisite for the award of credit points</b>	Written exam (K, 120 min)
<b>30c. Responsible examiner</b>	Dr. A. Saipa
<b>31c. Preliminary examinations</b>	None

<b>1a. Module title (German)</b> Führung	<b>1b. Modultitel (Englisch)</b> Management
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<b>2. Utilisability of the module in degree programs</b> B.Sc. Betriebswirtschaftslehre, B.Sc. Wirtschaftsinformatik, B.Sc. Wirtschaftsingenieurwesen, B.Sc. Digitales Management, B.Sc. Wirtschaftschemie, M.Sc. Chemistry			
<b>3. Person(s) responsible for module</b> Prof. Dr. Thomas Niemand		<b>4. Relevant faculty</b> Fakultät für Energie- und Wirtschaftswissenschaften	
<b>6. Language</b> German or English		<b>7. ECTS</b> 6	
<b>8. Duration</b> [X] 1 semester [ ] 2 semesters		<b>9. To be offered</b> [ ] each semester [X] each study year [ ] irregular	
<b>10. Learning/qualification objectives of the module</b> After successfully completing the module, students know the basics of management and can apply them in critical management situations. Students learn the basics: <ul style="list-style-type: none"> <li>• Understand Leadership from a psychological and business perspective</li> <li>• Recognize and implement forms of Leadership</li> <li>• Recognize and consider Leadership dimensions</li> <li>• Leadership at different levels</li> </ul>			

<b>Courses</b>						
<b>11. No.</b>	<b>12. Title of the course</b>	<b>13. Lecturer</b>	<b>14. Course -No.</b>	<b>15. Type of course</b>	<b>16. SWS</b>	<b>17. Workload attendance/internal study</b>
1	Führung (Management)	Prof. Dr. Thomas Niemand	W 6605	V + Ü	4	56 h / 124 h
<b>Sum:</b>					4	56 h / 124 h

<b>About No. 1:</b>	
<b>18. Rec. prerequisites</b>	---
<b>19. Contents</b>	<ul style="list-style-type: none"> <li>• Motivation and History</li> <li>• Psychological Basics</li> <li>• Self Leadership</li> <li>• Leadership Motivation</li> <li>• Transformational Management</li> <li>• Transactional Leadership</li> <li>• Full Range Leadership</li> </ul>
<b>20. Media forms</b>	Slides, projector, blackboard, teaching videos, Moodle
<b>21. Literature</b>	<ul style="list-style-type: none"> <li>• Avolio, B. J. (2011). Full Range Leadership Development, 2<sup>nd</sup> ed., Sage, Los Angeles et al.</li> <li>• Furtner, M., Baldegger, U. (2013). Self-Leadership und Führung, Springer Gabler, Wiesbaden.</li> </ul> (Subject to changes)
<b>22. Other</b>	

<b>Study/examination performance</b>					
<b>23. No.</b>	<b>24. Assigned courses</b>	<b>25. Exam type</b>	<b>26. ECTS</b>	<b>27. Evaluation</b>	<b>28. Anteil an der Modulnote</b>
<b>1</b>	Führung	LN	6	graded	0 % (§ 1 Abs. 6 APO i. V. m. § 13 Abs. 2 APO und § 18 Abs. 7 APO)
<b>29. Form of examination / prerequisite for the award of credit points</b>		Written examination (120 min) or oral examination (20 - 60 min). The course-specific examination form and assessment criteria will be announced to students at the beginning of the semester.			
<b>30. Responsible examiner</b>		Prof. Dr. Thomas Niemand			
<b>31. Preliminary examinations</b>		None			

**1. Module title**

## Mandatory Practical Course I

**2. Utilisability of the module in degree programs**

M.Sc. Chemistry (Mandatory Module "SR Applied Chemistry")

<b>3. Person(s) responsible for module</b> Lecturers of chemistry		<b>4. Relevant faculty</b> Faculty of Natural and Materials Science	<b>5. Module number</b>
<b>6. Language</b> English	<b>7. ECTS</b> 6	<b>8. Duration</b> [X] 1 semester [ ] 2 semesters	<b>9. To be offered</b> [X] each semester [ ] each study year [ ] irregularly

**10. Learning/qualification objectives of the module**

Through their practical and research-oriented participation in work groups, students know about current topics of their selected field (1 or 2). Students are able to work on and solve scientific questions according to their state of knowledge. They know experimental and theoretical methods and models and are able to apply them.

This module promotes technical and methodological competences, and social competence through the participation in a work group.

**Courses**

11. No.	12. Title of the course	13. Lecturer	14. Course -No.	15. Type of course	16. SWS	17. Workload attendance/ internal study
1	Mandatory Practical Course I	Lecturers of chemistry		P	5	130 h / 50 h
<b>Sum:</b>					5	130 h / 50 h

**About No. 1:**

<b>18. Rec. prerequisites</b>	The contents of the lectures of the respective field (1 or 2) are prerequisites.
<b>19. Contents</b>	Research-oriented practical course on a current topic of field 1 or 2.
<b>20. Media forms</b>	---
<b>21. Literature</b>	The choice of literature depends upon the individual research topic. Choosing literature is part of the practical course.
<b>22. Other</b>	---

<b>Study/examination performance</b>					
<b>23. No.</b>	<b>24. Assigned courses</b>	<b>25. Exam type</b>	<b>26. ECTS</b>	<b>27. Evaluation</b>	<b>28. Proportion of module grade</b>
<b>1</b>	Mandatory Practical Course I	MP	6	graded	100 %
<b>29. Form of examination / prerequisite for the award of credit points</b>		Practical assignment (PrA), Conducting of the practical work, preparing a work report			
<b>30. Responsible examiner</b>		Lecturers of chemistry			
<b>31. Preliminary examinations</b>		none			

**1. Module title**

## Mandatory Practical Course II

**2. Utilisability of the module in degree programs**

M.Sc. Chemistry (Mandatory Module "SR Applied Chemistry")

<b>3. Person(s) responsible for module</b> Lecturers of chemistry		<b>4. Relevant faculty</b> Faculty of Natural and Materials Science	<b>5. Module number</b>
<b>6. Language</b> English	<b>7. ECTS</b> 10	<b>8. Duration</b> [X] 1 semester [ ] 2 semesters	<b>9. To be offered</b> [X] each semester [ ] each study year [ ] irregularly

**10. Learning/qualification objectives of the module**

Through their practical and research-oriented participation in work groups, students know about current topics of their selected field (1 or 2). Students are able to work on and solve scientific questions according to their state of knowledge. They know experimental and theoretical methods and models and are able to apply them.

This module promotes technical and methodological competences, and social competence through the participation in a work group.

**Courses**

11. No.	12. Title of the course	13. Lecturer	14. Course -No.	15. Type of course	16. SWS	17. Workload attendance/ internal study
1	Mandatory Practical Course II	Lecturers of chemistry		P	12	240 h / 60 h
<b>Sum:</b>					12	240 h / 60 h

**About No. 1:**

<b>18. Rec. prerequisites</b>	The contents of the lectures of the respective field (1 or 2) are prerequisites.
<b>19. Contents</b>	Research-oriented practical course on a current topic of field 1 or 2.
<b>20. Media forms</b>	---
<b>21. Literature</b>	The choice of literature depends upon the individual research topic. Choosing literature is part of the practical course.
<b>22. Other</b>	---

<b>Study/examination performance</b>					
<b>23. No.</b>	<b>24. Assigned courses</b>	<b>25. Exam type</b>	<b>26. ECTS</b>	<b>27. Evaluation</b>	<b>28. Proportion of module grade</b>
<b>1</b>	Mandatory Practical Course II	MP	10	graded	100 %
<b>29. Form of examination / prerequisite for the award of credit points</b>		Practical assignment (PrA), conducting of the practical course, presentation in the respective work group			
<b>30. Responsible examiner</b>		Lecturers of chemistry			
<b>31. Preliminary examinations</b>		none			

**1. Module title**Microanalysis and Material  
Analysis**2. Utilisability of the module in degree programs**

M.Sc. Chemistry (Mandatory elective "Specialist field 1")

<b>3. Person(s) responsible for module</b> Prof. Dr. U. E. A. Fittschen		<b>4. Relevant faculty</b> Faculty of Natural and Materials Science	<b>5. Module number</b>
<b>6. Language</b> English	<b>7. ECTS</b> 10	<b>8. Duration</b> [ ] 1 semester [X] 2 semesters	<b>9. To be offered</b> [ ] each semester [X] each study year [ ] irregularly

**10. Learning/qualification objectives of the module**

Students develop specific knowledge of analytic chemistry, especially of chemical analyses of trace elements, micro analysis and material analysis with X-rays of matter containing little or no crystalline matter. They significantly deepen their theoretical and practical competence to characterize and analyze materials, functional materials in particular and such characterized by heterogeneous composition of aggregate phases. They understand elemental specification, separation processes and data evaluation. They gain insights in the challenges of developing new methods in analytical chemistry.

Students are able to actively participate in seminars on current problems of analytical chemistry by giving presentations and joining critical discussions.

In this module, students develop not only technical and methodological competence (analytical capability and rhetoric) but also social competence (esp. communication skills) and self-competence (esp. dedication and time management).

**Courses**

11. No.	12. Title of the course	13. Lecturer	14. Course- No.	15. Type of course	16. SWS	17. Workload attendance/ internal study
1	Instrumental Analysis II	Prof. Dr. U. Fittschen	W 3055	2V/1Ü	3	42 h / 48 h
2	X-Ray based Material and Micro-Analysis	Prof. Dr. U. Fittschen	S 3052	1V/1Ü	2	28 h / 32 h

<b>3</b>	Inductively-coupled plasma mass spectrometry	Prof. Dr. T. Ulrich	S 3064	1V/1Ü	2	28 h / 32 h
<b>4</b>	Working Methods in applied and technical Mineralogy	Dr. T. Schirmer	W 3059	V	2	28 h / 32 h
<b>5</b>	Seminar Analytical Chemistry	Prof. Dr. U. Fittschen	S 3063	S	1	14 h / 16 h
<b>Sum:</b>					10	140 h / 160 h

**About No. 1:**
**18a. Rec. prerequisites**

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**19a. Contents**

In these lectures the focus is placed on theoretical fundamental methods of trace analysis like chromatography, electrophoresis, atomic emission spectroscopy, atomic absorption spectroscopy, and electrochemical methods. Micro analysis and material analysis are covered as well. These include the comparison of material analytical methods. The analysis results are evaluated regarding quality assurance in analytical chemistry. The theoretical lectures are complemented by instrumental exercises and data collections.

**20a. Media forms**

Board, PowerPoint presentations

**21a. Literature**

- D. Harris, Quantitative Chemical Analysis, 9th edition, Freeman (2016)
- G. Schwedt: Analytische Chemie, Thieme Verlag (1995)
- M. Otto: Analytische Chemie, 2nd ed., Wiley - VCH (2000)
- R. Kellner, J.M. Mermet, M. Otto, H.M. Widmer: Analytical Chemistry, 2nd Ed., Wiley - VCH (2004)

**22a. Other**

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**About No. 2:**
**18b. Rec. prerequisites**

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**19b. Contents**

Building on the lecture on instrumental analysis, the possibilities and realization of methods of micro and microscopic analysis of solid and liquid phases are scrutinized (analysis of complex structured systems, boards, sediments, energy storage materials). Methods enabling element analysis of non-crystallized matter, e.g. solids, are the key topic of the course. These are, in particular, X-ray based methods, like micro-RFA and X-ray spectroscopy (XANES) and electron probes (SEM-EDX). Students develop deeper knowledge of physical fundamentals of X-ray spectrometry (interaction with matter, absorption, ionization, fluorescence, diffraction and refraction). Special importance is placed on the particular requirements of species (oxidation state, counterions,

	ligands) and the determination of elements across phase boundaries. The theoretical lectures are complemented by instrumental exercises and data collections.
<b>20b. Media forms</b>	Board, PowerPoint presentations
<b>21b. Literature</b>	<ul style="list-style-type: none"> <li>• R. E. van Grieken: Handbook of X-Ray Spectrometry, Marcel Dekker (2001)</li> <li>• R. Klockenkämper, A. von Bohlen: Total-Reflection X-Ray Fluorescence Analysis and Related Methods, Wiley (2015)</li> </ul>
<b>22b. Other</b>	---
<b>About No. 3:</b>	
<b>18c. Rec. prerequisites</b>	---
<b>19c. Contents</b>	<p>This lecture gives an overview of the fundamental physical and technical principles of inductively coupled plasma mass spectrometry. The working methods of the different mass filters (single quadrupole, triple quadrupole, sector-field, multi-collector and time-of-flight) are shown and their main applications are discussed.</p> <p>The possible types of sample introduction (solutions, laser ablation, single droplet/particle) into the mass spectrometer are shown and explained using application examples.</p> <p>The analysis protocols and the execution of analyses are presented and the data handling is demonstrated using examples and then worked out independently.</p>
<b>20c. Media forms</b>	Board, PowerPoint presentations
<b>21c. Literature</b>	<ul style="list-style-type: none"> <li>• Robert Thomas, Practical Guide to ICP-MS and Other Atomic Spectroscopy Techniques : A Tutorial for Beginners. Taylor &amp; Francis Group, 2023</li> <li>• John Dean, Practical Inductively Coupled Plasma Spectrometry, John Wiley &amp; Sons, 2019</li> </ul>
<b>22c. Other</b>	---
<b>About No. 4:</b>	
<b>18d. Rec. prerequisites</b>	---
<b>19d. Contents</b>	<p>Based on the existing knowledge of instrumental analysis, typical instrumental methods used in mineralogical characterization will be deepened (ICP-MS, XRF, RDA, ESMA) and others will be introduced (XPS, APT). Furthermore, basics of mineralogy are taught (crystallography, model systems, crystallization from the melt). Furthermore, the module contains an introduction to special mineralogy as well as basics of petrology and deposit science. The various properties and technical</p>

	<p>applications of mineral (crystalline) compounds and raw materials (ceramics, cement, natural building materials) are presented. Another topic is mineral residues (mining residues, tailings) and the targeted modification of slags for the enrichment of environmentally relevant or technologically interesting elements.</p>
<b>20d. Media forms</b>	---
<b>21d. Literature</b>	<ul style="list-style-type: none"> <li>• S. Okrusch, S. Matthes: Mineralogie: Eine Einführung in die spezielle Mineralogie, Petrologie und Lagerstättenkunde, Springer (2014)</li> <li>• Kristallographie, Springer (2002)</li> <li>• M. Götze, M. Göbbels: Einführung in die Angewandte Mineralogie (2017)</li> <li>• R. Telle: Keramik, Springer (2007)</li> <li>• R. Bock: Handbuch der analytisch-chemischen Aufschlussmethoden, Springer (2005)</li> <li>• U. Ritgen: Analytische Chemie I u. II, Springer (2019/2020)</li> <li>• V. K. Pecharsky, P. Y. Zavalij: Fundamentals of Powder Diffraction and Structural Characterization of Materials, Springer (2003)</li> <li>• B. Beckhoff et al: Handbook of Practical X-Ray Fluorescence, Springer (2006)</li> <li>• J. I. Goldstein et al: Scanning Electron Microscopy and X-Ray Microanalysis, Springer (2018)</li> </ul>
<b>22d. Other</b>	---
<b>About No. 5:</b>	
<b>18e. Rec. prerequisites</b>	---
<b>19e. Contents</b>	Current topics of analytical chemistry, which students present and discuss in a scientific talk.
<b>20e. Media forms</b>	Board, PowerPoint presentations
<b>21e. Literature</b>	---
<b>22e. Other</b>	---

<b>Study/examination performance</b>					
<b>23. No.</b>	<b>24. Assigned courses</b>	<b>25. Exam type</b>	<b>26. ECTS</b>	<b>27. Evaluation</b>	<b>28. Proportion of module grade</b>

<b>1</b>	Instrumental Analysis II, X-Ray based Material and Micro-Analysis, Inductively-coupled plasma mass spectrometry, Working Methods in applied and technical Mineralogy	MP	9	graded	100 %
<b>2</b>	Seminar Analytical Chemistry	LN	1	ungraded	0 % (§ 1 Abs. 6 APO i. V. m. § 13 Abs. 2 APO und § 18 Abs. 7 APO)
<b>About No. 1:</b>					
<b>29a. Form of examination / prerequisite for the award of credit points</b>		Oral examination (M45 minutes)			
<b>30a. Responsible examiner</b>		Prof. Dr. U. E. A. Fittschen			
<b>31a. Preliminary examinations</b>		None			
<b>About No. 2:</b>					
<b>29b. Form of examination / prerequisite for the award of credit points</b>		Quality of the student´s lecture in terms of content and type of presentation as well as oral participation in scientific discussions. (SL)			
<b>30b. Responsible examiner</b>		Prof. Dr. U. E. A. Fittschen			
<b>31b. Preliminary examinations</b>		None			

**1. Module title**

## Syntheses and Mechanisms

**2. Utilisability of the module in degree programs**

M.Sc. Chemistry (Mandatory elective "Specialist field 1")

**3. Person(s) responsible for module**

Prof. Dr. A. Schmidt

**4. Relevant faculty**Faculty of Natural and Materials  
Science**5. Module number****6. Language**

English

**7. ECTS**

10

**8. Duration** 1 semester 2 semesters**9. To be offered** each semester each study year irregularly**10. Learning/qualification objectives of the module**

In the lecture "Named Reactions" students develop deepened knowledge of synthesis methods and mechanisms which enables them to deepen their understanding of structure elucidation based on selected named reactions of organic chemistry. The interconnectedness of individual topics is shown and retrosynthetic approaches are discussed. Students are thus enabled to apply mechanistic basic principles also to unknown examples and to plan specific synthesis routes, to scrutinize mechanisms and to apply them to their own scientific questions. The course "Total Syntheses of Selected Target Molecules" is based on inductive learning methods and thus students are assigned to small groups. The groups conduct research on a given synthesis problem from the latest primary literature in a certain period of time while also applying all available media (library, databases: SciFinder, CrossFire and Web of Science; internet, online journals). Students will then present their didactically prepared results on the board in front of the other groups. This seminar is based on students' presentations on the latest developments in the fields of their research topics and synthesis problems. This module conveys mostly technical competence. Due to the research assignments, which include information procurement, structuring, evaluation and interpretation following the given task as well as the didactic presentation, this seminar also conveys methodological competence to a high degree. Training students to understand complex synthesis problems in model reactions and to draw conclusions from them, also supports their system competence. Working in teams helps students develop their social competence and fosters the integration of international and new students at TU Clausthal. All courses will be held in English.

<b>Courses</b>						
<b>11. No.</b>	<b>12. Title of the course</b>	<b>13. Lecturer</b>	<b>14. Course -No.</b>	<b>15. Type of course</b>	<b>16. SWS</b>	<b>17. Workload attendance/ internal study</b>
<b>1</b>	Total Syntheses of Selected Target Molecules	Prof. Dr. A. Schmidt	S 3199	V	2	28 h / 62 h
<b>2</b>	Advanced NMR-Methods	Dr. Namyslo	W 3135	2V/1Ü	3	42 h / 48 h
<b>3</b>	Named Reactions	Prof. Dr. A. Schmidt	W 3120	V	2	28 h / 62 h
<b>4</b>	Seminar for New Synthesis Methods	Prof. Dr. A. Schmidt	W 3171	S	2	14 h / 16 h
<b>Sum:</b>					9	112 h / 188 h
<b>About No. 1:</b>						
<b>18a. Rec. prerequisites</b>		---				
<b>19a. Contents</b>		Based on methods of inductive learning, students work out the latest total syntheses from the primary literature in small group. For this, students each receive synthesis problems as a cloze, in which either reagents or reaction products are to be added. Thus, the seminar is concerned with synthesis methods, reagents, mechanisms, side reactions, spectroscopic processes, application of models and theories (Zimmermann-Traxler, Cram, Felkin-Anh, Bürgi-Dunitz, Fukui-Concept, substitution effect etc.) as sort of a summary of the previously acquired knowledge.				
<b>20a. Media forms</b>		Board, slides, PowerPoint				
<b>21a. Literature</b>		<ul style="list-style-type: none"> <li>• Databases</li> <li>• Internet</li> <li>• Online journals</li> <li>• Textbooks from the Library of the Institute of Organic Chemistry</li> </ul>				
<b>22a. Other</b>		---				
<b>About No. 2:</b>						
<b>18b. Rec. prerequisites</b>		---				
<b>19b. Contents</b>		Development of FT-NMR, equipment, fields of application; advanced physical fundamentals, detection method; NMR-parameters in practice, independence of the chemical shift from the structure; homo- and heteronuclear spin-spin-coupling, decoupling methods: relaxation phenomena; Nuclear Overhauser Effect (NOE); polarization transfer experiments; 2D-methods, homo- and heteronuclear shift correlation in NMR spectroscopy, inverse detection, gradients in NMR spectroscopy,				

	molecular dynamics in NMR, determination of activation parameters. Heteronuclear NMR of organic chemically relevant cores (e.g. $^{15}\text{N}$ , $^{19}\text{F}$ , $^{11}\text{B}$ , $^{29}\text{Si}$ , $^{31}\text{P}$ ); an overview of additional NMR methods (solid-state NMR, imaging methods, medical applications); increment systems, computer-aided NMR prediction.
<b>20b. Media forms</b>	Board, slides, PowerPoint
<b>21b. Literature</b>	<ul style="list-style-type: none"> <li>• H. Friebolin, Basic One- and Two-Dimensional NMR Spectroscopy, Wiley-VCH, 2013.</li> <li>• S. Bienz, L. Bigler: Hesse/Meier/Zeeh, Spektroskopische Methoden in der Organischen Chemie, 9th edition, Thieme, 2016</li> <li>• J. K. M. Sanders, B. K. Hunter, Modern NMR Spectroscopy, A Guide for Chemists, 2nd edition, Oxford University Press, 1993.</li> <li>• R. S. Macomber, A Complete Introduction to Modern NMR Spectroscopy, Wiley, 1998.</li> <li>• S. Berger, S. Braun, 200 and More NMR Experiments: A Practical Course, Wiley-VCH, 2004.</li> <li>• E. Breitmaier, Structure Elucidation by NMR in Organic Chemistry: A Practical Guide, Wiley, 2002.</li> </ul>
<b>22b. Other</b>	---
<b>About No. 3:</b>	
<b>18c. Rec. prerequisites</b>	---
<b>19c. Contents</b>	<p><i>CC single bond formations</i></p> <ul style="list-style-type: none"> <li>- Stork enamine alkylation and variations: Imine variant of the Stork reaction, proline as organocatalyst, SAMP/RAMP, asymmetric induction</li> <li>- Aldol addition and related (Boroenolate, stereo chemistry, regio selectivity; Claisen-Schmidt, directed aldol addition, Mukaiyama Reaction, Iwanow Reaction, Myers Reaction, Eder-Sauer-Wiechert-Hajos-Parrish Reaction, Fujimoto-Belleau Reaction, Baylis-Hillman Reaction, Henry Reaction)</li> <li>- Non-aldol-type conversion of carbonyls</li> <li>- Normant Reagents, Stetter Reaction, Sakurai Allylation, Trost Allylation, Paternò-Büchi Reaction, de Mayo Reaction, Roush Coupling, Prins Reaction, Nazarov Cyclization, Pauson-Khand, Passerini, Ugi, Barbier)</li> <li>- Synthesis of and with amino acids (Dakin-West, Schöllkopf)</li> </ul> <p><i>C=C double bond formations</i></p>

	<p>-C=C double bond formations via phosphorous compounds (Wittig, Wittig-Schlosser, Still-Gennari, Cory-Winter, Barton-Kellog)</p> <p>-C=C double bond formations via silicon compounds (Peterson)</p> <p>-C=C double bond formations via sulfuric compounds (Julia-Lythgoe, Ramberg-Bäcklund)</p> <p>-C=C double bond formations via boric compounds (Bor-Wittig v., Zweifel Olefination)</p> <p>-C=C double bond formations via nitrogen compounds (Bamford-Stevens, Shapiro)</p> <p>-Olefin-Metathesis</p> <p>-Tebbe Reaction</p> <p>-Bergman and Myers Cyclization</p> <p><i>Reactions of non-activated CH-compounds</i></p> <p>-Hoffmann-Loeffler-Freytag Reaction</p> <p>-Barton Nitrite Photolysis</p> <p><i>Defunctionalization</i></p> <p>-Barton-McCombie vs. Chatgililoglus Reagent</p> <p><i>Oxidations</i></p> <p>-DMP, Pfitzner-Moffat, Cory-Kim, Riley, Jones, Collins, Sarett)</p> <p><i>Epoxidations</i></p> <p>-Jacobson-Katsuki, Shi, Rubottom</p> <p><i>Reductions</i></p> <p><i>Activation of carboxylic acid</i></p> <p>-Staab, Mukaiyamas Reagent, Yamaguchi, Cory-Nicolaou, Masamune Cyclization</p> <p><i>Cross coupling</i></p> <p>-Heck, Sonmogashira, Stille, Kumada, Suzuki-Miyaura, Negishi</p>
<p><b>20c. Media forms</b></p>	<p>Board, slides, PowerPoint</p>
<p><b>21c. Literature</b></p>	<ul style="list-style-type: none"> <li>• L. Kürti, B. Czako, <i>Strategic Applications of Named Reactions in Organic Synthesis</i>, Elsevier Academic Press, 2005.</li> <li>• F.A. Carey, R.J. Sundberg, <i>Advanced Organic Chemistry, Parts A and B</i>, Springer, 2007.</li> <li>• R. Brückner, <i>Reaktionsmechanismen: Organische Reaktionen, Stereochemie, Moderne Synthesemethoden</i>, Elsevier / Spektrum akademischer Verlag, 3rd corr. edition, 2009.</li> </ul>

	<ul style="list-style-type: none"> <li>• R. Brückner, <i>Advanced Organic Chemistry: Reaction Mechanisms</i>, 2001.</li> <li>• Houben-Weyl: <i>Methoden der organischen Chemie</i>, Thieme (Collection of Named Reactions, see volume 16/2, pp. 1179 et seq.)</li> <li>• Current reviews from research journals</li> </ul>
<b>22c. Other</b>	---
<b>About No. 4:</b>	
<b>18d. Rec. prerequisites</b>	---
<b>19d. Contents</b>	In this seminar, students give presentations on current developments in the field of their research work or present solution strategies of synthesis problems.
<b>20d. Media forms</b>	Board, slides, PowerPoint
<b>21d. Literature</b>	<ul style="list-style-type: none"> <li>• Current reviews from research journals</li> </ul>
<b>22d. Other</b>	---

<b>Study/examination performance</b>					
<b>23. No.</b>	<b>24. Assigned courses</b>	<b>25. Exam type</b>	<b>26. ECTS</b>	<b>27. Evaluation</b>	<b>28. Proportion of module grade</b>
<b>1</b>	Total Syntheses of Selected Target Molecules, Named Reactions, Advanced NMR-Methods	MP	9	graded	100 %
<b>2</b>	Seminar for New Synthesis Methods	LN	1	ungraded	0 % (§ 1 Abs. 6 APO i. V. m. § 13 Abs. 2 APO und § 18 Abs. 7 APO)
<b>About No. 1:</b>					
<b>29a. Form of examination / prerequisite for the award of credit points</b>		Oral examination (45 minutes)			
<b>30a. Responsible examiner</b>		Prof. Dr. A. Schmidt			
<b>31a. Preliminary examinations</b>		None			
<b>About No. 2:</b>					

<b>29b. Form of examination / prerequisite for the award of credit points</b>	Seminar assignment
<b>30b. Responsible examiner</b>	Prof. Dr. A. Schmidt
<b>31b. Preliminary examinations</b>	None

**1. Module title**

Special Topics in Physical Chemistry

**2. Utilisability of the module in degree programs**

M.Sc. Chemistry (Mandatory elective "Specialist field 1")

**3. Person(s) responsible for module**

Prof. Dr. D. Johannsmann

**4. Relevant faculty**

Faculty of Natural and Materials Science

**5. Module number****6. Language**

English

**7. ECTS**

10

**8. Duration**

[ ] 1 semester

[X] 2 semesters

**9. To be offered**

[ ] each semester

[X] each study year

[ ] irregularly

**10. Learning/qualification objectives of the module**

Students develop deeper knowledge of physical chemistry and current physicochemical topics, some with direct connection to the Institutes research areas.

In this course, students develop the following competences:

Technical competence: 70%, methodological competence: 10%, professional competences: 10%, social competence: 10%

**Courses**

11. No.	12. Title of the course	13. Lecturer	14. Course -No.	15. Type of course	16. SWS	17. Workload attendance/ internal study
1	Physical Chemistry in Astrophysics	Prof. Dr. D. Johannsmann	S 3232	V	1	14 h / 46 h
2	Biophysical Chemistry	Prof. Dr. D. Johannsmann	W 3216	V	2	28 h / 62 h
3	Modern Spectroscopic Methods (1SWS)	adj. Prof. Dr. J. Adams	S 3211	V	1	14 h / 46 h
4	Chemical Sensors	Prof. Dr. D. Johannsmann	S 3224	V	2	28 h / 62 h
<b>Sum:</b>					6	84 h / 216 h

<b>About No. 1: Physical Chemistry in Astrophysics</b>	
<b>18a. Rec. prerequisites</b>	---
<b>19a. Contents</b>	<p>The course elaborates on how Physical Chemistry governs astrophysical processes, as well. It is claimed that the laws are the same up there and down here. Astrophysics, however, is rich with exotic examples, which challenge our understanding. Neutron stars are a prominent case.</p> <p>One of the fathers of thermodynamics, Clausius, predicted that the universe would eventually suffer the “heat death”, which would amount to structureless medium with equal composition and equal temperature everywhere. Looking back, this state was close-to-perfectly realized 380 000 years after the big bang. We observe this state in the form of the cosmic microwave background (CMB). A key question to be addressed is, why complex entities today talk about the heat death, even though the heat death was a reality 13.8 billion years ago.</p> <p>Further topics are</p> <ul style="list-style-type: none"><li>- The thermodynamics of self-gravitating systems</li><li>- Mechanisms of structure formation</li><li>- The special role of magnetic fields</li><li>- Chaos in the three-body problem and elsewhere, non-ergodic and ergodic systems</li></ul>
<b>20a. Media forms</b>	Board, slides, lecture notes
<b>21a. Literature</b>	Binney, J.; Astrophysics: A Very Short Introduction, Oxford University Press 2016
<b>22a. Other</b>	---
<b>About No. 2: Biophysical Chemistry</b>	
<b>18b. Rec. prerequisites</b>	---

<b>19b. Contents</b>	<ul style="list-style-type: none"> <li>• Characteristics of living systems</li> <li>• Molecules and substances of importance           <ul style="list-style-type: none"> <li>- water, ions, concentrated electrolytes</li> <li>- polysaccharides</li> <li>- redox-active molecules</li> <li>- proteins</li> <li>- lipids</li> </ul> </li> <li>• Energy storage and energy conversion in biology</li> <li>• The biomembrane</li> <li>• Complexity</li> <li>• Biomaterials</li> <li>• Analytical biophysical chemistry: HPLC and electrophoresis</li> <li>• Signal transport in the brain, neuronal computing</li> </ul>
<b>20b. Media forms</b>	Board, slides, lecture notes
<b>21b. Literature</b>	B. Alberts et al.: Essential Cell Biology
<b>22b. Other</b>	---
<b>About No. 3: Modern Spectroscopic Methods</b>	
<b>18c. Rec. prerequisites</b>	Modern Spectroscopic Methods
<b>19c. Contents</b>	<ul style="list-style-type: none"> <li>• Interaction of electromagnetic radiation and matter</li> <li>• Single-molecule spectroscopy</li> <li>• Fluorescence spectroscopy           <ul style="list-style-type: none"> <li>○ Depolarization measurement</li> <li>○ Quenching</li> <li>○ Excimer and exciplex dynamics</li> <li>○ Förster resonance energy transfer</li> </ul> </li> </ul>
<b>20c. Media forms</b>	Board, slides, PowerPoint
<b>21c. Literature</b>	Various textbooks and monographies of physical chemistry
<b>22c. Other</b>	---
<b>About No. 4: Chemical Sensors</b>	
<b>18d. Rec. prerequisites</b>	---

<b>19d. Contents</b>	<ul style="list-style-type: none"> <li>• Properties and performance parameters of sensors</li> <li>• Dynamic range, strategies for extension</li> <li>• Methods to achieve specificity</li> <li>• Sensors grouped by transduction principals                             <ul style="list-style-type: none"> <li>- thermal</li> <li>- acoustic/mass</li> <li>- conductometric (MOX sensors, in particular)</li> <li>- potentiometric, logarithmic sensitivity (pH sensor, in particular)</li> <li>- amperometric (glucose sensor, in particular)</li> <li>- optical</li> </ul> </li> </ul>
<b>20d. Media forms</b>	Board, slides, lecture notes
<b>21d. Literature</b>	F.G: Banica: Chemical Sensors and Biosensors: Fundamentals and Applications, Wiley 2012
<b>22d. Other</b>	---

<b>Study/examination performance</b>					
<b>23. No.</b>	<b>24. Assigned courses</b>	<b>25. Exam type</b>	<b>26. ECTS</b>	<b>27. Evaluation</b>	<b>28. Proportion of module grade</b>
<b>1</b>	Physical Chemistry in Astrophysics, Biophysical Chemistry, Modern Spectroscopic Methods (1SWS), Chemical Sensors	MP	10	graded	100 %
<b>29. Form of examination / prerequisite for the award of credit points</b>		Oral examination (M, 45 minutes)			
<b>30. Responsible examiner</b>		Prof. Dr. D. Johannsmann			
<b>31. Preliminary examinations</b>		None			

**1. Module title**Special Aspects of Technical  
Chemistry**2. Utilisability of the module in degree programs**

M.Sc. Chemistry (Mandatory elective “Specialist field 1”)

**3. Person(s) responsible for module**

Prof. Dr. S. Beuermann

**4. Relevant faculty**Faculty of Natural and Materials  
Science**5. Module number****6. Language**

English

**7. ECTS**

10

**8. Duration**

[ ] 1 semester

[X] 2 semesters

**9. To be offered**

[ ] each semester

[X] each study year

[ ] irregular

**10. Learning/qualification objectives of the module**

Lecture ‘Modeling of Chemical Processes’:

In the lecture ‘Modeling of Chemical Processes’, students learn to apply the knowledge from ‘Chemical Reaction Engineering’ to the modeling of chemical/biochemical processes. They can link kinetic models for composite complex reactions in homogeneous phase to material transport processes. Students understand the impact of reaction control and temperature by evaluating computer-aided concrete reaction processes. These kinetic models are theoretically covered by deterministic and stochastic simulations.

Lecture ‘Process Intensification in Chemistry’:

Students know the essential principles of process optimization and experiment design. They are able to apply these principles to current examples. They know possibilities to establish sustainable processes (e.g. innovative reaction media, reactor design, microreaction technology, etc.)

Practical course:

Students develop deep knowledge of technical chemistry by working on a current topic of the field ‘Special aspects of technical chemistry’). Students apply their English skills by reading English technical literature. Students gain insight in ways of working and thinking in research by completing an experimental seminar paper (with subsequent presentation) on a current research topic of the Institute. By drafting an extensive protocol, students deepen their knowledge of scientific representation and discussion of results. In the presentation, students practice presentation techniques and multimedia competence.

The module focuses on technical and methodological competences. Students are able to fundamentally discuss current issues regarding the development of sustainable processes.

<b>Courses</b>						
<b>11. No.</b>	<b>12. Title of the course</b>	<b>13. Lecturer</b>	<b>14. Course -No.</b>	<b>15. Type of course</b>	<b>16. SWS</b>	<b>17. Workload attendance/ internal study</b>
<b>1</b>	Modeling of Chemical Processes	Dr. M. Drache	W 3303	1V/1Ü	2	28 h / 32 h
<b>2</b>	Process Intensification in Chemistry	Prof. Dr. S. Beuermann, Dr. M. Drache	S 3327	V	2	28 h / 32 h
<b>3</b>	Practical Course on Special Aspects of Technical Chemistry	Prof. Dr. S. Beuermann, N.N.	W/S 3361	P	4	70 h / 50 h
<b>4</b>	Seminar on the Practical Course on Special Aspects of Technical Chemistry	Prof. Dr. S. Beuermann, N.N.	W/S 3374	S	1	14 h / 46 h
<b>Sum:</b>					9	140 h / 160 h
<b>About No. 1:</b>						
<b>18a. Rec. prerequisites</b>		Fundamentals of Technical Chemistry				
<b>19a. Contents</b>		<ul style="list-style-type: none"> <li>– Reaction technology and modeling with deterministic and stochastic processes</li> <li>– Impact of the chemical reactor, idealized reactor types: Residence time distribution of chemical reactors, behavior of chemical reactors, reaction control, heat balance of chemical reactors, reactor stability</li> <li>– Simulation of polymerization reactions, product properties</li> </ul>				
<b>20a. Media forms</b>		Board, PowerPoint (presentations are made available on Stud.IP)				
<b>21a. Literature</b>		<ul style="list-style-type: none"> <li>• L. Boodhoo, A. Harvey, Process Intensification for Green Chemistry, Wiley-VCH</li> <li>• M. Baerns, A. Behr, A. Brehm, J. Gmehling, H. Hofmann, U. Onken, A. Renken, Technische Chemie, Wiley-VCH</li> <li>• O. Levenspiel: Chemical Reaction Engineering, Wiley &amp; Sons, New York</li> <li>• R. W. Missen, C. A. Mims, B. A. Saville: Introduction to Chemical Reaction Engineering and Kinetics, Wiley &amp; Sons, New York</li> <li>• Current scientific publications</li> </ul>				
<b>22a. Other</b>		---				

<b>About No. 2:</b>	
<b>18b. Rec. prerequisites</b>	Fundamentals of Technical Chemistry
<b>19b. Contents</b>	<ul style="list-style-type: none"> <li>– Principles of process intensification</li> <li>– Alternative reaction media</li> <li>– Alternative methods of energy input (e.g. microwave or ultrasound radiation)</li> <li>– Microreaction technology</li> <li>– Membrane process</li> <li>– Integral processes: e.g. reactive distillation, reactive extraction, heat coupling</li> <li>– Statistical experiment design</li> </ul>
<b>20b. Media forms</b>	Board, PowerPoint (presentations are made available on Stud.IP)
<b>21b. Literature</b>	<ul style="list-style-type: none"> <li>• L. Boodhoo, A. Harvey, Process Intensification for Green Chemistry, Wiley-VCH</li> <li>• M. Baerns, A. Behr, A. Brehm, J. Gmehling, H. Hofmann, U. Onken, A. Renken, Technische Chemie, Wiley-VCH</li> <li>• O. Levenspiel: Chemical Reaction Engineering, Wiley &amp; Sons, New York</li> <li>• R. W. Missen, C. A. Mims, B. A. Saville: Introduction to Chemical Reaction Engineering and Kinetics, Wiley &amp; Sons, New York</li> <li>• Current scientific publications</li> </ul>
<b>22b. Other</b>	---
<b>About No. 3:</b>	
<b>18c. Rec. prerequisites</b>	Fundamentals of Technical Chemistry
<b>19c. Contents</b>	Working on a current research topic of the Institute
<b>20c. Media forms</b>	---
<b>21c. Literature</b>	<ul style="list-style-type: none"> <li>• L. Boodhoo, A. Harvey, Process Intensification for Green Chemistry, Wiley-VCH</li> <li>• M. Baerns, A. Behr, A. Brehm, J. Gmehling, H. Hofmann, U. Onken, A. Renken, Technische Chemie, Wiley-VCH</li> <li>• O. Levenspiel: Chemical Reaction Engineering, Wiley &amp; Sons, New York</li> <li>• R. W. Missen, C. A. Mims, B. A. Saville: Introduction to Chemical Reaction Engineering and Kinetics, Wiley &amp; Sons, New York</li> <li>• Scientific literature on process intensification and the topic of the practical work</li> </ul>
<b>22c. Other</b>	---
<b>About No. 4:</b>	

<b>18d. Rec. prerequisites</b>	Fundamentals of Technical Chemistry
<b>19d. Contents</b>	The findings of the research will be presented and subsequently discussed.
<b>20d. Media forms</b>	Students' PowerPoint presentations
<b>21d. Literature</b>	<ul style="list-style-type: none"> <li>• L. Boodhoo, A. Harvey, Process Intensification for Green Chemistry, Wiley-VCH</li> <li>• M. Baerns, A. Behr, A. Brehm, J. Gmehling, H. Hofmann, U. Onken, A. Renken, Technische Chemie, Wiley-VCH</li> <li>• O. Levenspiel: Chemical Reaction Engineering, Wiley &amp; Sons, New York</li> <li>• R. W. Missen, C. A. Mims, B. A. Saville: Introduction to Chemical Reaction Engineering and Kinetics, Wiley &amp; Sons, New York</li> <li>• Scientific literature on process intensification and the topic of the practical work</li> </ul>
<b>22d. Other</b>	---

<b>Study/examination performance</b>					
<b>23. No.</b>	<b>24. Assigned courses</b>	<b>25. Exam type</b>	<b>26. ECTS</b>	<b>27. Evaluation</b>	<b>28. Proportion of module grade</b>
<b>1</b>	Modeling of Chemical Processes, Process Intensification in Chemistry	MP	4	graded	100 %
<b>2</b>	Practical Course on Special Aspects of Technical Chemistry	LN	4	ungraded	0 % (§ 1 Abs. 6 APO i. V. m. § 13 Abs. 2 APO und § 18 Abs. 7 APO)
<b>3</b>	Seminar on the Practical Course on Special Aspects of Technical Chemistry	LN	2	ungraded	0 % (§ 1 Abs. 6 APO i. V. m. § 13 Abs. 2 APO und § 18 Abs. 7 APO)
<b>About No. 1:</b>					
<b>29a. Form of examination / prerequisite for the award of credit points</b>		Oral examination (M, 45 minutes)			
<b>30a. Responsible examiner</b>		Prof. Dr. S. Beuermann			

<b>31a. Preliminary examinations</b>	None
<b>About No. 2:</b>	
<b>29b. Form of examination / prerequisite for the award of credit points</b>	Practical assignment (PrA)
<b>30b. Responsible examiner</b>	Prof. Dr. S. Beuermann
<b>31b. Preliminary examinations</b>	None
<b>About No. 3:</b>	
<b>29c. Form of examination / prerequisite for the award of credit points</b>	Quality of the student's lecture in terms of content and type of presentation as well as oral participation in scientific discussions. (SL)
<b>30c. Responsible examiner</b>	Prof. Dr. S. Beuermann
<b>31c. Preliminary examinations</b>	None

<b>1a. Module title (German)</b> Moderne Umweltchemie	<b>1b. Module title (English)</b> Modern Environmental Chemistry
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<b>2. Utilisability of the module in degree programs</b> M.Sc. Chemistry (Mandatory elective "Specialist field 2")			
<b>3. Person(s) responsible for module</b> Academic dean		<b>4. Relevant faculty</b> Faculty of Natural and Materials Science	<b>5. Module number</b>
<b>6. Language</b> German / English	<b>7. ECTS</b> 10	<b>8. Duration</b> [ ] 1 semester [X] 2 semesters	<b>9. To be offered</b> [ ] each semester [X] each study year [ ] irregular
<b>10. Learning/qualification objectives of the module</b> <p>Students develop deepened knowledge and deeper understanding of the different processes in environmental chemistry and recycling, chemical and physical analytical measurement methods, agent usage, aerosols, legal bases, mechanisms of degradation and recycling of the essential metals.</p> <p>They are able to evaluate current questions of environmental chemistry in a technically correct manner, to critically question processes and applications, to develop solutions and, if applicable, apply them to their own work.</p> <p>Students can describe ways of polymer recycling and explain the individual machines. They are also able to identify current topics of the complex "recycling", to prepare them scientifically and present them to the other participants.</p> <p>In this module, students develop technical and methodological competences and some social competences.</p>			

<b>Courses</b>						
<b>11. No.</b>	<b>12. Title of the course</b>	<b>13. Lecturer</b>	<b>14. Course -No.</b>	<b>15. Type of course</b>	<b>16. SWS</b>	<b>17. Workload attendance/ internal study</b>
<b>1</b>	Recycling von Metallen (Recycling of Metals)	Dr. J. Wendelstorf	S 7904	V/Ü	3	42 h / 48 h
<b>2</b>	Umweltanalytik I - Einführung in die Umweltchemie (Environmental Analysis I - Introduction to Environmental Chemistry)	Dr. A. Fischer	S 3050	V/S	2	28 h / 32 h

<b>3</b>	Umweltanalytik II - Chemische Umweltanalytik (Environmental Analysis II - Chemical Environmental Analysis)	Dr. A. Fischer	W 3051	V/S	2	28 h / 32 h
<b>4</b>	Recycling von Kunststoffen (Recycling of Polymers)	N.N.	W 7919	V/S	3	42 h / 48 h
<b>Sum:</b>					10	140 h / 160 h
<b>About No. 1:</b>						
<b>18a. Rec. prerequisites</b>		---				
<b>19a. Contents</b>		<ol style="list-style-type: none"> <li>1. Introduction</li> <li>2. Iron and steel recycling</li> <li>3. Copper recycling</li> <li>4. Zinc recycling</li> <li>5. Lead recycling</li> <li>6. Aluminum recycling</li> <li>7. Magnesium recycling</li> <li>8. Comparison of extractive metallurgy processes</li> </ol>				
<b>20a. Media forms</b>		PowerPoint, Films				
<b>21a. Literature</b>		H. Martens und D. Goldmann: Recyclingtechnik. Fachbuch für Lehre und Praxis. Springer Verlag (2016). ISBN 978-3-658-02786-5				
<b>22a. Other</b>		---				
<b>About No. 2:</b>						
<b>18b. Rec. prerequisites</b>		---				
<b>19b. Contents</b>		<ul style="list-style-type: none"> <li>- Substances in the environment</li> <li>- Environmental law</li> <li>- Transport phenomena</li> <li>- Media-related concepts</li> <li>- Eco-toxicology</li> <li>- Case studies (ozone, carbon dioxide, cadmium, phthalates, pentachlorophenol, dibenzofurans, volatile organic compounds)</li> </ul>				
<b>20b. Media forms</b>		Board, slides, PowerPoint				
<b>21b. Literature</b>		<ul style="list-style-type: none"> <li>• Lecture notes</li> <li>• R. A. Hites, J. D. Raff, P. Wiesen, Umweltchemie, Wiley-VCH, 2017</li> <li>• C. Bliefert, Umweltchemie, Wiley-VCH, 2010</li> </ul>				

<b>22b. Other</b>	---
<b>About No. 3:</b>	
<b>18c. Rec. prerequisites</b>	---
<b>19c. Contents</b>	<p><i>Environment and material cycles:</i></p> <ul style="list-style-type: none"> <li>- Definitions</li> <li>- Environmental fields</li> <li>- Material cycles (geological cycle, mineralization and biosynthesis, nitrogen cycle, sulfur cycle, phosphor cycle, global anthropogenic cycle)</li> </ul> <p><i>Analytical chemistry</i></p> <ul style="list-style-type: none"> <li>- History</li> <li>- Tasks and problems</li> <li>- Classification of analysis methods</li> <li>- Basic steps and work areas</li> <li>- Error analysis, calibration curves</li> </ul> <p><i>Mobile environmental analysis:</i></p> <ul style="list-style-type: none"> <li>- Basics, classification</li> <li>- Test sticks and test papers</li> <li>- Colorimetric tests</li> <li>- Titration methods</li> <li>- Gas detection tubes</li> <li>- Examination of soil air with gas detection tubes</li> <li>- Air-water extraction procedures with gas detection tubes</li> <li>- Analysis sets and compact carrying case</li> <li>- Electrometrical measurement methods (conductivity, pH-value, redox potential, electrochemical sensors, voltammetry)</li> <li>- Photometric processes (cuvette tests, reflectometry)</li> <li>- Gas sensors (UV- and IR-absorption, interferometry, thermal conductivity measurement, potentiometric and amperometric sensors, susceptibility measurements, chemiluminescence-sensors, multi gas detectors, portable hydrocarbon analyzers)</li> <li>- Oil-in-water analyses with NDIR</li> <li>- Multifunction meters in water analysis</li> <li>- Multifunction meters in air analysis</li> </ul>

- Fields of application of mobile gas chromatographs
  - Fields of application of mobile liquid chromatographs
  - Mobile mass spectrometers
  - Ion mobility sensor
  - Biological and biochemical test methods
- Surveillance of air pollution control*
- Federal Immission Control Act
  - Regulations, definitions, emissions- immissions
  - Measurement strategies (heated or cooled probe, isokinetic extraction, measuring gas treatment, measuring arrangement for inorganic gases, dust substances, metals and metalloids, PAK, dioxins and furans
  - Sampling and suction errors
  - Sampling and measurement with the FID
- Waters testing:*
- Ground water, surface water, drinking water, drinking water ordinance
  - Waste water and its examination parameters
  - Landfill leachates, analysis of key parameters
  - Chemical oxygen demand COD
  - Biochemical oxygen demand BOD
  - Sum parameters TC, TIC, TOC, DOC and POC
  - Sum parameters AOX, EOX , POX as well as phenolindex
  - DIN- and EN-standards
  - Ion chromatography
  - Element analyses with the ICP-OES
- Solids testing:*
- Sampling (total sample, tapering, partial sample)
  - Sampling soils
  - Breakdown of solid samples
  - Testing of PCB-contaminated soils
  - Processes for KW, PAK and pesticides in soils
  - Heavy metals in soils and solids
  - Mobilization of heavy metals, extraction results
  - Parameters of waste analysis, disposal channel incineration
  - Parameter of waste analysis, disposal channel landfills

<b>20c. Media forms</b>	Board, slides, PowerPoint
<b>21c. Literature</b>	<ul style="list-style-type: none"> <li>• C. Bliefert: Umweltchemie, 3rd ed. (2002), VCH Verlag, Weinheim</li> <li>• G. Schwedt: Taschenatlas der Umweltchemie, Wiley VCH (1996)</li> </ul>
<b>22c. Other</b>	---
<b>About No. 4:</b>	
<b>18d. Rec. prerequisites</b>	---
<b>19d. Contents</b>	<ul style="list-style-type: none"> <li>• Economic data on polymers</li> <li>• Thermal recycling</li> <li>• Mechanical recycling</li> <li>• Materials recycling</li> <li>• Examples of recycling</li> <li>• Application of recyclates</li> <li>• Legal bases</li> <li>• Designing for recyclability</li> </ul>
<b>20d. Media forms</b>	Board, slides, PowerPoint presentations, films
<b>21d. Literature</b>	<ul style="list-style-type: none"> <li>• G. Menges: Recycling von Kunststoffen, Carl Hanser Verlag, ISBN 978-3-4461-6437-6</li> <li>• N. Rudolph: Understanding Plastics Recycling, Carl Hanser Verlag, ISBN 978-1-5699-0676-7</li> </ul>
<b>22d. Other</b>	---

<b>Study/examination performance</b>					
<b>23. No.</b>	<b>24. Assigned courses</b>	<b>25. Exam type</b>	<b>26. ECTS</b>	<b>27. Evaluation</b>	<b>28. Proportion of module grade</b>
<b>1</b>	Recycling of Metals, Chemical Environmental Analysis I and II, Recycling of Polymers	MP	10	graded	100 %
<b>29. Form of examination / prerequisite for the award of credit points</b>		Oral examination (M, 45 minutes)			
<b>30. Responsible examiner</b>		Dr. J. Wendelstorf, Dr. A. Fischer, N.N.			
<b>31. Preliminary examinations</b>		None			

<b>1a. Module title (German)</b> Einführung in die Chemie des Brauwesens	<b>1b. Module title (English)</b> Introduction into the Chemistry of Brewing
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<b>2. Utilisability of the module in degree programs</b> M.Sc. Chemistry (Mandatory elective “Specialist field 2”)			
<b>3. Person(s) responsible for module</b> Prof. Dr. F. Endres		<b>4. Relevant faculty</b> Faculty of Natural and Materials Science	
<b>6. Language</b> German/ English		<b>7. ECTS</b> 10	
<b>8. Duration</b> <input type="checkbox"/> 1 semester <input checked="" type="checkbox"/> 2 semesters		<b>9. To be offered</b> <input type="checkbox"/> each semester <input checked="" type="checkbox"/> each study year <input type="checkbox"/> irregularly	
<b>10. Learning/qualification objectives of the module</b> The students know and explain the significance of the chemical and processes in the production of beer. They describe and evaluate the production and characterization of beers from the basic ingredients to the finished product. Students will understand basic physical and chemical properties of beers and possess in-depth knowledge of processes for their production and characterization. They outline their own recipes and carry out the brewing process in all stages up to the to the analysis of the finished product. They transfer and verify the gained knowledge practically on the basis of current research topics. Students work up their scientific results and discuss them critically. The module imparts technical, social and methodological competence.			

Courses						
11. No.	12. Title of the course	13. Lecturer	14. Course -No.	15. Type of course	16. SWS	17. Workload attendance/ internal study
1	Theorie und Praxis der Bierbrauerei (Theory and practice of brewing)	Prof. Dr. F. Endres	S 8036	V	2	28 h / 62 h
2	Bieranalytik (Beer analytics)	Prof. Dr. F. Endres	W 8056	V/Ü	2	28 h / 62 h

<b>3</b>	Praktikum in der TU Clausthal Brauerei (Practical course in the TU Clausthal Brewery)	Prof. Dr. F. Endres	S 8056	P	4	56 h / 34 h
<b>4</b>	Exkursion und Blockvorlesung zu kommerziellen Aspekten des Brauwesens (Excursion and block lecture on commercial aspects of brewing)	Prof. Dr. F. Endres Dr. M. Zarnkow	S 8090	1E/1V	2	20 h / 10 h
<b>Sum:</b>					10	132 h / 168 h
<b>About No. 1:</b>						
<b>18a. Rec. prerequisites</b>		Basic knowledge of physics and chemistry is required, such as those taught in the bachelor's degree program in chemistry at the TU Clausthal				
<b>19a. Contents</b>		<ul style="list-style-type: none"> <li>- History</li> <li>- The Purity Law of April 23, 1516</li> <li>- The provisional beer law of 1993</li> <li>- Fiscal aspects</li> <li>- The "craft beer" era</li> <li>- Classification of beers</li> <li>- Beer categories</li> <li>- Types of beer</li> <li>- Overview of the brewing process</li> <li>- Overview of malt production and malt varieties</li> <li>- Brewing water</li> <li>- Hops</li> <li>- Alcoholic fermentation and brewing yeasts</li> <li>- The technology of wort preparation (equipment, malt selection, malting, mashing)</li> <li>- Isothermal mashing at temperatures &gt; 70 °C</li> </ul>				
<b>20a. Media forms</b>		Board, slides, lecture notes, exercise block				
<b>21a. Literature</b>		<ol style="list-style-type: none"> <li>1. „Bier – Eine Geschichte von der Steinzeit bis heute“, G. Hirschfelder und M. Trummer, Theiss Verlag 2016</li> <li>2. „Abriss der Bierbrauerei“, L. Narziß, W. Back, M. Gastl, M. Zarnkow“, Wiley-VCH 2017</li> <li>3. „Die Bierbrauerei, Band 1: Die Technologie der Malzbereitung“, L. Narziß und W. Back, Wiley-VCH 2012</li> <li>4. „Die Bierbrauerei, Band 2: Die Technologie der Würzebereitung“, L.</li> </ol>				

	<p>Narziß und W. Back, Wiley-VCH 2009</p> <p>5. „Ausgewählte Kapitel der Brauereitechnologie“, W. Back, Fachverlag Hans Carl 2008</p> <p>6. „Gutes Bier selbst brauen: Schritt für Schritt - mit Rezepten“ (BLV) Taschenbuch – 9. März 2016, Hubert Hanghofer</p> <p>7. „Bier selbst gebraut“, K. Kling, Verlag die Werkstatt GmbH, 4. Auflage 2015</p>
<b>22a. Other</b>	---
<b>About No. 2:</b>	
<b>18b. Rec. prerequisites</b>	Basic knowledge of physics and chemistry is required, such as those taught in the bachelor's degree program in chemistry at the TU Clausthal
<b>19b. Contents</b>	<ul style="list-style-type: none"> <li>- Original gravity of unfermented wort by refractometry and</li> <li>- Bending oscillator</li> <li>- Determination of sugar distribution (enzymatic, HPLC)</li> <li>- Determination of amino acids (ninhydrin method, HPLC)</li> <li>- Determination of original gravity and alcohol content of finished beers by means of bending oscillator and NIR spectrometry</li> <li>- Determination of color and bitterness by UV/Vis-spectrometry</li> <li>- Determination of lactic acid content</li> <li>- Identification of lactic acid bacteria contamination</li> <li>- by means of the polymer cascade reaction</li> </ul>
<b>20b. Media forms</b>	Board, slides, lecture notes, exercise block
<b>21b. Literature</b>	Mitteleuropäische Brauanalysekommission (MEBAK), Würze, Bier, Biermischgetränke (WBBM). Selbstverlag der MEBAK, 2012, ISBN 978-3-9805814-6-2
<b>22b. Other</b>	---
<b>About No. 3:</b>	
<b>18c. Rec. prerequisites</b>	Basic knowledge of physics and chemistry is required, such as those taught in the bachelor's degree program in chemistry at the TU Clausthal
<b>19c. Contents</b>	<ul style="list-style-type: none"> <li>- Calculation of different brews</li> <li>- Brewing of 3 beers in the research brewery (bottom-fermented, top-fermented, non-alcoholic beer)</li> <li>- In situ monitoring of brewing parameters</li> <li>- Fermentation in cylindrical-conical fermentation tanks</li> <li>- Bottling under Counter-pressure</li> <li>- Beer analysis</li> <li>- HACCP - Hazard Analysis and Critical Control Points</li> </ul>

<b>20c. Media forms</b>	laboratory script, recent scientific publications
<b>21c. Literature</b>	---
<b>22c. Other</b>	---
<b>About No. 4:</b>	
<b>18d. Rec. prerequisites</b>	Basic knowledge of physics and chemistry is required, such as those taught in the bachelor's degree program in chemistry at the TU Clausthal
<b>19d. Contents</b>	<ul style="list-style-type: none"> <li>- Excursion to a brewery, familiarization with commercial brewing processes</li> <li>- brewing processes, accompanying lecture (by Dr. Zarnkow):</li> <li>- Malting - only an energetic paradox?</li> <li>- Mashing - from poorly soluble to liquid</li> <li>- Fermentation - almost inexhaustible variety</li> <li>- Foam - the characteristic of beer</li> <li>- Stability - the crux of globalization</li> <li>- Brewing history - beer as a driving force for sedentism?</li> </ul>
<b>20d. Media forms</b>	---
<b>21d. Literature</b>	Bier – Eine Geschichte von Hopfen und Malz. Meusdoerffer, F., Zarnkow, M., CH Beck Verlag, München, 2016
<b>22d. Other</b>	---

<b>Study/examination performance</b>					
<b>23. No.</b>	<b>24. Assigned courses</b>	<b>25. Exam type</b>	<b>26. ECTS</b>	<b>27. Evaluation</b>	<b>28. Proportion of module grade</b>
<b>1</b>	Theory and practice of brewing, Beer analytics, Practical course on brewing	MP	9	graded	100 %
<b>2</b>	Excursion and block lecture on commercial aspects of brewing	LN	1	ungraded	0 % (§ 1 Abs. 6 APO i. V. m. § 13 Abs. 2 APO und § 18 Abs. 7 APO)
<b>About No. 1:</b>					
<b>29a. Form of examination / prerequisite for the award of credit points</b>		Oral examination (M, 45 minutes)			

<b>30a. Responsible examiner</b>	Prof. Dr. F. Endres
<b>31a. Preliminary examinations</b>	None
<b>About No. 2:</b>	
<b>29b. Form of examination / prerequisite for the award of credit points</b>	Quality of the student´s lecture in terms of content and type of presentation as well as oral participation in scientific discussions (SL)
<b>30b. Responsible examiner</b>	Prof. Dr. F. Endres
<b>31b. Preliminary examinations</b>	None

<b>1a. Module title (German)</b> Energie und Materialphysik	<b>1b. Module title (English)</b> Energy and Materials Physics
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<b>2. Utilisability of the module in degree programs</b> M.Sc. Chemistry (Mandatory elective "Specialist field 2")			
<b>3. Person(s) responsible for module</b> Prof. Dr. H. Fritze		<b>4. Relevant faculty</b> Faculty of Natural and Materials Science	
<b>6. Language</b> German or Englisch		<b>7. ECTS</b> 10	
<b>8. Duration</b> [ ] 1 semester [X] 2 semesters		<b>5. Module number</b>	
<b>9. To be offered</b> [ ] each semester [X] each study year [ ] irregular			
<b>10. Learning/qualification objectives of the module</b> <i>Surface Analysis and Physics:</i> Students know essential properties of monocrystalline solid surfaces and thin layers as well as processes for their manufacturing and characterization. This course includes laboratory tutorials, teaching students essential surface analytical procedures and the determination of suitable analysis methods for different surfaces and surface chemistries. Furthermore, students gain insights in the modern ultra-high vacuum technology. <i>Functional materials:</i> Students know the different materials in batteries, fuel cells and sensors. They are familiar with the basic physical processes of the functional units and know their similarities. Students recognize the connection between function and material and are able to identify application-relevant material systems. <i>Introduction to Energy:</i> Students know basic physical processes for energy conversion. They are able to describe conventional and regenerative generation of electrical current and concepts of energy storage. The module focuses on technical and methodological competences.			

<b>Courses</b>						
<b>11. No.</b>	<b>12. Title of the course</b>	<b>13. Lecturer</b>	<b>14. Course -No.</b>	<b>15. Type of course</b>	<b>16. SWS</b>	<b>17. Workload attendance/ internal study</b>
<b>1</b>	Oberflächenanalytik und -physik (Surface Analysis and Physics)	Dr. K. Stallberg	W 2319	V/Ü	3	42 h / 78 h

<b>2</b>	Funktionsmaterialien (Functional Materials)	Prof. Dr. H. Fritze	S 2340	V	3	42 h / 78 h
<b>3</b>	Einführung Energie (Introduction to Energy)	PD Dr. U. Willer	W 2122	V/Ü	2	28 h / 32 h
<b>Sum:</b>					8	112 h / 188 h

**About No. 1:**

<b>18a. Rec. prerequisites</b>	None
<b>19a. Contents</b>	<ol style="list-style-type: none"> <li>1. Two-dimensional X-ray structure analysis - invariance of crystals and their surfaces with symmetry operations</li> <li>2. Defined surfaces and sample environment</li> <li>3. Determination of geometrical surface structures: Diffraction experiments</li> <li>4. States and electron transfer at solid surfaces (valence band and conduction band states)</li> <li>5. Surface imaging on an atomic scale: Scanning probe microscopy</li> <li>6. Interactions of electrons and matter</li> <li>7. Auger electron spectroscopy</li> <li>8. Photoemission electron spectroscopy</li> <li>9. Electron microscopy of surfaces: Setup and contrast mechanisms</li> <li>10. Analytical electron microscopy: EDS, WDS, SAM</li> <li>11. Ion-assisted methods of solid state analysis: SIMS and RBS</li> <li>12. Adsorption, diffusion and desorption</li> <li>13. Surface defects – equilibrium forms of crystals</li> <li>14. Growth and manufacturing of thin solid films</li> </ol>
<b>20a. Media forms</b>	Board, retrievable presentations, practical exercises on modern analysis tools
<b>21a. Literature</b>	<ul style="list-style-type: none"> <li>• H. Lüth: "Solid Surfaces, Interfaces and Thin Films", 4th Edition, Springer, 2001</li> <li>• H. Ibach: "Physics of Surfaces and Interfaces", Springer 2006</li> <li>• K. Oura et al.: Surface Science, Springer 2003</li> <li>• M. Henzler: "Oberflächenphysik des Festkörpers", Teubner 1991</li> </ul>
<b>22a. Other</b>	---
<b>About No. 2:</b>	
<b>18b. Rec. prerequisites</b>	none

<b>19b. Contents</b>	<ul style="list-style-type: none"> <li>• Energy resources and savings potentials</li> <li>• Anodes and cathodes materials for batteries</li> <li>• Materials for (high temperature) fuel cells</li> <li>• Sensor materials</li> </ul>
<b>20b. Media forms</b>	Board, PowerPoint, electronically retrievable lecture notes and presentations
<b>21b. Literature</b>	<p>Y-M. Chiang, D. P. Birnie, W. D. Kingery, Physical Ceramics, John Wiley &amp; Sons, 1996.</p> <p>S. Basu, Recent Trends in Fuel Cell Science and Technology, Springer, 2007.</p> <p>N. Sammers (Ed.), Fuel Cell Technology: Reaching Towards Commercialization (Engineering Materials and Processes), Springer 2006.</p> <p>P. Shewmon, Diffusion in Solids, John Wiley &amp; Sons, 2010.</p>
<b>22b. Other</b>	---
<b>About No. 3:</b>	
<b>18c. Rec. prerequisites</b>	none
<b>19c. Contents</b>	<ul style="list-style-type: none"> <li>• Energy in science and everyday life</li> <li>• Energy conversion processes, power stations</li> <li>• Conventional and regenerative energy</li> <li>• Energy storage</li> <li>• Power2X</li> </ul>
<b>20c. Media forms</b>	PowerPoint, electronically retrievable presentations, board
<b>21c. Literature</b>	electronically retrievable presentations
<b>22c. Other</b>	---

<b>Study/examination performance</b>					
<b>23. No.</b>	<b>24. Assigned courses</b>	<b>25. Exam type</b>	<b>26. ECTS</b>	<b>27. Evaluation</b>	<b>28. Proportion of module grade</b>
<b>1</b>	Surface Analysis and Physics	MTP	4	graded	33 %
<b>2</b>	Functional Materials	MTP	4	graded	33 %
<b>3</b>	Introduction to Energy	MTP	2	graded	33 %

<b>About No. 1:</b>	
<b>29a. Form of examination / prerequisite for the award of credit points</b>	Oral examination (M, 30 minutes)
<b>30a. Responsible examiner</b>	Dr. K. Stallberg
<b>31a. Preliminary examinations</b>	None
<b>About No. 2:</b>	
<b>29b. Form of examination / prerequisite for the award of credit points</b>	Oral examination (M, 30 minutes)
<b>30b. Responsible examiner</b>	Prof. Dr. H. Fritze
<b>31b. Preliminary examinations</b>	None
<b>About No. 3:</b>	
<b>29c. Form of examination / prerequisite for the award of credit points</b>	Oral examination (M, 30 minutes)
<b>30c. Responsible examiner</b>	PD Dr. U. Willer
<b>31c. Preliminary examinations</b>	None

**1. Module title**

## Macromolecular Chemistry and Processes

**2. Utilisability of the module in degree programs**

M.Sc. Chemistry (mandatory module "SR Polymer Chemistry")

**3. Person(s) responsible for module**

Prof. Dr. S. Beuermann

**4. Relevant faculty**

Faculty of Natural and Materials Science

**5. Module number****6. Language**

English

**7. ECTS**

8

**8. Duration**[ ] 1 semester  
[X] 2 semesters**9. To be offered**[ ] each semester  
[X] each study year  
[ ] irregular**10. Learning/qualification objectives of the module**

In the lecture 'Macromolecular kinetics and reaction technology', students develop deeper knowledge of polymerization kinetics and technology. Students dive into current methods to determine kinetic coefficients for elementary reactions. Due to their detailed understanding of elementary reactions, students are able to understand and explain the coupling of kinetics, reaction control and polymer architecture. Based on this knowledge, students can make suggestions for the synthesis of custom polymers. Students know examples of sustainable developments in polymer chemistry.

In the lecture 'Current Aspects of Polymer Chemistry', students become familiar with current developments and work in the field of polymer chemistry, especially the synthesis of polymers with custom properties and the coupling of synthetic polymers and biomacromolecules. They have deepened knowledge of different possibilities for the targeted synthesis of polymer architectures. Students can suggest synthesis strategies for complex polymer molecules.

In the course 'Modeling of Polymerization Processes', students learn about the modeling of polymerization processes and the resulting product properties. Based on the theoretical foundations, students can use computers to conduct parameter studies, extrapolations and optimization of polymerization processes and polymer properties.

The module focuses on technical and methodological competences. Students are able to engage well-informed in discussions about sustainability aspects of polymer chemistry.

<b>Courses</b>						
<b>11. No.</b>	<b>12. Title of the course</b>	<b>13. Lecturer</b>	<b>14. Course -No.</b>	<b>15. Type of course</b>	<b>16. SWS</b>	<b>17. Workload attendance/ internal study</b>
<b>1</b>	Macromolecular Kinetics and Process Technology	Prof. Dr. S. Beuermann	S 3334	V/Ü	3	42 h / 48 h
<b>2</b>	Modeling and Simulation in Polymer Reaction Engineering	Dr. M. Drache	S 3326	V/Ü	2	28 h / 32 h
<b>3</b>	Modern Aspects of Polymer Chemistry	Prof. Dr. V. Hirschberg	W 3334	V	2	28 h / 62 h
<b>Sum:</b>					8	98 h / 142 h
<b>About No. 1:</b>						
<b>18a. Rec. prerequisites</b>		The fundamentals of macromolecular chemistry as well as the fundamentals of organic chemistry, technical chemistry and physical chemistry as taught in the Bachelor program Chemistry.				
<b>19a. Contents</b>		<ul style="list-style-type: none"> <li>- Molar mass distribution</li> <li>- Coupling polymerization kinetics - molar mass distribution</li> <li>- Modern methods for determination of kinetic coefficients for elementary reactions</li> <li>- Targeted synthesis of polymer structures based on kinetics and modeling</li> <li>- Catalytic polymerizations</li> <li>- Reaction control influence</li> <li>- Sustainable developments in polymer chemistry</li> </ul>				
<b>20a. Media forms</b>		Board, PowerPoint (presentations are made available on Stud.IP)				
<b>21a. Literature</b>		<ul style="list-style-type: none"> <li>• G. Moad, D. H. Solomon „The Chemistry of Radical Polymerization“, Elsevier, 2. fully revised edition, 2006</li> <li>• G. Odian "Principles of Polymerization", Wiley, 4th edition, 2004</li> <li>• M.D. Lechner, K. Gerke, E.H. Nordmeier: Makromolekulare Chemie, Birkhäuser Verlag, Berlin</li> <li>• Echte: Handbuch der Technischen Polymerchemie, Wiley-VCH</li> <li>• Current scientific publications</li> </ul>				
<b>22a. Other</b>		---				
<b>About No. 2:</b>						
<b>18b. Rec. prerequisites</b>		Lecture / Exercise Macromolecular Kinetics and Reaction Technology				

<b>19b. Contents</b>	<ul style="list-style-type: none"> <li>- Modeling of polymerization processes with deterministic and stochastic simulation processes</li> <li>- Parameter studies – extrapolation – validation</li> <li>- Optimization of polymer properties</li> </ul>
<b>20b. Media forms</b>	Board, PowerPoint (presentations are made available on Stud.IP)
<b>21b. Literature</b>	<ul style="list-style-type: none"> <li>• G. Moad, D. H. Solomon „The Chemistry of Radical Polymerization", Elsevier, 2. fully revised edition, 2006</li> <li>• G. Odian "Principles of Polymerization", Wiley, 4th edition, 2004</li> <li>• M.D. Lechner, K. Gerke, E.H. Nordmeier: Makromolekulare Chemie, Birkhäuser Verlag, Berlin</li> <li>• Echte: Handbuch der Technischen Polymerchemie, Wiley-VCH</li> <li>• K.-D. Hungenberg, M. Wulkow „Modeling and Simulation in Polymer Reaction Engineering“, Wiley-VCH</li> <li>• Current scientific publications</li> </ul>
<b>22b. Other</b>	---
<b>About No. 3:</b>	
<b>18c. Rec. prerequisites</b>	The fundamentals of macromolecular chemistry as well as the fundamentals of organic chemistry, technical chemistry and physical chemistry as taught in the Bachelor program Chemistry.
<b>19c. Contents</b>	<ul style="list-style-type: none"> <li>- Custom-made polymers</li> <li>- Controlled radical polymerization</li> <li>- Click chemistry</li> <li>- Enzymatic polymerizations</li> <li>- Bioconjugates</li> <li>- Block copolymers</li> <li>- Polyolefines: Metallocene-catalyzed reactions</li> </ul>
<b>20c. Media forms</b>	Board, PowerPoint (presentations are made available on Stud.IP)
<b>21c. Literature</b>	<ul style="list-style-type: none"> <li>• G. Moad, D. H. Solomon „The Chemistry of Radical Polymerization", Elsevier, 2. fully revised edition, 2006</li> <li>• G. Odian "Principles of Polymerization", Wiley, 4th edition, 2004</li> <li>• „Macromolecular Engineering" (4 volumes), K. Matyjaszewski, Y. Gnanou, L. Leibler, Wiley-VCH 2007</li> <li>• Current scientific publications</li> </ul>
<b>22c. Other</b>	---

<b>Study/examination performance</b>					
<b>23. No.</b>	<b>24. Assigned courses</b>	<b>25. Exam type</b>	<b>26. ECTS</b>	<b>27. Evaluation</b>	<b>28. Proportion of module grade</b>
<b>1</b>	Macromolecular Kinetics and Process Technology, Modeling and Simulation in Polymer Reaction Engineering, Modern Aspects of Polymer Chemistry	MP	8	graded	100 %
<b>About No. 1:</b>					
<b>29. Form of examination / prerequisite for the award of credit points</b>		Oral examination (M, 45 minutes)			
<b>30. Responsible examiner</b>		Prof. Dr. S. Beuermann			
<b>31. Preliminary examinations</b>		None			

**1. Module title**Physicochemical Aspects of  
Polymers**2. Utilisability of the module in degree programs**

M.Sc. Chemistry (mandatory module "SR Polymer Chemistry")

**3. Person(s) responsible for module**

Prof. Dr. D. Johannsmann

**4. Relevant faculty**Faculty of Natural and Materials  
Science**5. Module number****6. Language**

English

**7. ECTS**

6

**8. Duration** 1 semester 2 semesters**9. To be offered** each semester each study year irregularly**10. Learning/qualification objectives of the module**

The students obtain profound knowledge on the structure of macromolecules, analytical methods, physical modifications of polymers, phase behavior, and polymer interfaces. They are familiar with traditional as well as modern methods of polymer analysis. They can solve problems related to modern polymer materials.

The module focuses on technical and methodological competences.

**Courses**

11. No.	12. Title of the course	13. Lecturer	14. Course -No.	15. Type of course	16. SWS	17. Workload attendance/ internal study
1	Analysis of Polymers	adj. Prof. Dr. J. Adams	W 3218	V	1	14 h / 46 h
2	Basics of Polymer Physics	Prof. Dr. D. Johannsmann	W3221	V	1	14 h / 46 h
3	Polymers at Interfaces	Prof. Dr. D. Johannsmann	S 3226	V	1	14 h / 46 h
<b>Sum:</b>					3	42 h / 138 h

<b>About No. 1: Analysis of Polymers</b>	
<b>18a. Rec. prerequisites</b>	The fundamentals of macromolecular chemistry, physical chemistry, organic chemistry and technical chemistry are required.
<b>19a. Contents</b>	<ul style="list-style-type: none"> <li>- Structure of macromolecules: Ideal and real chains</li> <li>- Characterization of polymers: Separation of polymers Determination of molar mass distribution and average molar mass Determination of thermodynamic parameters Structure and size of polymer coils</li> </ul>
<b>20a. Media forms</b>	Board, slides, PowerPoint
<b>21a. Literature</b>	<ul style="list-style-type: none"> <li>- H.-G. Elias: Makromoleküle, Band 2, Physikalische Strukturen und Eigenschaften, Wiley-VCH, 6th edition, 2001</li> <li>- S. Seiffert: Physical Chemistry of Polymers: A Conceptual Introduction De Gruyter Textbook 2nd edition, 2023</li> <li>- M. D. Lechner, K. Gehrke, E. H. Nordmeier: Makromolekulare Chemie, Birkhäuser Verlag, 2010</li> </ul>
<b>22a. Other</b>	---
<b>About No. 2: Basics of Polymer Physics</b>	
<b>18b. Rec. prerequisites</b>	...
<b>19b. Contents</b>	<ul style="list-style-type: none"> <li>- Polymer mostly are or contain flexible linear chains</li> <li>- Polymers combine order and mobility in a unique way</li> <li>- The random walk and its consequences</li> <li>- Rubber elasticity as a paradigm for entropy elasticity</li> <li>- Motion of polymers in solution and in the melt</li> <li>- Peculiar behavior of polymers in flow</li> <li>- Polymer gels and their use</li> <li>- Polyelectrolytes</li> <li>- Semicrystalline polymers</li> <li>- Electronic conductivity, organic electronics</li> </ul>
<b>20b. Media forms</b>	Board, slides, computer presentations
<b>21b. Literature</b>	<ul style="list-style-type: none"> <li>- M. Rubinstein: R. H. Colby, Polymer Physics, Oxford University Press, 2003</li> <li>- J. Young, P. Lovell: Introduction to Polymers, CRC Press</li> </ul>
<b>22b. Other</b>	---

<b>About No. 3: Polymers at Interfaces</b>	
<b>18c. Rec. prerequisites</b>	-
<b>19c. Contents</b>	<ul style="list-style-type: none"> <li>- Role of polymers in adhesion</li> <li>- Structural adhesives, pressure sensitive adhesive, Gecko-type adhesion</li> <li>- Polymer brushes and polymer adsorbates</li> <li>- Brush height as the result of a competition between osmotic pressure and rubber elasticity</li> <li>- Polyelectrolyte brushes</li> <li>- Responsive brushes, responsive polymers</li> </ul>
<b>20c. Media forms</b>	Board, slides, PowerPoint, computer presentations
<b>21c. Literature</b>	<ul style="list-style-type: none"> <li>- Pocius, A. V., Adhesion and Adhesives Technology. Hanser Gardner: 1996.</li> <li>- Abbott, S., Adhesion Science: Principles and Practice. DEStech Publications: 2015.</li> <li>- <a href="http://www.stevenabbott.co.uk/practical-adhesion">www.stevenabbott.co.uk/practical-adhesion</a></li> <li>- M. D. Lechner, K. Gehrke, E. H. Nordmeier: Makromolekulare Chemie, Birkhäuser Verlag, 2010</li> <li>- M. Rubinstein: R. H. Colby, Polymer Physics, Oxford University Press, 2003</li> <li>- L.H. Sperling: Introduction to Physical Polymer Science, Wiley, 1992</li> </ul>
<b>22c. Other</b>	---

<b>Study/examination performance</b>					
<b>23. No.</b>	<b>24. Assigned courses</b>	<b>25. Exam type</b>	<b>26. ECTS</b>	<b>27. Evaluation</b>	<b>28. Proportion of module grade</b>
<b>1</b>	Analysis of Polymers, Basics of Polymer Physics, Polymers at Interfaces	MP	6	graded	100 %
<b>About No. 1:</b>					
<b>29. Form of examination / prerequisite for the award of credit points</b>		Oral examination (M, 45 minutes)			
<b>30. Responsible examiner</b>		Prof. Dr. D. Johannsmann			
<b>31. Preliminary examinations</b>		None			

**1. Module title**

Plastics Engineering

**2. Utilisability of the module in degree programs**

M.Sc. Chemistry (mandatory module "SR Polymer Chemistry")

<b>3. Person(s) responsible for module</b> Dr. L. Steuernagel		<b>4. Relevant faculty</b> Faculty of Natural and Materials Science	<b>5. Module number</b>
<b>6. Language</b> English	<b>7. ECTS</b> 6	<b>8. Duration</b> [X] 1 semester [ ] 2 semesters	<b>9. To be offered</b> [ ] each semester [X] each study year [ ] irregular

**10. Learning/qualification objectives of the module**

Students are able to describe and explain processing machines as well as process regarding thermoplastic and thermosettings and fiber reinforced plastics. They can also describe and evaluate specific features of the individual processing steps and classify their material-specific characteristics.

The module focuses on technical and methodological competences.

**Courses**

11. No.	12. Title of the course	13. Lecturer	14. Course-No.	15. Type of course	16. SWS	17. Workload attendance/ internal study
1	Plastics Engineering	Dr. L. Steuernagel	W 7882	V/Ü	4	56 h / 124 h
<b>Sum:</b>					4	56 h / 124 h

**About No. 1:**
**18. Rec. prerequisites**

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<p><b>19. Contents</b></p>	<ul style="list-style-type: none"> <li>• Basics in plastics processing</li> <li>• Processing behavior fundamentals</li> <li>• Thermoplastic material:             <ul style="list-style-type: none"> <li>○ Extrusion technology</li> <li>○ Injection molding technology</li> <li>○ Press / transfer molding technology</li> <li>○ Foaming: Foam formation process, integral foam technology</li> </ul> </li> <li>• Thermosettings:             <ul style="list-style-type: none"> <li>○ Fiber composite technology: Prepreg, winding process, pressing technique, RTM-processes</li> </ul> </li> <li>• Joining and adhesive technologies</li> </ul>
<p><b>20. Media forms</b></p>	<p>PowerPoint presentation, videos, machine/process demonstrations</p>
<p><b>21. Literature</b></p>	<p>English literature:</p> <ul style="list-style-type: none"> <li>• K. Kohlgrüber, M. Bierdel, H. Rust: Plastics Compounding and Polymer Processing - Fundamentals, Machines, Equipment, Application Technology, 2021, Carl Hanser Verlag, ISBN: 978-1-569-90837-2</li> <li>• C. Bonten, Plastics Technology - Introduction and Fundamentals, 2020, Carl Hanser Verlag, ISBN: 978-1-56990-767-2</li> <li>• T. Osswald, Understanding Polymer Processing - Processes and Governing Equations, 2. Edition, 2017, Carl Hanser Verlag, ISBN: 9-781-569-90647-7</li> <li>• Böhlke, T., Henning, F., Hrymak, A., Kärger, L., Weidenmann, K., Wood, J., Continuous–Discontinuous Fiber-Reinforced Polymers - An Integrated Engineering Approach, 2019, Carl Hanser Verlag, ISBN: 978-1-56990-692-7</li> </ul> <p>Supporting German literature:</p> <ul style="list-style-type: none"> <li>• W. Michaeli: Einführung in die Kunststoffverarbeitung, Carl Hanser Verlag, ISBN 978-3-446-42488-3</li> <li>• W. Michaeli: Technologie der Kunststoffe, Carl Hanser Verlag, ISBN 978-3-446-41514-0</li> </ul> <p>G. W. Ehrenstein: Faserverbund-Kunststoffe, Carl Hanser Verlag, ISBN 978-3-446-22716-3</p> <ul style="list-style-type: none"> <li>• M. Flemming, G. Ziegmann, S. Roth: Faserverbundbauweisen, Springer Verlag, ISBN 978-3-540-60616-1</li> </ul>
<p><b>22. Other</b></p>	<p>---</p>

<b>Study/examination performance</b>					
<b>23. No.</b>	<b>24. Assigned courses</b>	<b>25. Exam type</b>	<b>26. ECTS</b>	<b>27. Evaluation</b>	<b>28. Proportion of module grade</b>
<b>1</b>	Plastics Engineering	MP	6	ben.	100 %
<b>29. Form of examination / prerequisite for the award of credit points</b>		Written examination (K, 90 minutes)			
<b>30. Responsible examiner</b>		Dr. L. Steuernagel			
<b>31. Preliminary examinations</b>		None			

**1. Module title**

## Practical Course on Polymers I

**2. Utilisability of the module in degree programs**

M.Sc. Chemistry (mandatory module "SR Polymer Chemistry")

**3. Person(s) responsible for module**Prof. Dr. S. Beuermann  
Prof. Dr. D. Johannsmann**4. Relevant faculty**Faculty of Natural and Materials  
Science**5. Module number****6. Language**

English

**7. ECTS**

6

**8. Duration**[X] 1 semester  
[ ] 2 semesters**9. To be offered**[X] each semester  
[ ] each study year  
[ ] irregular**10. Learning/qualification objectives of the module**

By active and research oriented participation in work groups, students know current topics of their selected field, either 'Macromolecular Chemistry and Processes', 'Physico-chemical Aspects of Polymers' or "Plastics Processing". Students are able to work on and answer scientific questions based on their state of knowledge. They know experimental and theoretical methods and models and are able to apply them.

This module promotes technical and methodological competences, and social competence through the participation in a work group.

**Courses**

11. No.	12. Title of the course	13. Lecturer	14. Course -No.	15. Type of course	16. SWS	17. Workload attendance/ internal study
1	Practical Course on Polymers I	Prof. Dr. S. Beuermann Prof. Dr. D. Johannsmann		P	5	130 h / 50 h
<b>Sum:</b>					5	130 h / 50 h

**About No. 1:****18. Rec. prerequisites**

The contents of the lectures of the respective field "Macromolecular Chemistry and Processes" or "Physico-Chemical Aspects of Polymers" are required.

<b>19. Contents</b>	Research-oriented practical course concerned with a current topic of the fields “Macromolecular Chemistry and Processes”, “Physico-Chemical Aspects of Polymers” or “Plastics Processing”.
<b>20. Media forms</b>	---
<b>21. Literature</b>	The choice of literature depends upon the individual research topic. Choosing literature is part of the practical course.
<b>22. Other</b>	---

<b>Study/examination performance</b>					
<b>23. No.</b>	<b>24. Assigned courses</b>	<b>25. Exam type</b>	<b>26. ECTS</b>	<b>27. Evaluation</b>	<b>28. Proportion of module grade</b>
<b>1</b>	Practical Course Polymers I	MP	6	graded	100 %
<b>29. Form of examination / prerequisite for the award of credit points</b>		Practical assignment (PrA) Conducting of the practical work, preparing a work report			
<b>30. Responsible examiner</b>		Prof. Dr. S. Beuermann, Prof. Dr. D. Johannsmann			
<b>31. Preliminary examinations</b>		none			

**1. Module title**

## Practical Course on Polymers II

**2. Utilisability of the module in degree programs**

M.Sc. Chemistry (mandatory module "SR Polymer Chemistry")

**3. Person(s) responsible for module**Prof. Dr. S. Beuermann  
Prof. Dr. D. Johannsmann**4. Relevant faculty**Faculty of Natural and Materials  
Science**5. Module number****6. Language**

English

**7. ECTS**

10

**8. Duration**[X] 1 semester  
[ ] 2 semesters**9. To be offered**[X] each semester  
[ ] each study year  
[ ] irregular**10. Learning/qualification objectives of the module**

Through their practical and research-oriented participation in work groups, students know about current topics of their selected field, either "Macromolecular Chemistry and Processes", "Physico-chemical Aspects of Polymers" or "Plastics Processing". Students are able to work on and solve scientific questions according to their state of knowledge. They know experimental and theoretical methods and models and are able to apply them.

This module promotes technical and methodological competences, and social competence through the participation in a work group.

**Courses**

11. No.	12. Title of the course	13. Lecturer	14. Course -No.	15. Type of course	16. SWS	17. Workload attendance/ internal study
1	Practical Course on Polymers II	Prof. Dr. S. Beuermann Prof. Dr. D. Johannsmann N.N.		P	12	240 h / 60 h
<b>Sum:</b>					12	240 h / 60 h

**About No. 1:****18. Rec. prerequisites**

The contents of the lectures of the respective field "Macromolecular Chemistry and Processes" or "Physico-Chemical Aspects of Polymers" are required.

<b>19. Contents</b>	Research-oriented practical course concerned with a current topic of the fields “Macromolecular Chemistry and Processes”, “Physico-Chemical Aspects of Polymers” or “Plastics Processing”.
<b>20. Media forms</b>	---
<b>21. Literature</b>	The choice of literature depends upon the individual research topic. Choosing literature is part of the practical course.
<b>22. Other</b>	---

<b>Study/examination performance</b>					
<b>23. No.</b>	<b>24. Assigned courses</b>	<b>25. Exam type</b>	<b>26. ECTS</b>	<b>27. Evaluation</b>	<b>28. Proportion of module grade</b>
<b>1</b>	Practical Course Polymers II	MP	10	graded	100 %
<b>29. Form of examination / prerequisite for the award of credit points</b>		Practical assignment (PrA), conducting of the practical course, presentation in the respective work group			
<b>30. Responsible examiner</b>		Prof. Dr. S. Beuermann, Prof. Dr. D. Johannsmann			
<b>31. Preliminary examinations</b>		none			

## List of abbreviations

### **Explanatory Notes:**

(1) Type of Course:

E	Excursion [Exkursion]
P	Practical Course [Praktikum]
S	Seminar [Seminar]
T	Tutorial Lecture [Tutorium]
V	Lecture [Vorlesung]
Ü	Exercise [Übung]

(2) Examination Form:

K	Written Exam [Klausur]
M	Oral examination [Mündliche Prüfung]
SL	Seminar performance [Seminarleistung]
PrA	Practical Work [Praktische Arbeit]
ThA	Theoretical Work [Theoretische Arbeit]
Ex	Excursion [Exkursion]
Ab	Final Thesis [Abschlussarbeit]

(3) Type of Examination:

LN	Certificate of performance [Leistungsnachweis]
MP	Module exam [Modulprüfung]
MTP	Module-part exam [Modulteilprüfung]
PV	Prerequisite [Prüfungsvorleistung]

(4) Further Abbreviations:

ben.	Graded performance [benotete Leistung]
unben.	Ungraded performance [unbenotete Leistung]
od.	or [oder]
LV	Course [Lehrveranstaltung]
Prüf.	Examination [Prüfung]
ECTS	Credit points according to the European Credit Transfer and Accumulation System [Leistungspunkte nach dem Europäischen System zur Übertragung und Akkumulierung von Studienleistungen]
SWS	Semester hours per week [Semesterwochenstunden]