Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

FAKULTÄT
FÜR MATHEMATIK, INFORMATIK
UND NATURWISSENSCHAFTEN

Chemistry (M.Sc.)

Module Handbook

valid from WS 2026/2027

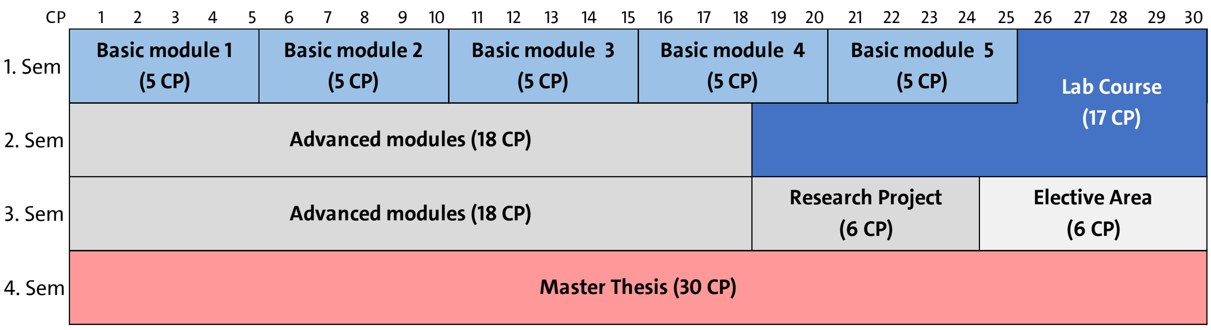
status: 22.01.2026

General Information

Abbreviations:

CP	Credit Points
P	attendance time
PV	exam preparation
S	self-study
Sem	Seminar
SWS	Semester week hours = hours per week during lecture period
Ü	exercises
V	lecture
Pr	Lab course

Curriculum:



Basic modules

Module title	**Advanced Inorganic Chemistry**				
Module ID	CHE 101				
Module applicability, type	M.Sc. Chemistry: Required elective module (introductory phase)				
Prerequisites	mandatory: none recommended: B.Sc. courses on symmetries and structures of molecules and solids, basics of spectroscopic methods, basics of molecular inorganic and organic chemistry, structure and reactivity of coordination compounds				
Responsible persons	Prof. Dr. A. Jacobi von Wangelin, Prof. Dr. L. Vondung, Dr. F. Hoffmann				
Language	English or German; usually English				
Learning outcomes	Thanks to their understanding of inorganic chemistry gained during their bachelor's degree programme, the students are able to tackle more advanced subjects by combining and verifying familiar concepts and theories, establishing relationships among topics and proposing solutions to problems.				
Contents	Organometallic and coordination chemistry; solid-state chemistry and space group symmetry; structures, properties and reactivities of molecular compounds with main group elements and transition metals, including lanthanoids and actinoids; mechanisms of key reaction classes and selected catalytic cycles of metal complexes; selected spectroscopic methods for structural and mechanistic investigations.				
Teaching formats	a) Molecular Chemistry & Reaction Mechanism | Molekülchemie und Reaktionsmechanismen (lecture)				2.5 SWS
	b) Solid-state and Structural Chemistry | Festkörper- und Strukturchemie (lecture)				1.5 SWS
Workload (by course and in total)		LP	P (Std)	S (Std)	PV (Std)
	a) Molecular Chemistry & Reaction Mechanism	3,5	35	50	20
	b) Solid-state and Structural Chemistry	1,5	21	14	10
	total	5	56	64	30
Requirements for participation and type of coursework/examinations	Coursework: none Exam: Written examination, 120 min (graded). Exam language: usually English				
Duration	1 semester				
Frequency	Winter semester, every year				
Literature	C. Elschenbroich, "Organometallics", Wiley VCH, **2006** F. Hoffmann, „Solid-State Chemistry", 1st ed., DeGruyter, **2023**				

<table>
<tr><th>Module title</th><th colspan="5">Advanced Organic Chemistry</th></tr>
<tr><td>Module ID</td><td colspan="5">CHE 102 int</td></tr>
<tr><td>Module applicability and type</td><td colspan="5">M.Sc. Chemistry: Required elective module (introductory phase)</td></tr>
<tr><td>Prerequisites</td><td colspan="5">mandatory: „none“
recommended: „none“</td></tr>
<tr><td>Responsible person(s)</td><td colspan="5">Dr. L. Longwitz</td></tr>
<tr><td>Language</td><td colspan="5">English or German; usually English</td></tr>
<tr><td>Learning outcomes</td><td colspan="5">Thanks to their understanding of organic chemistry gained during their bachelor's degree program, students are able to tackle advanced questions, including those from current research. They have in-depth expertise in the field of organic chemistry of complex target structures as well as classical and modern heterocyclic chemistry. They can analyze and evaluate syntheses and synthesis plans for complex and multifunctional organic compounds from different compound classes. They are also able to carry out strategic synthesis planning (e.g., for heterocycles, natural products, and active ingredients) and develop protective group concepts. Based on the specialist knowledge they have acquired; they can derive reaction mechanisms and thus explain product distributions and selectivities. They are proficient in all common methods for elucidating mechanisms and methods for identifying synthesis products, product ratios, intermediates, etc. (NMR, IR, MS, etc.).</td></tr>
<tr><td>Content</td><td colspan="5">Strategic synthesis planning, protective group chemistry, and protective group concepts. Classical and modern aromatic and heterocyclic chemistry, synthesis of heterocyclic natural products and active ingredients (classics and examples from current research). Pericyclic reactions, transition metal-catalyzed synthesis methods, reaction mechanisms, and model concepts of advanced organic synthesis. Elucidation of mechanisms and identification or analysis of intermediates, products (including isomers) and product mixtures.</td></tr>
<tr><td>Teaching format(s)</td><td colspan="4">Advanced Organic Chemistry (lecture)</td><td>4 SWS</td></tr>
<tr><td rowspan="3">Workload
(by course and in total)</td><td></td><td>LP</td><td>P (Std)</td><td>S (Std)</td><td>PV (Std)</td></tr>
<tr><td>Advanced Organic Chemistry (lecture)</td><td>5</td><td>56</td><td>64</td><td>30</td></tr>
<tr><td>total</td><td>5</td><td>56</td><td>64</td><td>30</td></tr>
<tr><td>Requirements for participation and type of coursework and examinations</td><td colspan="5">Coursework: „none“
Exam: Written examination, 120 min. “ (graded)
Examination language: „usually English“</td></tr>
<tr><td>Duration</td><td colspan="5">1 semester</td></tr>
<tr><td>Frequency</td><td colspan="5">1 semester, every year</td></tr>
</table>

Literature	E. J. Corey, The Logic of Chemical Synthesis; R. W. Hoffmann, Elements of Synthesis Planning;L. Kurti, B. Czakó, Strategic Applications of Named Reactions in Organic Synthesis; T. Eicher, S. Hauptmann, A. Speicher, The Chemistry of Heterocycles; R. R. Gupta, Heterocyclic Chemistry, Vol I & II

Module title	**Advanced Physical Chemistry**				
Module ID	CHE 103 int				
Module applicability and type	M.Sc. Chemistry: Required elective module (introductory phase)				
Prerequisites	mandatory: „none" recommended: „none"				
Responsible person(s)	Prof. Dr. A Mews				
Language	English or German; usually English				
Learning outcomes	Students can explain the key principles of kinetic gas theory and have a detailed understanding of energy distribution and collision processes in the gas phase. Students can describe vibronic and electronic properties of molecules and solids. They understand the formation of electronic bands and can derive material properties. Furthermore, students are able to connect quantum mechanical values with thermodynamic properties.				
Content	Kinetic gas theory, velocity distribution, mean free path, group theory, molecular vibrations, electronic transitions, solids, band structures in solids, tight binding model, electron gas, nearly free electron model, statistical mechanics, thermodynamic functions, applications.				
Teaching format(s)	a) Advanced Physical Chemistry (lecture) b) Exercises on Advanced Physical Chemistry (exercises)				3 SWS 1 SWS
Workload (by course and in total)		LP	P (Std)	S (Std)	PV (Std)
	a) Advanced Physical Chemistry	4	42	46	32
	b) Exercises on Advanced Physical Chemistry	1	14	16	
	total	5	56	62	32
Requirements for participation and type of coursework and examinations	Coursework: „none" Exam: Written examination, 90 min. (graded) Examination language: „usually English"				
Duration	1 semester				
Frequency	Winter semester, every year				
Literature	Physikalische Chemie, P. W. Atkins/ J. de Paula, Wiley-VCH Grundlagen der Physikalischen Chemie, W. J. Moore, de Gruyter Physikalische Chemie, T. Engel/ P. Reid, Pearson Studium				

<table>
<tr><th>Module title</th><th colspan="5">Spectroscopy</th></tr>
<tr><td>Module ID</td><td colspan="5">CHE 104 int.</td></tr>
<tr><td>Module applicability and type</td><td colspan="5">M.Sc. Chemistry: Required elective module (introductory phase)</td></tr>
<tr><td>Prerequisites</td><td colspan="5">mandatory: none
recommended: none</td></tr>
<tr><td>Responsible person(s)</td><td colspan="5">Dr. T. Hackl, Dr. Jennifer Menzel</td></tr>
<tr><td>Language</td><td colspan="5">English</td></tr>
<tr><td>Learning outcomes</td><td colspan="5">The objective of the module is to learn and to deepen theory and backgrounds of analytical techniques for the structure elucidation of molecules of different classes. After successfully completing the module, students should be able to select the matching analytical method for their research question, to interpret the analysis results, critically question them and elucidate the structure of unknown molecules. The fundamentals learned are applied to selected examples. This should enable students to transfer their knowledge to unknown compounds and solve such analyses through this transfer.</td></tr>
<tr><td>Content</td><td colspan="5">General Part (10 weeks)
Basic concepts of NMR spectroscopy, basic physical equations, ^{1}H and ^{13}C-NMR spectroscopy, chemical shift, coupling constants, Karplus equation, relationship between coupling constants, chemical shift, and chemical structure, dynamic NMR, nomenclature, spectra of higher order, increment calculations of chemical shift, the vector model, T_1 and T_2 relaxation, homo- and hetero nuclear 2D spectroscopy, basics of NOE (Nuclear Overhauser Effect), trends in NMR.
Basic concepts of mass spectrometry, isotopic ratios, charge states, configuration of mass spectrometers, ionization, mass analyzers, hyphenation to chromatographic systems, quantitation with MS, trends in MS.
Advanced NMR (4 weeks), one of the following specializations
I. NMR of bio molecules: NMR of Peptides and Proteins, Metabolomics and the analysis of complex mixtures; advanced exercise using a complex example for analyzing NMR spectra
II. NMR of hetero nuclei and solid-state NMR: NMR properties and spectra of other nuclei from elements of the Periodic Table; quadrupolar momentum, para magnetism, relaxation, basics of solid-state NMR
III. NMR of polymers: basic concepts in the analysis of polymers, quantitative ^{13}C-NMR, relaxation, basics of solid-state NMR</td></tr>
<tr><td>Teaching format(s)</td><td colspan="4">a) Spectroscopy; Spektroskopie (lecture)
b) Spectroscopy advanced NMR; Spektroskopie-Vertiefung (lecture)
c) Spectroscopy exercises; Übungen zur Spektroskopie</td><td>2 SWS
1 SWS
1 SWS</td></tr>
<tr><td>Workload
(by course and in total)</td><td></td><td>LP</td><td>P (Std)</td><td>S (Std)</td><td>PV (Std)</td></tr>
<tr><td></td><td>a) Spectroscopy</td><td>3</td><td>28</td><td>38</td><td>24</td></tr>
<tr><td></td><td>b) spectroscopy advanced NMR</td><td>1</td><td>14</td><td>10</td><td>6</td></tr>
<tr><td></td><td>c) Spectroscopy exercises</td><td>1</td><td>14</td><td>16</td><td></td></tr>
</table>

	total	5	56	64	30
Requirements for participation and type of coursework and examinations	Coursework: none Exam: Written examination, 90 min (graded) Examination language: usually English				
Duration	1 semester				
Frequency	Winter semester, every year				
Literature	Hesse, Meier, Zeeh; Spektroskopische Methoden in der organischen Chemie Claridge; High Resolution NMR Techniques in Organic Chemistry Gross; Massenspektrometrie ein Lehrbuch				

Module title	**Introduction to Chemical and Polymer Reaction Engineering**
Module ID	CHE 106 int.
Module applicability and type	M.Sc. Chemistry: Required elective module (introductory phase)
Prerequisites	Mandatory: none Recommended: none
Responsible person(s)	Prof. Dr. Ing. J. Albert, Prof. G. A. Luinstra, Dr. W. Pauer, Dr. D. Voß,
Language	English
Learning outcomes	Students are able to present the topics discussed in Chemical and Polymer Reaction Engineering. Furthermore, the topics discussed can be classified and applied to unknown situations. Unknown questions can be analyzed and assessed, and solutions can be developed and evaluated independently.
Content	Chemical processes in basic examples: from raw material to end product - taking social effects into account. Basics of scale-up. Technical catalysis. Introduction to basic operations, z. e.g. mixing and stirring. Basics of mass and heat transfer, basic design of technical apparatus, technical catalysis and simple practical solutions to reaction engineering problems, basic knowledge of thermal and mechanical operations. Chemical processes and process development in selected examples. Introduction to the kinetics of chemical and polymer reactions. Definitions, terminology & nomenclature in the field of macromolecular substances; use of polymers; classification of polymers; Theoretical description of the polymer, Standard analysis of polymers in solution, molar mass and distribution. Synthesis of polymers, structure and properties of macromolecular polymers. Production methods & processing. The lecture is structured in such a way that there is sufficient time for discussion and collaborative acquisition of the material.

Teaching format(s)	a) Chemical reaction Engineering (V/S) b) Polymer Reaction Engineering (V/S)				2 SWS 2 SWS
Workload (by course and in total)		LP	P (Std)	S (Std)	PV (Std)
	a) Chemical Reaction Engineering (V/S)	2,5	28	32	15
	b) Polymer Reaction Engineering (V/S)	2,5	28	32	15
	total	5	56	64	30
Requirements for participation and type of coursework and examinations	Prerequisites for the module examination: none Type of module examination: written examination (graded) Examination language: English				
Duration	1 semester				
Frequency	Winter semester, every year				
Literature	A. Jess, P. Wasserscheid, "Chemical Technology," Wiley VCH, 2013 Polymer Reaction Engineering Edited by José M. Asua; Polymer Chemistry by Sebastian Koltzenburg				

Modul titel	**Lab Course**
Module ID	CHE 108 Int.
Module applicability, type	M.Sc. Chemistry: Mandatory module
Prerequisites	mandatory: none recommended: none
Responsible persons	Dr. K. Hoppe, Dr. D. Schaarschmidt, Dr. D. Voß
Language	English or German; usually English
Learning outcomes	The students will deepen and, in some cases, acquire important key qualifications (methodological competence, skills in work planning, occupational safety and time management, error discussion, social competence and teamwork, the ability to prepare protocols using chemistry-specific software, and proficiency in literature research) in conjunction with subject-specific knowledge. Physical Chemistry Lab Course The objectives of the lab course are to acquire knowledge of modern techniques and methods in physical chemistry and to gain first insights into current research concepts. After a brief introduction, students will be able to independently operate complex measuring devices and explain their fundamental functions. They will create protocols using chemistry-specific software to analyse measurement data, formatted to align with scientific project presentations. They will develop the ability to conduct literature research and to compare theoretical concepts with experimental results, enabling them to explain their observations. The

	students will learn to select appropriate measurement methods for specific scientific questions and to plan and coordinate their work within a team. Inorganic and Organic Chemistry Lab Course Based on the fundamental theoretical principles of molecular, solid-state, and natural product chemistry, students will be capable of independently planning, executing, and analysing the synthesis of complex, functionalized, and reactive molecules and materials, as well as evaluating the results. They will understand and be able to explain practical procedures, reaction mechanisms, and compound characterizations of modern synthetic methods from the literature, and apply this knowledge to their own practical problems at the laboratory scale. Technical and Macromolecular Chemistry Lab Course Students will apply selected working methods and characterization techniques of technical and macromolecular chemistry, as well as thermal separation procedures and modern (polymer) reaction engineering investigations in a hands-on environment. Based on given research questions, experiments are conducted independently in pairs, and measurement data are analyzed. Students will be able to assess the influence of chemical reactors, reaction parameter, and (poly)reaction types on the process as well as the resulting product properties. Furthermore, the students will understand the principles of reaction management, evaluate and discuss the results and document their findings on their own. Presentation Seminar Students will be able to prepare a scientific short presentation based on independent literature research, deliver it, and defend it in a discussion.
Contents	Fundamentals of safe working in laboratories: hazards for humans and the environment, labelling of hazardous substances, safety signs, protective measures and rules of conduct (including personal protective equipment, fire protection), safety equipment and technical protective measures, behaviour in case of danger and in the event of accidents, first aid, disposal, hazardous wastes, operating instructions, legal regulations. Safe handling of glassware and apparatus, execution of standard laboratory procedures, and operation of (laboratory) equipment. Safe handling of hazardous compounds: identification of hazards and implementation of appropriate safety measures (including safety data sheets), procedures for proper disposal, handling of not fully tested substances, and special considerations for CMR substances. Good Scientific Practice: principles, scientific misconduct, documentation (including laboratory notebooks), data management (original data, data collection, data manipulation, data selection), scientific literature (citation, plagiarism), and preparation of protocols and scientific theses. Literature search using scientific databases. Physical Chemistry Lab Course Concepts of modern physical chemistry covering spectroscopy (UV, Vis, IR, Raman), electrochemistry, light scattering, magnetochemistry, microscopy, electron microscopy, confocal laser microscopy, X-ray techniques, theoretical chemistry, and nanochemistry involving colloidal and nanostructured materials and their superstructures, which include metals, semiconductors, carbon nanotubes, polymers, and biopolymers. Conducting experiments and

<table>
<tr><td></td><td colspan="5">projects in both classical physical chemistry and current research areas offers students insights into the broad spectrum of the field. For this purpose, complex materials are prepared and investigated using a selection of specialized methods.
<u>Inorganic and Organic Chemistry Lab Course</u>
Synthesis of complex compounds at the interface between inorganic and organic chemistry, as well as at the intersection of molecular and solid-state chemistry, utilizing techniques such as catalysis, stereoselective synthesis, and self-assembly. Application of inert gas and Schlenk techniques, working in gloveboxes, handling of hazardous and reactive compounds, safe operation of modern synthesis and analytical apparatus, conducting experiments under special conditions (heat, cold, air-free, high pressure, gases, microscale, light), understanding and safe application of characterization techniques for compounds and materials, such as chromatography, spectroscopy (including NMR), mass spectrometry, elemental analysis, and diffraction. Documentation of safety aspects, chemical data, experimental procedures, equipment usage, and waste disposal in a laboratory notebook and operating instructions. Preparation of scientific protocols for preparative and analytical experiments.

<u>Technical and Macromolecular Chemistry Lab Course</u>
Practical execution of fundamental chemical/ polymer engineering operations, experimental characterization of chemical reactors, as well as practical problem-solving in reaction engineering:
Introduction and process simulation using Aspen Plus
Thermal separation of azeotroping binary mixtures (rectification)
Extraction
Determination of reaction kinetics in a batch reactor
Residence time behavior of ideal reactors
Calorimetry and heat measurement
Conducting polymer syntheses in autoclaves at laboratory and pilot scale. Processing polymers through extrusion and injection molding, as well as characterization in solution (polymer coil size and molar mass distribution) and in the solid phase/melt (rheological, thermal, mechanical properties).

<u>Presentation Seminar</u>
Presentation of advanced aspects of inorganic, macromolecular, organic, physical, and/or technical chemistry, including their theoretical foundations, in the form of a short presentation followed by a discussion.</td></tr>
<tr><td>Teaching formats</td><td colspan="4">a) Seminar on Lab Course (S)
b) Lab Course (Pr)
c) Presentation seminar (S)</td><td>0,5 SWS
16 SWS
2 SWS</td></tr>
<tr><td rowspan="2">Workload
(by course and in total)</td><td>
a) Seminar on Lab Course
b) Lab Course
c) Presentation seminar</td><td>LP
1
14
2</td><td>P (Std)
7
256
30</td><td>S (Std)
11
164
0</td><td>PV (Std)
12
0
30</td></tr>
<tr><td>total</td><td>17</td><td>293</td><td>175</td><td>42</td></tr>
<tr><td>Requirements for participation and type of coursework/examinations</td><td colspan="5">Requirements for participation in the Lab Course: Attendance at safety training and passing the 1st module examination.

The module examination has three parts.
Requirements for the 1st module examination: Attendance at Seminar on Lab</td></tr>
</table>

	Course. **1st. Exam**: Written examination (graded, 20 %). **Requirements for the 2nd module examination:** none **2nd Exam**: Lab work completed (graded, 20 %) **Requirements for the 3rd module examination**: The practical work of the lab course must be completed **3rd Exam:** Colloquium (graded, 60 %) Exam language: usually English
Duration	2 semesters
Frequency	annually, beginning in the winter semester

Advanced modules

Module title	**Nanochemistry**				
Module ID	CHE 111 A				
Module applicability and type	B.Sc. Nanowissenschaften: Mandatory module M.Sc. Chemie: Required elective module M.Sc. Chemistry: Required elective module M.Sc. Molecular Life Sciences: Required elective module				
Prerequisites	mandatory: „none“ recommended: Introductory courses in Physical Chemistry				
Responsible person(s)	Prof. Dr. N. Bigall, Dr. D. Dorfs				
Language	English or German; usually English				
Learning outcomes	The course summarizes the fundamental properties of colloidal nanoparticles. The students will understand e.g. the size quantization effect, the localized plasmon resonance and superparamagnetism and learn about possible applications. Upon completion of the course, students will be able to recall possible synthesis routes for nanocrystals and biocompatible nanoparticles and apply this knowledge to unknown problems to outline and prepare suitable synthesis methods. Furthermore, students will understand the fundamental concepts of biological labeling and be able to connect these with current methods of fluorescence spectroscopy and magnetic resonance imaging (MRI), explain these methods, and determine the appropriate experimental approach based on this knowledge. Students will also grasp the basics of specific drug enrichment and be able to articulate these.				
Content	Semiconductor quantum dots, size quantization effect, Synthesis of quantum dots, applications of quantum dots, superparamagnetic and plasmonic nanoparticles, biocompatible nanoparticles, concepts of phase transfer, biological labeling and molecular imaging, modern methods of fluorescence spectroscopy in nanochemistry, magnetic resonance imaging (MRI), synthesis strategies for nanoparticulate contrast agents.				
Teaching format(s)	a) Nanochemistry (V)				2 SWS
Workload (by course and in total)		LP	P (Std)	S (Std)	PV (Std)
	a) Nanochemistry	3	28	42	20
	total	3	28	42	20

Requirements for participation and type of coursework and examinations	Prerequisites for module examination: none Exam: usually written exam, alternatively oral examination (graded) Language of examination: usually English
Duration	1 semester
Frequency	Summer semester, every year
Literature	1. Colloidal semiconductor Q-particles - Chemistry in the transition region between solid-state and molecules H. Weller - Angew. Chem. - Int. Ed. 32, 41 (**1993**) 2. Schmid, G. Nanoparticles. (Wiley-VCH Verlag GmbH & Co. KGaA, **2003**). ISBN: 978-3-527-32589-4 3. Ultrathin PbS Sheets by Two-Dimensional Oriented Attachment Schliehe, C. et al. Science 30, 550 (**2010**) 4. Smith, B. R. & Gambhir, S. S. Nanomaterials for In Vivo Imaging. Chem. Rev. 117, 901–986 (**2017**).

Module title	**Nanochemistry – Lab work**				
Module ID	CHE 111 B				
Module applicability and type	M.Sc. Chemie: Required elective module M.Sc. Chemistry: Required elective module M.Sc. Molecular Life Sciences: Required elective module M.Sc. Physics and Chemistry of Nanomaterials: Required elective module				
Prerequisites	mandatory: CHE 111 A Nanochemistry – Lecture Module recommended: Introductory courses in Physical Chemistry				
Responsible person(s)	Prof. Dr. N. Bigall, Dr. D. Dorfs				
Language	English or German; usually English				
Learning outcomes	Upon successful completion, students will be able to recall suitable methods for solving experimental problems and apply them within the scope of a limited scientific research project. This includes independently preparing and planning their own research, which involves both autonomous information gathering (literature research) and collaborative work within a team. Moreover, students will be capable of processing the obtained data appropriately, evaluating it concerning the project goal, and documenting it in the form of qualified scientific protocols.				
Content	Synthesis and assembly of nanoparticles and or biocompaticle nanoparticles, concepts of functionalization and imaging, modern methods of fluorescence spectroscopy in nanochemistry, magnetometry, spectroelectrochemistry, synthesis strategies for nanoparticulate contrast agents.				
Teaching format(s)	a) Nanochemistry Laboratory (Pr)				6 SWS
Workload		LP	P (Std)	S (Std)	PV (Std)

(by course and in total)	a) Nanochemistry Laboratory	6	140	20	20
	total	6	140	20	20
Requirements for participation and type of coursework and examinations	Coursework: regular participation in the seminar (attendance mandatory) Exam: Final assignment(graded) Examination language: usually English				
Duration	1 semester				
Frequency	summer semester, every year				
Literature	1. Colloidal semiconductor Q-particles - Chemistry in the transition region between solid-state and molecules H. Weller - Angew. Chem. - Int. Ed. 32, 41 (**1993**) 2. Schmid, G. Nanoparticles. (Wiley-VCH Verlag GmbH & Co. KGaA, **2003**). ISBN: 978-3-527-32589-4 3. Ultrathin PbS Sheets by Two-Dimensional Oriented Attachment Schliehe, C. et al. Science 30, 550 (**2010**) 4. Smith, B. R. & Gambhir, S. S. Nanomaterials for In Vivo Imaging. Chem. Rev. 117, 901–986 (**2017**).				

Module title	**Regenerative Energy Conversion**
Module ID	CHE 112 A
Module applicability and type	M.Sc. Chemie: Required elective module M.Sc. Chemistry: Required elective module M.Sc. Physics and Chemistry of Nanomaterials: Required elective module
Prerequisites	mandatory: none recommended: Introductory courses to inorganic chemistry and physical chemistry
Responsible person(s)	Dr. H. Heller
Language	English or German; usually English
Learning outcomes	Students acquire knowledge of energy conversion in solar cells and fuel cells. This knowledge serves as a basis for sustainable solutions in the independent, scientific investigation of physical and chemical problems. Students are familiar with the types of solar cells and can classify them into different generations. Students understand fundamental principles of solid-state physics and can use these to evaluate the advantages and disadvantages of different solar cell types. They can analyze the performance of a solar cell using an equivalent circuit. Students distinguish between the types of fuel cells and can select suitable dynamic electrochemistry methods to assess their efficiency.
Content	- Solid-state physics fundamentals of photovoltaics - Semiconductor band model - Semiconductor doping - p-n junction with charge separation - Properties of solar radiation

	- First, second, and third generation solar cells - Dynamic electrochemistry - Transport processes and electrode kinetics - Types of fuel cells and their efficiencies - Electrochemical analysis methods				
Teaching format(s)	a) Regenerative Energy Conversion (V)				2 SWS
Workload (by course and in total)		LP	P (Std)	S (Std)	PV (Std)
	a) Regenerative Energy Conversion (V)	3	28	42	20
	total	3	28	42	20
Requirements for participation and type of coursework and examinations	Coursework: none Exam: written examination (graded) Examination language: usually English				
Duration	1 semester				
Frequency	winter semester, every year				
Literature	Nelson, J. *The Physics of Solar Cells*, 1st ed.; Imperial College Press: London, **2004**. Schmidt, V. *Elektrochemische Verfahrenstechnik*, 1st ed.; Wiley-VCH: Winheim, **2003**.				

Module title	**Regenerative Energy Conversion – Lab work**
Module ID	CHE 112 B
Module applicability and type	M.Sc. Chemie: Required elective module M.Sc. Chemistry: Required elective module M.Sc. Physics and Chemistry of Nanomaterials: Required elective module
Prerequisites	mandatory: none recommended: Introductory courses to inorganic chemistry and physical chemistry
Responsible person(s)	Dr. H. Heller
Language	English or German; usually English
Learning outcomes	Students acquire knowledge and practical skills in areas of physical chemistry relevant to energy conversion in solar cells and fuel cells. Students conduct challenging preparative and analytical experiments. They collaborate within the team of the host research group. Students organize their practical work in the laboratory and plan experiments or experimental series. They research the necessary literature and summarize it in a protocol. They also document the experiments conducted and evaluate the results obtained in a report.
Content	The content is based on the specific research project. One or more of the following topics will be covered:

	- Quantum mechanical and solid-state physics fundamentals of photovoltaics - Functional polymers with reference to organic solar cells - Spectroscopic investigation methods - Chromophores based on semiconductor materials - Interaction between ligands and surfaces - Electrochemical investigation methods				
Teaching format(s)	a) Research internship				6 SWS
Workload (by course and in total)		LP	P (Std)	S (Std)	PV (Std)
	a) Research internship	6	140	20	20
	total	6	140	20	20
Requirements for participation and type of coursework and examinations	Coursework: „none“ Exam: project completion (graded) Examination language: usually English				
Duration	1 semester				
Frequency	winter semester, every year				
Literature	Nelson, J. *The Physics of Solar Cells*, 1st ed.; Imperial College Press: London, **2004**. Schmidt, V. *Elektrochemische Verfahrenstechnik*, 1st ed.; Wiley-VCH: Winheim, **2003**.				

Module title	**Energy – new materials for energy conversion and storage**
Module ID	CHE 114
Module applicability and type	M.Sc. Chemie: Required elective module M.Sc. Chemistry: Required elective module M.Sc. Physics and Chemistry of Nanomaterials: Required elective module
Prerequisites	mandatory: CHE 101 (N/Int.) und CHE 103 (Int.) recommended: none
Responsible person(s)	Prof. Dr. M. Fröba
Language	English or German; usually English
Learning outcomes	The students understand the aspects of energy conversion and energy storage and are able to explain them. They can identify the energy-correlated properties of inorganic materials and describe their relation to the solid-state structure. They can predict the applications of materials in energy conversion and storage. They can plan and carry out own research work within a project and present their results in a talk in a structured manner.
Content	Modern materials for energy storage and conversion, technological basics of energy storage and conversion, hydrogen storage technologies, lithium-ion batteries, lithium-sulfur batteries, lithium-air batteries, structural-chemical and physical aspects of gas and electricity storage in porous solids, capacitors (double-layer capacitors, supercapacitors), fuel cells (AFC, PEMFC, SOFC),

	materials and technologies for thermal storage.				
Teaching format(s)	a) Fuel cells, batteries and gas storage: new materials for energy conversion and storage (V) b) Advanced lab course „energy“ (P)				2 SWS 6 SWS
Workload (by course and in total)		LP	P (Std)	S (Std)	PV (Std)
	a) Fuel cells, batteries and gas storage: new materials for energy conversion and storage	3	28	35	27
	b) Advanced lab course „energy“	6	160	0	20
	Gesamtaufwand	9	188	35	47
Requirements for participation and type of coursework and examinations	Coursework: none Exam: Final assignment (graded) Examination language: usually English				
Duration	1 semester				
Frequency	Summer semester, every year				

Module title	**Reaction Engineering**				
Module ID	CHE 117				
Module applicability and type	M.Sc. Chemie: Required elective module M.Sc. Chemistry: Required elective module				
Prerequisites	Mandatory: none Recommended: Introductory courses in inorganic, organic, and technical chemistry				
Responsible person(s)	Prof. Dr. J. Albert				
Language	German or English				
Learning outcomes	Students know and understand the basic procedures of chemical reaction engineering. They interpret reaction conditions used to set up a reactor model and work on the exercises independently and cooperatively.				
Content	• Homogeneous catalysis • Multiphase reactions • Heterogeneous catalysis • Real reactors and reaction control • Industrial examples and safety				
Teaching format(s)	a) Reaction technology (V) b) Exercises in reaction technology (Ü) c) Reaction technology lab course (P)				3 SWS 1 SWS 3 SWS
Workload		LP	P (Std)	S (Std)	PV (Std)

(by course and in total)	a) Reaction technology (V) b) Exercises in reaction technology (Ü) c) Reaction technology lab course (P)	4,5 1,5 3	42 14 140	63 21 20	30 10 20
	total	9	196	104	60
Requirements for participation and type of coursework and examinations	Prerequisites for the module examination: Completion of internship Type of module examination: Oral examination (graded) Examination language: Usually German or English				
Duration	1 semester				
Frequency	winter semester, every year				
Literature	A. Jess, P. Wasserscheid, "Chemical Technology," Wiley VCH, 2013 M. Baerns et al., "Technical Chemistry," Wiley VCH, 2013				

Module title	**Current Polymers: Synthesis and Materials Properties**
Module ID	CHE 118
Module applicability and type	M.Sc. Chemie: Required elective module M.Sc. Chemistry: Required elective module
Prerequisites	Mandatory: CHE 022A or CHE 106 Recommended: CHE 007, CHE 005, CHE 009, CHE 002 A, CHE 002 MA, CHE 071
Responsible person(s)	Prof. Dr. G. Luinstra
Language	English or German; usually English
Learning outcomes	Insights into the preparation (control by catalysis, action of catalysts) and properties of thermoplastic polymers (used in society some in the context of their history). Know how on polymerization processes, recycling of common polymers, relation between property profile (thermal, rheological and mechanical properties) and application (mainly on polyolefins as profound examples). Applying knowledge in the implementation of a research project (also as part of a larger research project) involving chemical and physical tasks. Developing assessment skills with regard to the results in relation to the state of the art. Learning professional reporting skills.
Content	Details of the synthesis of common macromolecules, kinetics, catalysis, determination of microstructure, morphological, thermal, rheological, and mechanical properties of polymers, plastics processing, and use. Current topics in materials development (e.g. smart materials). Practical synthesis of polymeric materials/gels, processing by extrusion (possibly by 3D printing), characterization by chromatography, NMR/IR spectroscopy etc.

Teaching format(s)	a) Current Polymers Seminar (prior reading, discussions on content) b) Current Polymers Laboratory course with protocols				4 SWS 6 SWS
Workload (by course and in total)		LP	P (Std)	S (Std)	PV (Std)
	Current Polymers Seminar	6	60	100	40
	Current Polymers Laboratory course	6	140	20	20
	total	12	200	120	60
Requirements for participation and type of coursework and examinations	Coursework: „reading of supplied texts " Exams: Written examination, 120 min; graded Presentation on practical course work, 30 min; 30 min examination; graded. Examination language: „usually English"				
Duration	1 Semester				
Frequency	summer semester, every year				
Literature	Variable, compilations are supplied in advance				

Module title	**Bioorganic analytical methods**
Module ID	CHE 119
Module applicability and type	M.Sc. Chemie: Required elective module M.Sc. Chemistry: Required elective module M.Sc. Lebensmittelchemie: Required elective module
Prerequisites	mandatory: module CHE 104 (int.) Spectroscopy recommended: none
Responsible person(s)	Dr. T. Hackl, Dr. J. Menzel, Prof. Dr. V. Vill
Language	English
Learning outcomes	The objective of the module is to learn and to deepen theory and backgrounds of analytical techniques for the investigation of biomolecules. After successfully completing the module, students should be able to select the matching analytical method for their research question, to interpret the analysis results and critically question them. Discussion about recent publications will improve the capability to present and critically discuss the results of other scientists.
Content	LC, GC, MS, NMR, circular dichroism (CD), surface plasmon resonance (SPR), isothermal calorimetry (ITC) and microscalar thermophoresis (MST). Modern analytical methods will be covered that are used in chemistry and life sciences in order to investigate the structures of complex molecules and their interactions with proteins and DNA/RNA. **HPLC, GC**: Basics of chromatography, different types of chromatography: separation, field of application, limitations. **MS**: modern ionization techniques, principles of mass separation, identification and quantification of different classes of biomolecules. **NMR**: application of 2D- and 3D-NMR, relaxation phenomena,

	saturation phenomena. NOE, ligand- and protein-based methods for the investigation of molecular interactions, Product Operator Formalism. **CD (circular dichroism)**: Theory, Octant rule, Cotton effect.				
Teaching format(s)	a) Bioorganic analytical methods; Bioorganisch-analytische Methoden (lecture)				2 SWS
	b) Seminar of modern analytical techniques; Seminar zu modernen analytischen Verfahren (seminar)				2 SWS
Workload (by course and in total)		LP	P (Std)	S (Std)	PV (Std)
	a) lecture Bioorganic analytical methods	3	38	42	10
	b) Seminar of modern analytical techniques	3	18	42	30
	total	6	56	84	40
Requirements for participation and type of coursework and examinations	Coursework: Passed online-test Exam: presentation (graded) Examination language: English				
Duration	1 semester				
Frequency	Summer semester, every year				
Literature	Bioanalytics (Lottspeich), Understanding NMR Spectroscopy (Keeler), recent publications				

Module title	**Natural Product Chemistry**
Module ID	CHE 120
Module applicability and type	M.Sc. Chemie: Required elective module M.Sc. Chemistry: Required elective module
Prerequisites	mandatory: CHE 102 (Int.) recommended: none
Responsible person(s)	Prof. Dr. R. Holl
Language	English or German; usually English
Learning outcomes	Based on the students’ understanding of organic chemistry gained in the bachelor's degree program, they are able to tackle advanced questions on natural product chemistry and medicinal chemistry, including those from current research. The students have in-depth expertise in the field of natural product chemistry and natural product synthesis. They are familiar with all relevant classes of natural products (e.g., carbohydrates, nucleotides, peptides and proteins, alkaloids, lipids, polyketides, aromatics, and terpenes), can categorize them, and know their typical structures or structural elements as well as possible pharmacological effects. They have detailed knowledge on with the most important biosynthetic pathways and are familiar with methods for the elucidation of biosynthetic pathways. They know methods for the

	isolation, characterization, and structural elucidation of natural products, other metabolites, and further unknown compounds or intermediates (e.g., from biological sources). The students are familiar with classical and modern synthetic approaches and synthesis concepts for all relevant classes of natural products and can critically analyze and evaluate them. Furthermore, the students are able to independently develop appropriate synthesis proposals for all relevant classes of natural products. In addition, the students are familiar with the basics of medicinal chemistry and know the role of natural products in the field of medicinal chemistry as well as the principles of medicinal chemistry research.
Content	The most important classes of natural products (e.g., carbohydrates, nucleotides, peptides and proteins, alkaloids, lipids, polyketides, aromatics, and terpenes) are covered, taking into account the biosynthesis as well as the chemical synthesis of the respective compounds. Additionally, modern methods for their isolation and structural elucidation are also presented. Furthermore, the fundamentals of medicinal chemistry, methods for identifying lead structures, and methods for the synthesis of compound libraries are discussed. In the practical course, current issues in the fields of drug design, natural product chemistry, natural product synthesis, and modern synthetic chemistry are worked on.
Teaching format(s)	a) Natural Product Chemistry (lecture) — 4 SWS b) Research internship on Natural Product Chemistry (practical course) — 6 SWS
Workload (by course and in total)	see below
Requirements for participation and type of coursework and examinations	Coursework: none Exams: presentation (1/3 graded) and completion of lab work (2/3 graded) Examination language: usually English
Duration	1 semester
Frequency	summer semester, every year
Literature	Robert V. Stick, Spencer J. Williams, “Carbohydrates: The Essential Molecules of Life”, Elsevier A. Varki, “Essentials of Glycobiology”, Cold Spring Harbor Laboratory Press Paul M. Dewick, “Medicinal Natural Products: A Biosynthetic Approach”, John Wiley & Sons Gerhard Klebe, “Drug Design: From Structure and Mode-of-Action to Rational Design Concepts”, Springer

Workload (by course and in total):

	LP	P (Std)	S (Std)	PV (Std)
a) Natural Product Chemistry	6	56	84	40
b) Research internship on Natural Product Chemistry	6	140	20	20
total	12	196	104	60

Module title	**Applied Organic Synthesis**				
Module ID	CHE 121				
Module applicability and type	M.Sc. Chemie: Required elective module M.Sc. Chemistry: Required elective module				
Prerequisites	mandatory: CHE 102 (Int.) recommended: none				
Responsible person	Prof. Dr. C. Meier				
Language	English or German; usually English				
Learning outcomes	Thanks to their understanding of organic chemistry gained during their bachelor's degree program, students are able to tackle advanced questions, including those arising from current research. They have in-depth expertise in the field of multistage synthesis sequences and total synthesis, with a particular focus on stereoselective methods and catalytic processes. This includes both the analysis and evaluation of specified reaction sequences and the independent planning of syntheses. Students will be familiar with classic concepts of retrosynthetic analysis and can apply them to complex target structures, taking stereoselective processes into account. In addition to methods used in research laboratories, students will also be familiar with syntheses and processes for the production of compounds mainly on a laboratory scale and can analyze these critically. In the internship, which is carried out in one or two research groups at the Institutes of Organic Chemistry or Pharmaceutical Chemistry, the knowledge acquired is applied in practice in the context of research-related projects.				
Content	Modern, organic synthesis methods with special emphasis on stereoselective processes; concept of retrosynthesis, retrosynthetic analysis, and synthesis planning; examples from total syntheses of complex target molecules from research laboratories and industrial syntheses; practical implementation and application in research-related projects in one or two research groups at the Institutes of Organic Chemistry or Pharmaceutical Chemistry.				
Teaching format(s)	a) Applied Organic Synthesis (lecture) b) Research internship on Applied Organic Synthesis (Pr) c) Attending 4 Guest Speaker lectures/Seminars				3 SWS 7,9 SWS 0,1 SWS
Workload (partial and total)		Points	P (h)	S (h)	PV (h)
	a) pplied Organic Synthesis	4,5	42	63	30
	b) Practical laboratory training in Applied Organic Synthesis	7,5	175	5	5
	Grand total	12	217	68	35
Requirements for participation and	Coursework: regular attendance				

type of coursework and examinations	Exam: oral exam for the course (graded, 33 %) and completion of labwork (protocol and oral presentation;graded, 67 %); external guest speaker presentations: confirmation of attendance (0 %, not graded) Examination language: usually English
Duration	1 semester
Frequency	winter semester, anually

Module title	**Modern Molecular Chemistry (MoMo)**
Module ID	CHE 124
Module applicability, type	M.Sc. Chemie: Required elective module M.Sc. Chemistry: Required elective module
Prerequisites	mandatory: CHE 101 (Int.) Advanced Inorganic Chemistry recommended: CHE 016 Inorganic Chemistry III or equivalent
Responsible persons	Prof. Dr. A. Jacobi von Wangelin, Prof. Dr. L. Vondung
Language	English or German; usually English
Learning outcomes	After completing the module, students will be able to explain the structures, properties, and reactivity of selected elements and classes of compounds, particularly the p-, d-, and f-block elements. Students will be able to discuss and compare modern concepts of bond activation and bond formation in inorganic and organic molecular chemistry and explain them as components of complex mechanistic relationships. They will be able to describe the applications of various compounds classes of the p-, d-, and f-block elements in modern synthesis methods and explain the underlying properties through interpretation of modern analytical methods. Upon completion of the practical part of the module, students will be able to analyze the current literature on a specific topic and develop their own research project based on this analysis. Furthermore, they will be able to successfully carry out challenging molecular chemical syntheses and the associated analytics, analyze the obtained results, and contextualize them in relation to the current literature.
Contents	*Lecture*: Physicochemical aspects of special classes of compounds of main group and transition elements, e.g., optical, magnetic, and electronic properties; syntheses and applications of modern inorganic molecular chemistry, including chemistry of lanthanides/actinides and selected p-block elements; current developments in transition metal chemistry; modern concepts of bond activation (electro- and photochemistry, frustrated Lewis pairs, heterogeneous materials, catalysis, etc.); modern aspects of sustainable chemistry; criticality and circularity of elements; specific applications in the fields of molecular magnets, dyes, sensors, bioinorganic chemistry, and medicinal chemistry.

	Seminar: Participation in a seminar on current research topics; including giving a presentation on a selected topic from current literature related to inorganic molecules; discussion of structure- and reactivity principles as well as modern spectroscopy techniques for elucidating reaction mechanisms. *Research Internship*: Current issues in the molecular chemistry of p-, d-, and f-block elements concerning bond activation; literature research; structure- and reactivity principles; mechanism studies; modern spectroscopy; electronic and optical properties.				
Teaching formats	a) Modern Molecular Chemistry (lecture) b) Modern Molecular Chemistry (seminar) c) Modern Molecular Chemistry (research internship)				2 SWS 1 SWS 6 SWS
Workload (by course and in total)		LP	P (Std)	S (Std)	PV (Std)
	a) lecture	3	28	42	20
	b) seminar	1,5	14	21	10
	c) research internship	6	140	20	20
	total	10,5	182	83	50
Requirements for participation and type of coursework/examinatio ns	Prerequisite for examination: completion of the research internship Examination: written report on the research internship (ungraded, 0 %) and oral exam (graded, 100 %) Examination language: English or German				
Duration	1 semester				
Frequency	summer semester, every year				
Literature	S. Cotton, Lanthanide and Actinide Chemistry, 2^{nd} ed. 2024, Wiley C. Janiak, H.-J. Meyer, D. Gudat, P. Kurz, Riedel Moderne Anorganische Chemie, 2018, De Gruyter Current articles from scientific journals				

Module title	**Crystal Structure Analysis**
Module ID	CHE 127
Module applicability and type	M.Sc. Chemie: Required elective module M.Sc. Chemistry: Required elective module
Prerequisites	mandatory: CHE 101 (Int.) or lectures on solid state and structural chemistry as well as symmetry, in particular space group symmetry recommended: none
Responsible persons	Dr. F. Hoffmann & Dr. M. Perbandt
Language	English or German; usually English

<table>
<tr><td>Learning outcomes</td><td colspan="5">Upon completion of the module, students should understand all processes that occur when X-rays pass through crystalline matter and be able to outline them. Furthermore, they should be able to explain all characteristics of a diffraction pattern. The students should be able to explain the key differences in experimental setup and requirements for structural elucidation of small molecules and biological macromolecules. The students should also be able to name and explain the limitations and possibilities of structure-function analysis of biomacromolecules using modern synchrotrons and free electron lasers. Finally, the students should be able to use the software for evaluating single crystal data sets of small molecules and biomacromolecules and to assess the quality of the structural models that they have refined by themselves.</td></tr>
<tr><td>Content</td><td colspan="5">Discovery and nature of X-rays (W.C. Röntgen), first X-ray diffraction experiment on crystals by Max v. Laue, generation of X-rays by X-ray tubes, synchrotron sources, spectrum of an X-ray tube, monochromatisation of X-rays, formation of diffraction patterns (scattering and interference), Bragg's law and Miller indices, real and reciprocal lattices, symmetry of the diffraction pattern, Laue classes, Friedel's law, Ewald sphere, intensity of X-ray reflections, atomic form factor, temperature factor, disorder, structure amplitude and factor, Euler's formula, from the diffraction pattern to the crystal structure, space group determination, systematic extinctions, Fourier transformations, phase problem, Patterson method, direct methods, charge flipping algorithm, structure and function of biomacromolecules, methods for obtaining protein crystals, phasing methods for solving the phase problem in biomacromolecules, iterative modelling and structure refinement.
Practical use of the software packages ShelXTL, WinGX, Phenix, Coot and Pymol.</td></tr>
<tr><td>Teaching formats</td><td colspan="4">a) Crystal Structure analysis (lecture)
b) Practical Exercises in Crystal Structure Analysis (practical course)
c) Crystal Structure Analysis of Proteins (lecture)
d) Practical Exercises in Crystal Structure Analysis of Proteins (practical course)</td><td>1 SWS
2 SWS
0.5 SWS
0.5 SWS</td></tr>
<tr><td rowspan="2">Workload
(by course and in total)</td><td></td><td>LP</td><td>P (Std)</td><td>S (Std)</td><td>PV (Std)</td></tr>
<tr><td>a) Crystal Structure Analysis
b) Practical Exercises in Crystal Structure Analysis
c) Crystal Structure Analysis of Proteins
d) Practical Exercises of Crystal Structure Analysis of Proteins</td><td>1.5
3
0.75
0.75</td><td>14
28
7
7</td><td>21
28
10
10</td><td>20
25
5
5</td></tr>
<tr><td></td><td>total</td><td>6</td><td>56</td><td>69</td><td>55</td></tr>
<tr><td>Requirements for participation and type of</td><td colspan="5">Coursework: none</td></tr>
</table>

coursework and examinations	Exam: oral examination in groups of two students, 45 min for a) & b) plus 15 min for c) & d) (graded) Examination language: usually English
Duration	1 semester
Frequency	Winter semester, every year
Literature	W. Borchardt-Ott, „Crystallography“, Springer, 3rd Edition, **2012** F. Hoffmann, „Introduction to Crystallography“, Springer Nature, 1st Edition, **2020** W. Massa, „ Crystal Structure Determination “, Springer, 2nd Edition, **2014** Li-Ling Ooi, „Principles of X-ray Crystallography“, Oxford University Press, 1st Edition, **2010** W. Clegg, „Crystal Structure Determination“, Oxford University Press, 2nd Edition, **2015** B. Rupp, “Biomolecular Crystallography”, Garland Science, 1st Edition, **2009**

Module title	**Catalysis: Theory, Mechanisms and Applications**
Module ID	CHE 128
Module applicability, type	M.Sc. Chemie: Required elective module
Prerequisites	mandatory: CHE 101 Int. (Advanced Inorganic Chemistry) recommended: CHE 016, CHE017 or comparable modules
Responsible persons	Prof. Dr. A. Jacobi von Wangelin, Prof. Dr. Lisa Vondung
Language	English or German; usually English
Learning outcomes	Understanding of the physical and chemical fundamentals of catalysis. Description and characterization of the different types of catalysts and catalytic reactions. Analysis and description of catalytic reaction mechanisms using theoretical, spectroscopic, and preparative methods. Analysis and evaluation of existing catalytic processes for the production of basic chemicals and functionalized molecules. Description of technical material flows. Description of economic and ecological efficiency criteria of catalytic processes in research and production. Understanding of complex reaction mechanisms and application to current research topics in catalysis research.
Contents	The lecture provides an overview of: - the fundamentals of catalysis, including physical, chemical, and theoretical aspects, - analytical, physical, and preparative methods for elucidating reaction mechanisms, including kinetics, isotope effects, stereochemistry, and reaction monitoring using IR, UV-Vis, and NMR spectroscopy,

	- the types of catalysts and their characterization, - current trends in catalysis research, exemplified by organocatalysis, metal catalysis, and specialized aspects such as electro- and photo-catalysis, - technical catalytic processes involving fossil and renewable resources, platform chemicals, and functionalized fine chemicals, as well as selected materials and active substances, - specific applications of homogeneous metal catalysis and coordination chemistry in the production of organic molecules in industry and laboratory.				
Teaching formats	a) Catalysis I: Foundations and applications of homogeneous transition metal catalysis (lecture) b) Catalysis II: Theory, spectroscopy and mechanisms (lecture) c) Current trends in applied catalysis research (seminar and research internship)				2 SWS 2 SWS 5 SWS
Workload (by course and in total)		LP	P(Std)	S(Std)	PV(Std)
	a) Catalysis I	3	28	32	30
	b) Catalysis II	3	28	32	30
	C) Current trends	6	140	20	20
	total	12	196	84	80
Requirements for participation and type of coursework/examinatio ns	Requirements for the module examination: regular participation in the seminar (attendance mandatory) Type of module examination: project completion (ungraded) and oral examination (graded, 100%) Language of examination: English or German				
Duration	1-2 semesters				
Frequency	Summer semester (lecture, seminar, internship), Winter semester (only seminar, internship)				
Literature	Current articles from scientific journals				

Module title	**HighTech Polymer Chemistry**
Module ID	CHE 130 A
Module applicability and type	M.Sc. Chemie: Required elective module M.Sc. Chemistry: Required elective module
Prerequisites	mandatory: none recommended: CHE 106 Int.
Responsible person(s)	Dr. W. Pauer, Dr. C. Wutz
Language	English or German; usually English

Learning outcomes	Students will be able to apply new developments in the field of polymer research and production technologies in the corresponding professional context and present them. They can classify the corresponding chemical processes in a scientific context. They be able to reproduce the basics of process and apparatus engineering and can apply these to industrially relevant processes. They know important technical polymers and their synthesis routes and can draw conclusions about their properties/justify their properties. They understand the specific properties of polymer networks and can describe their functionality.				
Content	Modern interdisciplinary methods that lead to a resource-saving intensification of chemical intensification of chemical processes, contribute to improving process process safety and enable inherently safe reaction control are presented and discussed. On the material side additives for plastics, elastomers (rubber), polymer blends, resins, coatings, adhesives, foams, bioplastics, high-performance polymers, polymer membranes, functional polymers, nano-polymers, smart polymers covered.				
Teaching format(s)	a) Micro reaction engineering / Mikroreaktionstechnik (V) b) HighTech Polymers and Materials / HighTech Polymere und Werkstoffe (V)				2 SWS 2 SWS
Workload (by course and in total)		LP	P (Std)	S (Std)	PV (Std)
	a) Micro reaction engineering	3	28	42	20
	b) HighTech Polymers and Materials	3	28	42	20
	total	6	56	84	40
Requirements for participation and type of coursework and examinations	Coursework: none Exam(s): graded presentation (33 %) and graded written examamination, 2 h (67 %) Examination language: usually English, if desired by all course students German.				
Duration	1 Semester				
Frequency	Summer Semester, every year				
Literature	Depending on the prior knowledge and interests of the participants, this will be selected together with the participants in the first lecture hour				

Module title	**HighTech Polymer Chemistry – Lab work**
Module ID	CHE 130 B

Module applicability and type	M.Sc. Chemie: Required elective module M.Sc. Chemistry: Required elective module				
Prerequisites	mandatory: CHE 130 A recommended: Introductory lectures of the Technical, Chemical and/or Polymer Reaction Engineering and Macromolecular Chemistry				
Responsible person(s)	Dr. W. Pauer, Dr. C. Wutz				
Language	English or German; usually English				
Learning outcomes	Students are able to recognize new developments in science and technology in the relevant professional context in experiments, classify chemical processes in a scientific context, characterize and classify manufactured polymers. Furthermore, understand the basics of process and apparatus engineering and be able to apply them appropriately. Students can apply modern interdisciplinary methods that lead to a resource-saving intensification of chemical processes apply them.				
Content	Independent implementation of a research project (also as a sub-project) of a research project) with technical-chemical and physical Tasks. Professional documentation (in written form, presentation as management excerpt). Carrying out cross-scale and cross-process syntheses. Chemical processes in terms of selectivity and space-time yield, Optimization of reactor control and characterization of usually polymer products. Optimization of product properties through process optimization and adaptation of synthesis routes.				
Teaching format(s)	Research Lab Course – Chemical and Polymer reaction engineering				6 SWS
Workload (by course and in total)		LP	P (Std)	S (Std)	PV (Std)
	Research Lab Course – Chemical and Polymer reaction engineering	3	140	20	20
	total	6	140	20	20
Requirements for participation and type of coursework and examinations	Coursework: none Exam(s): graded presentation or graded protocol. The kind of examination will be fixed together with the students before lab course. Examination language: usually English, if desired by students German.				
Duration	1 Semester				
Frequency	Summer and Winter semester, every year				
Literature	Depending on the prior knowledge and interests of the participants, this will be selected together with the participants in the first lecture hour				

Module title	**Electronic Transport in Molecules and Nanoscopic Systems**
Module ID	CHE 136

Module applicability and type	M.Sc. Chemie: Required elective module M.Sc. Chemistry: Required elective module M.Sc. Physics and Chemistry of Nanomaterials: Required elective module M.Sc. Data Science and Artificial Intelligence: Domain Knowledge in Data Science and Artificial
Prerequisites	mandatory: none recommended: none
Responsible person(s)	Prof. Dr. C. Herrmann
Language	English or German; usually English
Learning outcomes	The students are able to explain, discuss, and evaluate various models and mechanisms of electrical conductivity for different systems. They are capable of constructing numerical models and conducting simulations with them.
Content	Detailed introduction to various models of electrical conductivity, with a focus on phenomena and concepts in molecular electronics, spintronics, and other nanoscale systems. Topics discussed include: • Why molecular electronics and spintronics? • Various transport mechanisms (tunneling, hopping) • What should be considered in theoretical description? • Charge transport through nanoparticles and nanoparticle networks • Structure-conductivity relationship • Quantum interference • Why do some molecules conduct significantly worse than structurally very similar ones? • Influence of magnetic fields and unpaired spins, helical molecules as spin filters • Molecules as rectifiers • Switchable molecules • Molecular optoelectronics • Mechanical control • •Transport through two-dimensional systems • •What are the possible applications? These topics are complemented by simulations and models, which are conducted or adapted by the students themselves.
Teaching format(s)	a) Electronic Transport in Molecules and Nanoscopic Systems (V) — 2 SWS

Workload (by course and in total)		LP	P (Std)	S (Std)	PV (Std)
	a) Electronic Transport in Molecules and Nanoscopic Systems	3	28	42	20
	total	3	28	42	20

Requirements for participation and type of	Coursework: none Exam(s): presentation (graded)

coursework and examinations	Examination language: usually English
Duration	1 Semester
Frequency	Summer Semester, every year
Literature	Depending on the prior knowledge and interests of the participants, this will be selected together with the participants in the first lecture hour

Module title	**Sustainable Soft Materials**				
Module ID	CHE 137 A				
Module applicability and type	M.Sc. Chemie: Required elective module M.Sc. Chemistry: Required elective module M.Sc. Physics and Chemistry of Nanomaterials: Required elective module				
Prerequisites	mandatory: none recommended: Introductory courses in physical chemistry and macromolecular chemistry				
Responsible person(s)	Prof. Dr. V. Abetz, Dr. B. Hankiewicz, Dr. A. Meyer, Dr. M. Radjabian				
Language	English or German; usually English				
Learning outcomes	Knowledge of the characteristics of soft matter and various related material classes, especially polymers, networks, gels, vitrimers, and colloids. Knowledge of sustainable synthesis methods for such materials. Application of this knowledge in a presentation on a specialist publication in the seminar, followed by a discussion.				
Content	Sustainable syntheses, as well as the preparation and characterization of polymeric materials, networks, gels, vitrimers, and colloidal systems. Relationships between the chemical structure of materials and their phases in bulk and solution, as well as their physical properties (mechanics, optics).				
Teaching format(s)	a) Sustainable Soft Materials (lecture) b Sustainable Soft Materials (seminar)				1 SWS 1 SWS
Workload (by course and in total)		LP	P (Std)	S (Std)	PV (Std)
	a) Sustainable Soft Materials (lecture)	1,5	14	21	10
	b) Sustainable Soft Materials (seminar)	1,5	14	11	20
	total	3,0	28	32	30
Requirements for participation and type of coursework and examinations	Coursework: Regular attendance at lectures Exam(s): Presentation (graded) Examination language: usually English				
Duration	1 semester				

Frequency	Summer semester, every year
Literature	Doi „Soft Matter Physics“, Lodge, Hiemenz „Polymer Chemistry“, Strobl „The Physics of Polymers“

Module title	**Sustainable Soft Materials – Lab work**				
Module ID	CHE 137 B				
Module applicability and type	M.Sc. Chemie: Required elective module M.Sc. Chemistry: Required elective module M.Sc. Physics and Chemistry of Nanomaterials: Required elective module				
Prerequisites	mandatory: Sustainable Soft Materials – lecture module recommended: Practical courses in inorganic and organic chemistry, practical courses in physical chemistry, and technical and macromolecular chemistry.				
Responsible person(s)	Prof. Dr. V. Abetz, Dr. B. Hankiewicz, Dr. A. Meyer, Dr. M. Radjabian				
Language	English or German; usually English				
Learning outcomes	Gain practical experience in the production and characterization of polymeric materials or colloids using sustainable (green) chemistry methods or experience in the theoretical treatment of such materials. The ability to work independently and plan research independently should be acquired within a research project in cooperation with a team in a working group. The protocol should be written in the style of a scientific publication and serves to develop the ability to prepare texts for publication.				
Content	Production and characterization or theoretical work in the subject areas of the lecture module Sustainable Soft Materials – Lecture Module.				
Teaching format(s)	a) Sustainable Soft Materials (practical course)				6 SWS
Workload (by course and in total)		LP	P (Std)	S (Std)	PV (Std)
	a) Sustainable Soft Materials (practical course)	6	56	56	68
	total	6	56	56	68
Requirements for participation and type of coursework and examinations	Coursework: none Exam(s): Project completion (graded) (Report (75%), Working group presentation (25%)) Examination language: usually English				
Duration	1 semester				
Frequency	every semester				
Literature	Doi „Soft Matter Physics“, Lodge, Hiemenz „Polymer Chemistry“, Strobl „The Physics of Polymers“				

Module Title	Laser Spectroscopy of Nanostructures				
Module ID	CHE 138 A				
Module applicability and type	M.Sc. Chemie: Required elective module M.Sc. Chemistry: Required elective module M.Sc. Physics and Chemistry of nanomaterials: Required elective module				
Prerequisites	mandatory: CHE 103 (Int.) recommended: Introductory courses in quantum mechanics and spectroscopy				
Responsible person(s)	Dr. T. Kipp, Prof. Dr. A. Mews				
Language	English or German; usually English				
Learning outcomes	Understanding the concepts of lasers and of the optical spectroscopy of nanoscale materials. Understanding connections between quantummechanic transitions and optical spectra.				
Content	Light-matter interaction and its description; basic principles of laser operation, laser resonators, generation of ultrashort laser pulses, examples of lasers for spectroscopy on nanostructures; time-resolved spectroscopy: photon counting and pump-probe methods; frequency-resolved spectroscopy: Raman and photoluminescence; spatially resolved methods: confocal microscopy				
Teaching format(s)	Laser Spectroscopy of Nanostructures (V)				2 SWS
Workload (by course and in total)		LP	P (Std)	S (Std)	PV (Std)
	Laser Spectroscopy of Nanostructures (lecture)	3	28	28	34
	total	3	28	28	34
Requirements for participation and type of coursework and examinations	Exam(s): usually oral exam, otherwise written exam (graded) Examination language: usually English Requirements: none				
Duration	1 semester				
Frequency	Annually during the summer semester				
Literature	Meschede: Optik, Licht und Laser, Svelto: Principles of Lasers, Demtröder: Laser Spectroscopy 1, Lakowicz: Principles of Fluorescence Spectroscopy, supplemented by current journal articles.				

Module Title	Laser Spectroscopy of Nanomaterials – Lab work
Module ID	CHE 138 B
Module applicability and type	M.Sc. Chemie: Required elective module M.Sc. Chemistry: Required elective module M.Sc. Physics and Chemistry of nanomaterials: Required elective module

Prerequisites	mandatory: CHE 138 A, CHE 103 (Int.) recommended: Introductory courses in quantum mechanics and spectroscopy				
Responsible person(s)	Dr. T. Kipp, Prof. Dr. A. Mews				
Language	English or German; usually English				
Learning outcomes	Students acquire knowledge and practical skills in the field of optical spectroscopy of nanoscale materials. They perform demanding preparative and analytical experiments, such as analyzing various dynamic processes in nanocrystalline solids and understanding the origin of signals in different spectroscopic methods. Students collaborate within the team of the hosting research group. They organize their practical work in the laboratory and plan experiments or experimental series. To do so, they research the necessary literature and summarize it in a protocol. In the protocol, they also document the experiments conducted and evaluate the results obtained.				
Content	Light-matter interaction and its description; basic principles of laser operation, laser resonators, generation of ultrashort laser pulses, examples of lasers for spectroscopy on nanostructures; time-resolved spectroscopy: photon counting and pump-probe methods; frequency-resolved spectroscopy: Raman and photoluminescence; spatially resolved methods: confocal microscopy				
Teaching format(s)	Laser Spectroscopy of Nanostructures (P)				6 SWS
Workload (by course and in total)		LP	P (Std)	S (Std)	PV (Std)
	Laser Spectroscopy of Nanostructures (practical course)	6	90	45	45
	total	6	90	45	45
Requirements for participation and type of coursework and examinations	Requirements for examination: none Exam(s): Project completion (graded) Examination language: usually English				
Duration	1 semester				
Frequency	Every semester				
Literature	Meschede: Optik, Licht und Laser, Svelto: Principles of Lasers, Demtröder: Laser Spectroscopy 1, Lakowicz: Principles of Fluorescence Spectroscopy, ergänzt durch aktuelle Zeitschriftenartikel.				

Module title	**Nanomaterials in Optics, Electronics and Sensors**
Module ID	CHE 139
Module applicability and	M.Sc. Chemie: Required elective module

type	M.Sc. Chemistry: Required elective module M.Sc. Physics and Chemistry of nanomaterials: Required elective module				
Prerequisites	mandatory: none recommended: Introductory courses in physical chemistry and inorganic chemistry (CHE 101 (Int.) und CHE 103 (Int.))				
Responsible person(s)	Prof. Dr. A. Mews, Dr. T. Vossmeyer				
Language	English or German; usually English				
Learning outcomes	The students acquire knowledge of the optical and electronic properties of nanomaterials and their applications as sensors. This knowledge supports students in independently conducting scientific work on physico-chemical issues and serves as a basis for sustainable solutions. The students understand the specific optical and electronic properties of nanomaterials and are able to assign these properties to the operational principles of various electronic components and sensor types. They comprehend fundamental concepts of solid-state physics and can use this understanding to evaluate the advantages and disadvantages of different sensor types for various application needs. They are capable of analyzing and interpreting the functioning of sensors with optical or electrical signal transduction based on classical and quantum mechanical models, as well as the use of equivalent circuit diagrams. The students are trained to conduct subject-specific literature research. They can develop solutions for the design of suitable sensors made from nanomaterials to address given application problems.				
Content	• Production of metallic and semiconducting nanomaterials • Spectroscopic and microscopic methods for characterizing nanomaterials • Optical and electrical properties of metallic and semiconducting nanostructures • Operating principles of electronic components based on nanostructures • Operating principles of chemical and physical sensors • Sensors made from nanomaterials with optical signal transduction • Sensors made from nanomaterials with electrical signal transduction • Examples of current research: Advantages of nanomaterials for the design of highly sensitive chemical and physical sensors.				
Teaching format(s)	a) Nanomaterials in Optics, Electronics and Sensors (lecture) b) Seminar on Nanomaterials in Optics, Electronics, and Sensors (seminar)				3 SWS 1 SWS
Workload (by course and in total)		LP	P (Std)	S (Std)	PV (Std)
	a) Nanomaterials in Optics, Electronics, and Sensors	4,5	42	56	37
	b) Seminar on Nanomaterials in Optics, Electronics and Sensors	1,5	14	14	17
	total	6	56	70	54
Requirements for participation and type of coursework and examinations	Coursework: none Examination: Presentation (40 %, graded) and written examination (60 %, graded) Examination language: usually English				

Duration	1 semester
Frequency	Summer semester, every year

Module title	**Introduction to Membrane Technology**				
Module ID	CHE 146				
Module applicability and type	M.Sc. Chemie: Required elective module M.Sc. Chemistry: Required elective module M.Sc. Physics and Chemistry of Nanomaterials: Required elective module				
Prerequisites	mandatory: none recommended: Introductory courses in physical chemistry, inorganic chemistry and technical and macromolecular chemistry				
Responsible person(s)	Prof. Dr. V. Abetz, Dr. Md. M. Rahman				
Language	English or German; usually English				
Learning outcomes	Knowledge of the various membrane-based separation processes and their areas of application, application of knowledge from thermodynamics and kinetics to explain mass transport mechanisms in porous and non-porous membranes, application of knowledge from macromolecular and inorganic chemistry to discuss properties of membrane materials.				
Content	Membrane materials, membrane manufacturing, mass transport in membranes, membrane modules, membrane processes (micro- and ultrafiltration, nanofiltration, gas separation, reverse osmosis, dialysis, electrodialysis).				
Teaching format(s)	a) Introduction to Membrane Technology (lecture) b) Introduction to Membrane Technology (seminar)				1 SWS 1 SWS
Workload (by course and in total)		LP	P (Std)	S (Std)	PV (Std)
	a) Intr. to Membrane Technology	1,5	14	20	9
	b) Seminar intr. to Membrane Technology	1,5	14	20	4
	total	3,0	28	45	13
Requirements for participation and type of coursework and examinations	Coursework: Regular attendance at lectures Exam: Presentation (graded) Examination language: usually English				
Duration	1 semester				
Frequency	winter semester, every year				
Literature	Strathmann “Introduction to Membrane Science and Technology”				

Module title	**Water in special environments**				
Module ID	CHE 156				
Module applicability and type	M.Sc. Chemie: Required elective module M.Sc. Chemistry: Required elective module				
Prerequisites	mandatory: none recommended: none				
Responsible person(s)	Prof. Dr. M. Fröba				
Language	English or German; usually English				
Learning outcomes	The students are familiar with the basic physical and chemical properties of water and can explain and apply them to the behavior of water and aqueous solutions in different environments. Working as part of a team, the students can plan and carry out a small research project in the field of the physical and chemical properties of water in different environments and present their results in a talk in a structured manner.				
Content	1. Introduction to the structures and properties of water and ice 2. Introduction to selected anomalies of water 3. Water in inorganic environments (pores, rocks) 4. Water in biological environments (proteins, aquaporins) 5. Water in technical processes (green chemistry) 6. Water in the universe (extreme conditions) 7. Aqueous salt solutions (changes in structure and properties) 8. Methods: XRD, SAXS, SANS, correlation spectroscopy (XPCS, XCCA), PDF, Raman, IR, DSC/calorimetry, QENS, MAS-NMR, PFG-NMR Lab course: 1. Synthesis methods for producing nanoporous materials with defined porosity 2. Techniques for filling nanopores with water and aqueous solutions. 3. Application of different methods (in theory and practice) for characterizing the phase behavior of water and aqueous solutions in different environments				
Teaching format(s)	a) Water in special environments (V) b) Lab work Water in special environments (P)				2 SWS 6 SWS
Workload (by course and in total)		LP	P (Std)	S (Std)	PV (Std)
	a) Water in special environments	3	28	35	27
	b) Lab work Water in special environments	6	160	0	20
	Gesamtaufwand	9	188	35	47
Requirements for participation and type of coursework and examinations	Coursework: none Exams: oral examination (graded, 33 %) and final assignment (graded, 67 %) Examination language: usually English				
Duration	1 semester				
Frequency	Summer semester, every year				

Module title	**Sustainable production of platform chemicals**
Module ID	CHE 161
Module applicability and type	M.Sc. Chemie: Required elective module M.Sc. Chemistry: Required elective module
Prerequisites	Mandatory: none Recommended: Introductory courses in inorganic chemistry, Introductory courses in organic chemistry, Introductory courses in technical chemistry
Responsible person(s)	Prof. Dr. J. Albert, Dr. D. Voß
Language	German or English
Learning outcomes	Students analyze and evaluate existing processes for producing basic chemicals from fossil raw materials with regard to substitution possibilities. Students gain an overview of possible biogenic raw materials for use in the chemical industry. Students develop concepts for the sustainable production of selected platform chemicals. Students evaluate and compare existing processes with alternatives based on biogenic raw materials.
Content	The lecture provides an overview of possibilities for the sustainable production of platform chemicals from biogenic raw materials. The focus is on processes for the chemical conversion of carbohydrates, triglycerides, and lignocellulose into intermediates for the polymer and pharmaceutical industries. Another focus is on the production of marketable fuels and chemicals based on renewable energies and biomass as the only available renewable carbon source. Using selected examples from current research and literature, ways of creating chemical value from renewable raw materials will be demonstrated. At the beginning of the lecture, the problem of the foreseeable shortage of fossil raw materials for the production of platform chemicals will be addressed and possible solution scenarios will be presented. This will be followed by detailed examples from our current research and other processes relevant to large-scale technology. Finally, perspectives for the substitution of fossil raw materials in other chemical production processes will be presented. In addition, novel catalyst systems from the group of polyoxometalates for the conversion of complex biomasses into selective value chains will be presented. Block 1: Introduction and fundamentals -Introduction to the issue -Definition and classification of biomass Block 2: Bio-based acids as an example of platform chemicals -Production of biogenic formic acid in OxFA-Process -Sustainable production of acrylic acid -Bio-based succinic acid—a versatile all-rounder -Selective depolymerization of lignin to functionalized aromatic acids Block 3: Bio-based plastics as an example of platform chemicals Block 3: Bio-based plastics as an example of platform chemicals

	-Production of PLA as a biodegradable plastic -Alternative production of ethylene from bioethanol or biomethane for PESynthesis -Production of green PET substitutes from biomass Block 4: Sustainable process paths for coupling renewable energy sources -Power-to-liquid using the example of methanol from CO2 and renewable hydrogen -Power-to-gas using the example of methane from CO2 and renewable hydrogen -Outlook on further substitution possibilities for petroleum/natural gas-based products				
Teaching format(s)	a) Sustainable production of platform chemicals (V) b) Exercises on sustainable production of platform chemicals (Ü) c) Sustainable lab course (P)				2 SWS 1 SWS 1 SWS
Workload (by course and in total)		LP	P (Std)	S (Std)	PV (Std)
	a) Sustainable production of platform chemicals (V)	3	28	42	20
	b) Exercises on sustainable production of platform chemicals (Ü)	1,5	14	21	10
	c) Sustainable lab course (P)	1,5	30	10	5
	total	6	72	73	35
Requirements for participation and type of coursework and examinations	Prerequisites for the module examination: Completion of lab course Type of module examination: Oral examination (graded)				
Duration	1 semester				
Frequency	Winter semester, every year				
Literature	A. Jess, P. Wasserscheid, “Chemical Technology,” Wiley VCH, 2013 M. Kaltschmitt, H. Hartmann, H. Hofbauer, "Energy from Biomass—Fundamentals, Techniques, and Processes," Springer Verlag, 2009. J. Albert, “The Erlangen OxFA Process,” SVH, 2016.				

Module title	**Power-to-X-technologies**
Module ID	CHE 162
Module applicability and type	M.Sc. Chemie: Required elective module M.Sc. Chemistry: Required elective module
Prerequisites	Mandatory: none

	Recommended: CHE 117 Reaction Engineering, CHE 161 Sustainable Production of Platform Chemicals, CHE 023 Technical Chemistry
Responsible person(s)	Prof. Dr. J. Albert, Dr. D. Voß
Language	German or English
Learning outcomes	Students analyze and evaluate the energy transition in Germany. Students gain an overview of the diverse applications of power-to-X technologies. Students develop concepts for the technical implementation of power-to-X processes. Students evaluate and compare different Power-to-X concepts in terms of their technical challenges and social benefits. Students learn practical aspects of energy conversion to platform chemicals through laboratory experiments.
Content	The lecture provides an overview of various power-to-X concepts in the context of the German energy transition - Renewable surplus energy - Electrolysis - CO2 sources for power-to-X - Power-to-heat - Power-to-power - Power-to-gas (SNG) - Power-to-syngas - Power-to-methanol - Power-to-fuels - Power-to-ammonia - LOHC (liquid organic hydrogen carrier) - Economic and ecological comparison of different concepts
Teaching format(s)	a) Power-to-X technologies (V) — 2 SWS b) Exercises on Power-to-X technologies (Ü) — 1 SWS c) Lab course “Power-to-X” (P) — 1 SWS

Workload (by course and in total)		LP	P (Std)	S (Std)	PV (Std)
	a) Power-to-X technologies (V)	3	28	42	20
	b) Exercises on Power-to-X technologies (Ü)	1,5	14	21	10
	c) Lab course “Power-to-X” (P)	1,5	30	10	5
	total	6	72	73	35

Requirements for participation and type of coursework and examinations	Prerequisites for the module examination: Completion of lab course Type of module examination: Oral examination (graded)
Duration	1 semester
Frequency	Summer semester, every year

Literature	A. Jess, P. Wasserscheid, “Chemical Technology,” Wiley VCH, 2013 H. Watter, “Regenerative Energy Systems,” Springer, 2015

Module title	**Biohybrid nanostructures**
Module ID	CHE 163 A
Module applicability and type	M.Sc. Chemie: Required elective module M.Sc. Chemistry: Required elective module M.Sc. Physics and Chemistry of Nanomaterials: Required elective module M.Sc. Molecular Life Sciences: Required elective module M.Sc. Bioinformatik: Required elective module
Prerequisites	mandatory: none recommended: introductory courses of inorganic and physical chemistry and biochemistry
Responsible person(s)	Prof. Dr. T. Beck
Language	English
Learning outcomes	The students possess knowledge about the use of biomolecules for the design and synthesis of biohybrid nanostructures that consist of biomolecules and inorganic components. This knowledge serves as a foundation for students to independently address scientific questions and develop their own solution strategies. To this end, the students are familiar with the fundamentals of protein structure determination and the possibilities of protein design. The students understand the various methods for characterizing nanostructures, including their strengths and limitations, and can assess which methods should be used for the questions under discussion. They can discuss methods for arranging nanostructures and explain the collective properties of nanomaterials. The students have learned to analyze potential applications of biohybrid nanostructures and can choose which building blocks are suitable for each application.
Content	- Biomineralization and bio-template-based synthesis of nanostructures - Biomolecules (proteins, DNA) as building blocks for nanomaterials - Protein and enzyme design, also using machine learning - Methods for protein structure elucidation, especially protein crystallography - Inorganic nanoparticle synthesis - Characterization of nanostructures using modern methods such as SAXS, DLS, SANS, electron microscopy, synchrotron methods - Collective properties of nanomaterials - Arrangement of nanoscale building blocks into ordered structures - Applications of biohybrid nanostructures

Teaching format	a) Biohybrid nanostructures (lecture)				2 SWS
Workload (by course and in total)	 Biohybrid nanostructures	LP 3	P (Std) 28	S (Std) 42	PV (Std) 20
	Total	3	28	42	20
Requirements for participation and type of coursework and examinations	Coursework: none Exam: oral examination (graded) Examination language: English				
Duration	1 semester				
Frequency	Summer semester, every year				
Literature	See lecture notes				

Module title	**Industrial homogeneous catalysis**
Module ID	CHE 164
Module applicability and type	M.Sc. Chemie: Required elective module M.Sc. Chemistry: Required elective module
Prerequisites	Mandatory: none Recommended: CHE 117 Reaction Engineering, CHE 161 Sustainable Production of Platform Chemicals, CHE 023 Technical Chemistry
Responsible person(s)	Prof. Dr. J. Albert, Dr. D. Voß, Dr. M. J. Poller
Language	German or English
Learning outcomes	After successful participation, students will have achieved the following learning outcomes: Students will be able to: • explain the principle of homogeneous catalysis, • provide an overview of the versatile applications of homogeneous catalysis in industry, • evaluate various homogeneously catalyzed reactions in terms of their technical challenges and economic significance, • develop concepts for the technical implementation of homogeneous catalysed reactions, • evaluate practical aspects of homogeneous catalysis using laboratory experiments, • apply the knowledge they have learned to various homogeneous catalysed reactions.

	• independently discuss solutions and problems in the field of homogeneous catalysis in a small interdisciplinary group, • work together in small groups on subject-specific tasks, • Work together in small groups on subject-specific tasks, • Use laboratory experiments to work out the practical aspects of homogeneous catalysis, carry out and evaluate the analysis of the products, and summarize the results of the experiments precisely in a report.				
Content	Lecture content: • Introduction to homogeneous catalysis • Elementary steps of catalysis • Homogeneous transition metal catalysis • Hydroformylation • Wacker process • Monsanto process • Shell higher olefin process (SHOP) • Extractive oxidative desulfurization (ECODS) • Phase transfer catalysis • Liquid-liquid two-phase catalysis • Catalyst recycling • Reactor concepts In the lecture hall exercise, the contents of the lecture are further deepened and transferred into practical application. This is done using example tasks from practice, which are made available to the students. The students should solve these tasks independently or in groups with the help of the lecture material. The solution is then discussed with the students under scientific guidance, with parts of the task being presented on the board. In the laboratory practical, practical experiments related to the industrial application of homogeneous catalysis are carried out. Here, students are made aware of the obstacles to the technical implementation of homogeneously catalyzed reactions. The associated analysis of the test samples is also part of the laboratory practical and is carried out and evaluated by the students themselves. The results are summarized precisely in a test report and presented scientifically.				
Teaching format(s)	a) Industrial homogeneous catalysis (V) b) Exercise on industrial homogeneous catalysis (Ü) c) Homogeneous catalysis in application (P)				2 SWS 1 SWS 1 SWS
Workload (by course and in total)		LP	P (Std)	S (Std)	PV (Std)
	a) Industrial homogeneous catalysis (V)	3	28	42	20
	b) Exercise on industrial homogeneous catalysis (Ü)	1,5	14	21	10
	c) Homogeneous catalysis in application (P)	1,5	30	10	5

	total	6	72	73	35
Requirements for participation and type of coursework and examinations	Prerequisites for the module examination: none Type of module examination: oral examination (graded), completion of internship (report) (ungraded) Examination language: German or English				
Duration	1 semester				
Frequency	Winter semester, every year				
Literature	A. Jess, P. Wasserscheid, “Chemical Technology,” Wiley VCH, 2013 A. Behr, “Applied Homogeneous Catalysis,” Wiley-VCH, 2008				

Module title	**Hydrogen and Fuel Cell Technology**
Module ID	CHE 172
Module applicability and type	M.Sc. Chemie: Required elective module M.Sc. Chemistry: Required elective module M.Sc. Physics and Chemistry of Nanomaterials: Required elective module
Prerequisites	mandatory: „none” recommended: „none“
Responsible person(s)	Prof. Dr. M. Özaslan, Dr. F. Hasché
Language	English or German; usually English
Learning outcomes	Students will gain in-depth knowledge of hydrogen production, utilization and transport/storage. They will be able to explain and evaluate the various state-of-the-art and future technologies. Furthermore, they can explain proton exchange membrane (PEM) fuel cell technology in detail and are able to correlate component/material selection with their corresponding operating mode/application. Students can apply their knowledge gained to specific problems and outline possible solutions.
Content	Lecture *Topic Hydrogen:* Properties of hydrogen, hydrogen as an energy carrier, relevance of hydrogen in the chemical industry, differences and critical evaluation of various technologies for hydrogen production, such as steam reforming, water electrolysis, and their impact of the CO_2 footprint, investment and production costs, comparison with other energy carriers, various applications, possible transport and storage technologies, evaluation of polarization curves of water electrolyzer, heat and mass management, component selection. *Topic PEM Fuel Cell:*

	Component and material selection, catalyst systems, catalyst-coated membranes, current-voltage characteristics, mass and charge transport processes, water and heat management, characterization of fuel cell stacks and their specific functions of components, evaluation of polarization curves and determination of ideal operating strategies for fuel cell stacks, possible fields of application, degradation mechanisms in PEM fuel cells, development of accelerated stress tests (AST) of catalyst materials. Seminar Individual presentation on a specific aspect of hydrogen and fuel cell technology. Excursion Discover the practical application of hydrogen and/or fuel cell technology during a guided site visit or technical exhibition.				
Teaching format(s)	a) Hydrogen and Fuel Cell Technology Lecture (V)				2 SWS
	b) Hydrogen and Fuel Cell Technology Seminar (S)				1 SWS
	c) Hydrogen and Fuel Cell Technology Excursion (E)				1 SWS
Workload		LP	P (Std)	S (Std)	PV (Std)
(by course and in total)	a) Hydrogen and Fuel Cell Technology Lecture (V)	3	28	22	40
	b) Hydrogen and Fuel Cell Technology Seminar (S)	2	14	35	11
	c) Hydrogen and Fuel Cell Technology Excursion (E)	1	14	14	2
	total	6	56	71	53
Requirements for participation and type of coursework and examinations	Coursework: „none" Exam(s)**: Oral examination (30 min.) graded Examination language: „usually English"				
Duration	1 semester				
Frequency	Winter semester, every year				
Literature	Will be announced during the course				

Final Thesis

<table>
<tr><th>Module title</th><th colspan="5">Master’s Thesis</th></tr>
<tr><td>Module ID</td><td colspan="5">CHE 110</td></tr>
<tr><td>Module applicability, type</td><td colspan="5">M.Sc. Chemistry: Mandatory module</td></tr>
<tr><td>Prerequisites</td><td colspan="5">Mandatory: Students may be admitted to the master's thesis if they have successfully completed all modules of the introductory phase and compulsory elective modules of the advanced phase totaling at least 36 ECTS credits, as well as the research internship. An elective module of the advanced phase may be registered for but must not yet be completed.
Recommended: none</td></tr>
<tr><td>Responsible persons</td><td colspan="5">See the list of reviewers</td></tr>
<tr><td>Language</td><td colspan="5">English or German; usually English</td></tr>
<tr><td>Learning outcomes</td><td colspan="5">Students work independently in a scientific manner, deepening their knowledge by focusing on a specific area of chemistry, both theoretically and experimentally. They are familiar with the principles of good scientific practice, important publications, and theories related to their specialized field, and they apply this knowledge purposefully.</td></tr>
<tr><td>Contents</td><td colspan="5">Under supervision, students have acquired the ability to work independently and comprehensively on a current topic within a subfield of chemistry, in theory and/or practice. They are familiar with the principles of good scientific practice and have an in-depth understanding of important publications, experimental findings, and theories in their specialized area. They can apply this knowledge purposefully. Students can develop work plans to systematically address their tasks and independently implement them by applying learned, discipline-specific scientific methods and conducting literature research. Student are capable of planning experiments and/or simulations in consultation with their supervisors. They can evaluate, interpret, and critically assess results in comparison to scientific publications and presentations. Their methodological skills also include the preparation of a scientific report and its oral presentation, followed by a discussion of the work.</td></tr>
<tr><td>Teaching formats</td><td colspan="4">Master’s Thesis + colloquium</td><td></td></tr>
<tr><td rowspan="2">Workload</td><td></td><td>LP</td><td>P (Std)</td><td>S (Std)</td><td>PV (Std)</td></tr>
<tr><td>Master’s Thesis + colloquium</td><td>30</td><td></td><td></td><td></td></tr>
<tr><td>Requirements for participation and type of coursework/examinations</td><td colspan="5">Coursework: none
Exam: Master’s Thesis (graded, 5/6) und colloquium (graded, 1/6)</td></tr>
<tr><td>Duration</td><td colspan="5">1 semester</td></tr>
<tr><td>Frequency</td><td colspan="5">every semester</td></tr>
</table>