Module Handbook

of the

Master's Degree Programs

Chemistry

and

Chemical Biology

22. Februar 2024

Table of Contents

Abbreviations

AC	Inorganic Chemistry
OC	Organic Chemistry
PC	Physical Chemistry
TC	Industrial Chemistry
MC	Medicinal Chemistry
ZB	Molecular Cell Biology
CB	Chemical Biology
M. M.	Molecules and Materials: Syntheses, Structures, Functions
E. T.	Experiment and Theory: Spectroscopy, Computational Chemistry, Industrial Processes
SoC	Further Studies in Chemistry or Natural Sciences
SoN	Supplementary Non-Natural Sciences Studies
V	Lecture
Ü	Exercise
S	Seminar
P	Laboratory course

Notes

For the allocation of courses to the examination subjects according to the examination regulations, the announcements of the Dean's Office must also be observed.
Modules that have already been passed in a Bachelor's degree program at TU Dortmund University cannot be selected again.

Compulsory elective lectures in Inorganic Chemistry

Module name		Compulsory elective lecture **Organometallic Chemistry and Reaction Mechanisms**		
Abbreviation		MWV		
Interval of offer annual	**Duration** 1 semester	**Semester of study** B. Sc. 5 or 6 M. Sc. 1 to 4	**Credits** 4	**Curriculum assignment** B. Sc. Chemie B. Sc. Chemische Biologie M. Sc. Chemistry Subject: AC Major subject: M. M. M. Sc. Chemical Biology Subject: SoC

Module structure

No.	Course	Type	CP	SWS	Presence time	Self-study
1	Organometallic Chemistry and Reaction Mechanisms	V	3	2	30 h	60 h
2	Exercises for Organometallic Chemistry and Reaction Mechanisms	Ü	1	1	15 h	15 h
	Total		**4**	**3**	**45 h**	**75 h**

Person responsible for the module	Prof. Dr. Andreas Steffen
Lecturer(s)	Prof. Dr. Andreas Steffen and co-workers
Language	English
Requirements according to examination regulations	None
Recommended requirements	Basic knowledge in inorganic and coordination chemistry, as well as in organic and physical chemistry as taught in the regular modules of the B. Sc. Study curriculum.
Coursework / module examination / partial assessments	Oral examination, repeatability and rotation according to examination regulations.
Learning objectives	Students acquire basic knowledge of the reaction mechanisms of transition metal organic compounds as well as their application in stoichiometric and homogeneous catalytic synthesis planning.
Learning outcomes and competencies	Upon successful completion of the module, students will be able to

	– explain the basic principles on the electronic and steric properties of important ligand classes, reaction mechanisms of coordinated ligands and important metal-mediated reaction mechanisms. – analyze and predict stoichiometric organometallic reactions and homogeneous catalytic reaction cycles considering kinetic and thermodynamic aspects and use them for own synthesis planning. – plan the synthesis of organometallic and organic products using transition metal complexes as stoichiometric reagents or as homogeneous catalysts, making use of specific steric and electronic control through appropriate selection of the ligands and metal centres. – analyze the kinetic and thermodynamic aspects of the targeted transformations and apply them for successful process control, e.g. in basic research as well as industrial (technical) chemistry.
Content	1. Review of important aspects of coordination chemistry. 2. Bonding modes and strengths as well as reactions of important dative and covalent ligands (CO, phosphanes, H_2, sigma complexes, hydrides, alkyls, pi-ligands, carbenes) 3. Reaction mechanisms: kinetics and thermodynamics of substitution reactions, oxidative addition/reductive elimination, (alpha/beta/gamma)-eliminations, migratory insertion, sigma-bond metathesis, nucleophilic and electrophilic addition/abstraction to ligands 4. Fundamentals of organometallic catalysis: energetics, kinetics, reaction profiles, transition states, resting states, selectivity, Curtin-Hammett principle 5. Exemplary applications: H_2-/C-H activation, olefin polymerisation, hydrofunctionalisations e.g. hydroformylation, hydrogenation, metathesis, cross-couplings
Media forms	Blackboard, PowerPoint presentations
Literature	1. R. H. Crabtree, „The organometallic chemistry of the transition metals", Wiley VCH, Weinheim, 6th edition, 2014 (ISBN: 978-1118138076) 2. J. F. Hartwig, "Organotransition metal chemistry – From bonding to catalysis", University Science Books, Mill Valley, California, 2010 (ISBN: 978-1891389535)

<table>
<tr><td>Module name</td><td colspan="7">Compulsory elective lecture
Molecular Photophysics and Photochemistry</td></tr>
<tr><td>Abbreviation</td><td colspan="7">MWV</td></tr>
<tr><td>Interval of offer
annual</td><td>Duration
1 semester</td><td colspan="2">Semester of study
B. Sc. 5 or 6
M. Sc. 1 to 4</td><td>Credits
4</td><td colspan="3">Curriculum assignment
B. Sc. Chemie
B. Sc. Chemische Biologie
M. Sc. Chemistry
Subject: AC
Major subject: M. M. and E. T.
M. Sc. Chemical Biology
Subject: SoC</td></tr>
<tr><td colspan="8">Module structure</td></tr>
<tr><td>No.</td><td colspan="2">Course</td><td>Type</td><td>CP</td><td>SWS</td><td>Presence time</td><td>Self-study</td></tr>
<tr><td>1</td><td colspan="2">Molecular Photophysics and Photochemistry</td><td>V</td><td>3</td><td>2</td><td>30 h</td><td>60 h</td></tr>
<tr><td>2</td><td colspan="2">Exercises for Molecular Photophysics and Photochemistry</td><td>Ü</td><td>1</td><td>1</td><td>15 h</td><td>15 h</td></tr>
<tr><td colspan="4">Total</td><td>4</td><td>3</td><td>45 h</td><td>75 h</td></tr>
<tr><td>Person responsible for the module</td><td colspan="7">Prof. Dr. Andreas Steffen</td></tr>
<tr><td>Lecturer(s)</td><td colspan="7">Prof. Dr. Andreas Steffen and co-workers</td></tr>
<tr><td>Language</td><td colspan="7">English</td></tr>
<tr><td>Requirements according to examination regulations</td><td colspan="7">None</td></tr>
<tr><td>Recommended requirements</td><td colspan="7">Basic knowledge in inorganic and coordination chemistry, as well as in organic and physical chemistry as taught in the regular modules of the B. Sc. Study curriculum.</td></tr>
<tr><td>Coursework / module examination / partial assessments</td><td colspan="7">Oral examination, repeatability and rotation according to examination regulations.</td></tr>
<tr><td>Learning objectives</td><td colspan="7">Students acquire basic knowledge of the interaction of light and matter and its application in the design of molecular emitters for OLEDs, for imaging or in the field of photochemical reactions based on energy or electron transfer. After completing the module, they can apply their knowledge to develop new ideas in the field.</td></tr>
<tr><td>Learning outcomes and competencies</td><td colspan="7">Upon successful completion of the module, students will be able to</td></tr>
</table>

	– explain the nature and properties of electronically excited states, basic device processes, photophysical processes in molecules, energy and electron transfers as well as basic spectroscopic methods, analyse them and use them for emitter design or photochemical synthesis planning. – analyse excited states of organic and organometallic compounds and use them for the targeted modification of luminescence properties. – select suitable emitter candidates for technical applications. – successfully carry out the synthesis planning of organic products using electron or energy transfer reactions, primarily initiated by transition metal complexes. – analyse kinetic and thermodynamic aspects of the targeted transformations and successfully apply them to process control, e.g. in basic research as well as industrial (technical) chemistry.
Content	1. Review of important aspects of physical chemistry and spectroscopy 2. Nature and properties of electronically excited states 3. Nature of light 4. Energy potential surfaces 5. Light absorption, Lambert-Beer law, selection rules 6. Franck-Condon principle 7. Intersystem crossing, spin-orbit coupling (El-Sayed) 8. Fluorescence, phosphorescence, TADF, circularly polarised luminescence 9. Radiationless deactivation, energy gap law 10. Energy transfer, electron transfer, Marcus-Hush theory, conical intersections, photoredox processes 11. Structure and function of LEDs and solar cells 12. Excitons, plasmon resonance 13. Triplet-triplet annihilation, singlet emission 14. Photocatalysis 15. Photodynamic therapy
Media forms	Blackboard, PowerPoint presentations
Literature	– N.J. Turro, V. Ramamurthy, J.C. Scaiano, “Modern Molecular Photochemistry of Organic Molecules”, University Science Books, U.S., 2010 (ISBN: 978-1891389252) – or other editions. – J.-P. Launay, M. Verdaguer, “Electrons in Molecules: From Basic Principles to Molecular Electronics”, Oxford University Press, 2014 (ISBN: 978-0199297788) – J.R. Lakowicz, “Principles of fluorescence spectroscopy”, Springer, 5th Edition, 2010 (ISBN: 978-0387312781) – P.W. Atkins, “Physical Chemistry“, Wiley-VCH, Weinheim, 5th Edition, 2013 (ISBN: 978-3-527-33247-2) – or other editions.

	– Selected current literature (announcement during lecture course)

Module name	Compulsory elective lecture **Nichtmetallchemie (Non-Metal Chemistry)**
Abbreviation	MWV

Interval of offer annual	**Duration** 1 semester	**Semester of study** B. Sc. 5 or 6 M. Sc. 1 to 4	**Credits** 4	**Curriculum assignment** B. Sc. Chemie B. Sc. Chemische Biologie M. Sc. Chemistry Subject: AC Major subject: M. M. M. Sc. Chemical Biology Subject: SoC

Module structure

No.	**Course**	**Type**	**CP**	**SWS**	**Presence time**	**Selfstudy**
1	Nichtmetallchemie	V	3	2	30	60
2	Übung zu Nichtmetallchemie	Ü	1	1	15	15
		Total	**4**	**3**	**45**	**75**

Person responsible for the module	Prof. Dr. C. Strohmann
Lecturer(s)	Prof. Dr. C. Strohmann
Language	German
Requirements according to examination regulations	None
Recommended requirements	Solide Kenntnisse der Anorganischen und Organischen Chemie
Coursework / module examination / partial assessments	Teilleistung Prüfung (Partial assessment: Exam): Klausur oder mündliche Prüfung (2 CP), Teilleistung Vortrag (Partial assessment: Presentation): benoteter Vortrag (2 CP), Wiederholungsmöglichkeiten und Turnus gemäß PO.
Learning objectives	Die Studierenden erlernen moderne Aspekte der Nichtmetallchemie unter Hinzuziehung aktueller Forschungsergebnisse. Nach Abschluss des Modules können sie verstehen elementübergreifende Prinzipien der Nichtmetallchemie, verstehen und auf die Lösung von für sie neue Aufgabenstellungen aus der Chemie der Nichtmetalle übertragen.
Learning outcomes and competencies	Durch die erfolgreiche Beendigung dieses Moduls sind die Studierenden in der Lage,

	– grundlegende Entwicklungen („Meilensteine“) auf dem Gebiet der Nichtmetallchemie im gesamt-historischen Kontext der Chemiegeschichte einordnen zu können und neuerliche Entwicklungen auf diesem Gebiet unter Zuhilfenahme dieses Hintergrundwissens bezüglich ihrer Wichtigkeit differenziert zu würdigen. – Vorkommen, Gewinnung von Nichtmetallen und deren wichtigsten Verbindungen zu erläutern sowie Beispiele für die Anwendungen von Nichtmetallen und deren Verbindungen in Naturwissenschaft und Technik geben zu können. – Kenntnis der Modellvorstellungen und grundlegender Konzepte (Bindungskonzepte, Reaktionsmechanismen) der Nichtmetallchemie einzusetzen, um diese gegeneinander abzuwägen und zu reflektieren. – Stoffeigenschaften von Nichtmetallverbindungen bezüglich ihrer Reaktivität und Struktur zu erklären, einzuschätzen und Vorhersagen für neue Verbindungen auf Grundlage ihres Wissens über Konzepte und periodische Trends im PSE zu machen. – auf Basis ihres Wissens zur Synthese von Nichtmetallverbindungen und zu Stoffeigenschaften speziellen Arbeitstechniken für die Darstellung von Verbindungen vorzuschlagen, zu begründen und umzusetzen – analytische Methoden für die Untersuchung von Nichtmetallen und deren Verbindungen, für neue Problemlösungen auszuarbeiten, einzusetzen und die Ergebnisse zu interpretieren. – spezielle Aspekte der Nichtmetallchemie selbstständig zu erarbeiten und die Ergebnisse den Kommilitonen/innen in einem Vortrag anschaulich zu vermitteln. – sich selbstorganisiert spezielle Aspekte der Nichtmetallchemie aus Originalliteratur (Fachartikel in englischer Sprache) anzueignen und die Kenntnisse zur Lösung für neue Problemstellungen einzusetzen. – selbständig erarbeitetes Wissen in einem Vortrag mittels moderner Präsentationstechniken anschaulich und gut verständlich aufzubereiten und wiederzugeben.
Content	**Vorlesung** 1. Trends der Nichtmetalle im PSE 2. Konzepte zur Beschreibung und Analyse der Bindung und Struktur von Nichtmetallverbindungen (u. a. VSEPR-Modell, VB-Theorie, MO-Theorie, „Computational Chemistry“). 3. Spezielle Arbeitstechniken im Bereich der Nichtmetallchemie (u. a. Matrixisolationstechnik) 4. Besprechung der Chemie ausgewählter Elemente und deren Verbindungen aus dem Bereich der Nichtmetalle. 5. Besprechung ausgewählter Thematiken aus der Nichtmetallchemie (u.a. Hypervalenz, Ozonproblematik, Sauerstoff und Stickstoff in Organismen und Pflanzen, toxische Phosphor-Verbindungen)

	Übung Vorträge der Studierenden zu Themengebieten aus der Vorlesung.
Media forms	Tafel, PowerPoint-Präsentationen, Originalpublikationen
Literature	**R. Steudel**: *Chemie der Nichtmetalle. Von Struktur und Bindung zu Anwendung*, W. de Gruyter, 3. Aufl. 2008, 520 Seiten. **J. E. Huheey**: *Anorganische Chemie. Prinzipien von Struktur und Reaktivität*, W. de Gruyter, 4. Aufl. 2012, 1284 Seiten. **C. E. Housecroft, A. G. Sharpe**: *Anorganische Chemie (Gebundene Ausgabe)*, Pearson, 2. Aufl. 2008, 1040 Seiten. **C. E. Housecroft, A. G. Sharpe**: *Inorganic Chemistry (Broschiert)*, Pearson, 4. Aufl. 2012, 1256 Seiten. **C. Elschenbroich:** *Organometallchemie,* Teubner Studienbücher Chemie, 6. Aufl. 2008. Originalpublikationen zu o. g. Themengebieten.

Module name	Compulsory elective lecture **Silicon Chemistry**			
Abbreviation	MWV			
Interval of offer annual	**Duration** 1 semester	**Semester of study** 1 to 4	**Credits** 4	**Curriculum assignment** M. Sc. Chemistry Subject: AC Major subject: M. M. M. Sc. Chemical Biology Subject: SoC

Module structure

No.	**Course**	**Type**	**CP**	**SWS**	**Presence time**	**Self-study**
1	Silicon Chemistry	V	3	2	30	60
2	Exercise for Silicon Chemistry	Ü	1	1	15	15
		Total	**4**	**3**	**45**	**75**

Person responsible for the module	Prof. Dr. Carsten Strohmann
Lecturer(s)	Prof. Dr. Carsten Strohmann
Language	English
Requirements according to examination regulations	None
Recommended require-ments	Solid knowledge of inorganic and organic chemistry.
Coursework / module ex-amination / partial assess-ments	Module examination: oral exam, repeat options and rotation according to examination regula-tions.
Learning objectives	The students learn modern aspects of silicon chemistry with the help of current research results to understand cross-ele-mental principles. After completion of the module, they will be able to transfer their knowledge to the solution of tasks and new ideas in the field of silicon chemistry.
Learning outcomes and competencies	By successfully completing this module, students will be able to – put basic developments ("milestones") in the field of sili-con chemistry in the historical context of chemistry and to understand recent developments in this field with the help of this background knowledge with regard to their importance.

	– explain the occurrence and extraction of silicon and its most important compounds, and give examples of the applications of silicon and its compounds in science and technology. – use knowledge of model and basic concepts (bonding concepts, reaction mechanisms) of silicon chemistry in order to weigh them up against each other and reflect on them. – explain material properties of silicon compounds with respect to their reactivity and structure, assess and make predictions for new compounds based on their knowledge of concepts and periodic trends in the periodic table. – propose, justify and use special working techniques for the synthesis of silicon compounds on the basis of their knowledge, propose their material properties, and interpret analytical results. – work out special aspects of silicon chemistry independently, and communicate the results clearly to fellow students in a talk. – acquire special aspects of silicon chemistry from original literature in a self-organized way, and use the knowledge to solve new problems.
Content	**Lecture** 1. Synthesis of silicon compounds. 2. Concepts for the description and analysis of silicon-specific effects. *α*- and *β*-effect hybridization effect bond polarity 3. Reaction mechanisms of reactions at the silicon center 4. High and low coordination numbers at the silicon center hypervalency multiple bonds 5. Discussion of selected topics from the silicon chemistry silylenes silenes silanols silicones silyl anions and cations silyl radicals structural protection polymers rings silapharmaceuticals protective groups ^{29}Si NMR stereochemistry **Exercise** Talks by students on selected topics from the lecture.
Media forms	Blackboard, PowerPoint presentations, original publications

Literature	**J. E. Huheey**: *Inorganic Chemistry: Prinzipals of Structure and Reaktivity*, W. de Gruyter, 4th edit. 2012, 1284 pages. **C. Elschenbroich:** *Organometallics,* Wiley-VCH, Weinheim, 3rd edit. 2016. Original publications on above topics.

<table>
<tr><td colspan="2">Module name</td><td colspan="5">Compulsory elective lecture
Bioanorganische Chemie (Bioinorganic Chemistry)</td></tr>
<tr><td colspan="2">Abbreviation</td><td colspan="5">MWV</td></tr>
<tr><td>Interval of offer
annual</td><td>Duration
1 semester</td><td>Semester of study
B. Sc. 6
M. Sc. 1 to 4</td><td>Credits
4</td><td colspan="3">Curriculum assignment
B. Sc. Chemie
M. Sc. Chemistry
Subject: AC
Major subject: M. M.
M. Sc. Chemical Biology
Subject: CB / BioAC</td></tr>
</table>

Module structure

No.	Course	Type	CP	SWS	Presence time	Self-study
1	Bioanorganische Chemie	V	3	2	30	60
2	Übung zu Bioanorganische Chemie	Ü	1	1	15	15
		Total	**4**	**3**	**45**	**75**

Person responsible for the module	Prof. Dr. Guido Clever
Lecturer(s)	Prof. Dr. Guido Clever und Mitarbeitende
Language	German
Requirements according to examination regulations	None
Recommended requirements	Solide Grundlagen der anorganischen Chemie und der Koordinationschemie sowie Grundkenntnisse in Biochemie
Coursework / module examination / partial assessments	Modulprüfung: Klausur, Wiederholungsmöglichkeiten und Turnus gemäß PO.
Learning objectives	Die Studierenden erwerben grundlegende Kenntnisse der Rolle von Metallen in biologisch relevanten Prozessen und medizinischen Applikationen sowie die sichere Anwendung dieser Kenntnisse bei der Lösung von Aufgabenstellungen aus dem Grenzgebiet von Anorganischer Chemie und Biochemie.
Learning outcomes and competencies	Durch die erfolgreiche Beendigung des Moduls sind die Studierenden in der Lage,

	– die Bedeutung und Funktion von Metallen in biologisch relevanten Prozessen zu erklären und diese aus dem anorganisch-chemischen Blickwinkel zu bewerten. – die Funktion von Metallen in biologischen Prozessen im Hinblick auf mechanistische Aspekte beschreiben zu können. – die erworbenen Grundkenntnisse medizinischen/biologisch-diagnostischen Anwendung anorganischer Verbindungen sicher anzuwenden und nachvollziehbar schriftlich dokumentieren zu können. – das vermittelte theoretische Wissen für den Entwurf von Lösungsstrategien zur Bearbeitung praktischer Problemstellungen selbstständig zu nutzen.
Content	1. Essentielle Elemente 2. Biomoleküle als Liganden von Metallionen 3. Metalloproteine (Transport, Regulierung, Lagerung von Metallionen) 4. Elektronentransferproteine 5. Sauerstofftransport und Sauerstoffaktivierung 6. Stickstoff-Aktivierung 7. Hydrolasen 8. Toxizität von Metallen 9. medizinische und diagnostische Anwendungen 10. Bio-Nanotechnologie
Media forms	Tafel, Powerpointpräsentation
Literature	1. W. Kaim, B. Schwederski „Bioanorganische Chemie“, Vieweg + Teubner: Stuttgart (5. Auflage 2012, ISBN: 9783834806345) 2. H.-B. Kraatz, N. Metzler-Nolte „Concepts and Models in Bioinorganic Chemistry“, Wiley-VCH: Weinheim (1. Auflage 2006, ISBN: 9783527313051)

Module name	Compulsory elective lecture **Supramolecular Coordination Chemistry**
Abbreviation	MWV

Interval of offer	**Duration**	**Semester of study**	**Credits**	**Curriculum assignment**
annual	1 semester	1 to 4	4	M. Sc. Chemistry Subject: AC Major subject: M. M. M. Sc. Chemical Biology Subject: CB / BioAC

Module structure

No.	**Course**	**Type**	**CP**	**SWS**	**Presence time**	**Self-study**
1	Supramolecular Coordination Chemistry	V	3	2	30 h	60 h
2	Exercise for Supramolecular Coordination Chemistry	Ü/S	1	1	15 h	15 h
		Total	4	3	45 h	75 h

Person responsible for the module	Prof. Dr. Guido Clever
Lecturer(s)	Prof. Dr. Guido Clever and coworkers
Language	English
Requirements according to examination regulations	None
Recommended requirements	Successful participation in MACa, MOCa
Coursework / module examination / partial assessments	Written or oral exam as determined by the examiner, repeatability and rotation according to PO
Learning objectives	Students acquire knowledge of supramolecular chemistry, with a focus on coordination compounds and bio-inspired or bio-derived systems, non-covalent interactions, self-assembly, host-guest chemistry, molecular switches and machines, supramolecular catalysis, as well as physical-organic fundamentals and analytical methods.
Learning outcomes and competencies	By successfully completing the module, students will be able to, – explain basic terms and concepts of supramolecular chemistry, physical-organic chemistry, intermolecular interactions and their characterization and quantification.

	– use the knowledge of these concepts for the analysis of supramolecular structures and understand the design concepts underlying the synthesis and application – use the acquired theoretical knowledge to design simple supramolecular systems and to select the appropriate analytical methods for the characterization of these systems – and evaluate the results of the analyses – understand key concepts from the disciplines of chemistry, as well as biology and physics and to use them for the solution of interdisciplinary problem – discuss and develop of solution strategies and communicate one's own point of view appropriately and cooperatively.
Content	1. General aspects of supramolecular chemistry, inspiration from nature 2. Non-covalent interactions, types and strengths 3. Physical examination methods 4. Self-assembly and host-guest chemistry 5. Bioorganic, biological and bioinspired systems 6. Selection of supramolecular materials and interfaces 7. Topology of mechanically linked architectures, catenanes and rotaxanes 8. Molecular switches and machines 9. Supramolecular catalysis
Media forms	Blackboard, PowerPoint presentation, molecular models, 3D prints
Literature	J. W. Steed, J. L. Atwood, Supramolecular Chemistry, 3rd edition, Wiley, 2022. ISBN: 978-1-119-58251-9 "Modern Supramolekular Chemistry", F. Diederich, P. J.Stang, R. R. Tykwinski (Eds.), Wiley-VCH, Weinheim 2008, ISBN: 978-3-527-31826-1. “Supramolecular Chemistry", P. D. Beer, P. A. Gale, D. K. Smith, Oxford University Press, Oxford, 1999. H.-J. Schneider, A. Yatsimirsky, Principles and Methods in Supramolecular Chemistry, John Wiley & Sons Ltd. 2000. J.M. Lehn Supramolecular Chemistry, VCH, 1995

Module name		Compulsory elective lecture **f-Elements**		
Abbreviation		MWV		
Interval of offer annual	**Duration** 1 semester	**Semester of study** B. Sc. 5 or 6 M. Sc. 1 to 4	**Credits** 4	**Curriculum assignment** B. Sc. Chemie B. Sc. Chemische Biologie M. Sc. Chemistry Subject: AC Major Subject: M. M. M. Sc. Chemical Biology Subject: SoC

Module structure

No.	**Course**	**Type**	**CP**	**SWS**	**Presence time**	**Self-study**
1	f-Elements	V	3	2	30 h	60 h
2	Exercise for f-Elements	Ü	1	1	15 h	15 h
	Total		4	3	45 h	75 h

Person responsible for the module	Dr. Elisabeth Kreidt
Lecturer(s)	Dr. Elisabeth Kreidt
Language	English
Requirements according to examination regulations	None
Recommended requirements	Fundamental knowledge in inorganic chemistry and coordination chemistry, knowledge of most important concepts of organic and physical chemistry.
Coursework / module examination / partial assessments	Module examination: Written or oral exam. Repeatability and interval of offer according to examination regulations. The type of examination will be announced two weeks after start of the course at the latest.
Learning objectives	The students acquire knowledge of the special chemical and physical properties of lanthanoids and actinoids. After successful completion, the students will be able to explain and predict these properties based in the electronic structure of the f-elements and will be able to comprehend, analyze and apply the strategies applied in current research on f-element coordination compounds.

Learning outcomes and competencies	By successfully completing this module, students will be able to – explain and discuss the special properties of f-elements in contrast to transition metals – make informed predictions concerning the properties of an f-element coordination compound based on a structural formula and to develop design suggestions for the realization of coordination compounds with desired properties. – plan the characterization of f-element coordination compounds – explain the fundamental working principles of bioimaging techniques such as MRI and PET and to explain the importance of f-elements for these techniques – explain the basic principles of more complex phenomena such as upconversion and circularly polarized luminescence – comprehend the general aims in modern research on f-elements.
Content	1. History of the f-elements, sourcing 2. Electronic structure of the f-elements (properties of f-electrons, Russel-Saunders-coupling, energetic relation between spin-orbit coupling and ligand field effects, differences between lanthanoids and actinoids) 3. Coordination chemistry (preferred coordination numbers and ligand arrangements, kinetic lability, established coordination scaffolds, dynamic behavior in solution) 4. Photophysical properties (f-f-transitions, antenna effect, peculiarities of emission spectra, luminescence lifetimes, non-radiative deactivation processes) 5. Magnetic properties (magnetic moments and anisotropies, peculiarities in NMR spectra (paramagnetic NMR), differences to transition metals 6. Radioactivity (types of ionizing radiation, decay chains, implications for the practical work with radioactive elements) 7. Application in (bio-)medicine (MRI, PET, (time-gated) bioimaging, multiplexing, theranostics, NIR-radiation, special requirements to be considered in ligand design) 8. Research towards the realization of single molecule magnets (SMMs) 9. More complex photophysical phenomena such as upconversion and circularly polarized luminescence
Media forms	Blackboard, PowerPoint presentations, original publications.
Literature	*The Rare Earth Elements: Fundamentals and Applications*, Editor: D. A. Atwood, John Wiley & Sons, 2013. Particularly chapters: “The Electronic structure of the Lanthanides” (A. de Bettencourt-Dias), “Lanthanides: Coordination Chemistry” (S. A. Cotton and J. M. Harrowfield), “Lanthanides: “Comparison to 3d Metals”” (S. A. Cotton), “Luminescence” (J. Andres und A.-S. Chauvin) and “Magnetism” (B.-W. Wang und S. Gao). *Lanthanide and Actinide Chemistry*, Editor: S. Cotton, John Wiley & Sons, 2006. Particularly chapters: “The Lanthanides -

	Principles and Energetics", "Coordination Chemistry of the Lanthanides", "Electronic and Magnetic Properties of the Lanthanides", "Introduction to the Actinides" and "Coordination Chemistry of the Actinides".

Module name	Compulsory elective lecture **Functional Coordination Networks**
Abbreviation	MWV

Interval of offer annual	**Duration** 1 semester	**Semester of study** B. Sc. 5 or 6 M. Sc. 1 to 4	**Credits** 4	**Curriculum assignment** B. Sc. Chemie B. Sc. Chemische Biologie M. Sc. Chemistry Subject: AC Major subject: M. M. and E. T. M. Sc. Chemical Biology Subject: SoC

Module structure

No.	**Course**	**Type**	**CP**	**SWS**	**Presence time**	**Selfstudy**
1	Functional Coordination Networks	V	3	2	30 h	60 h
2	Exercise on Functional Coordination Networks	Ü	1	1	15 h	15 h
		Total	4	3	45 h	75 h

Person responsible for the module	Prof. Dr Sebastian Henke
Lecturer(s)	Prof. Dr. Sebastian Henke and coworkers
Language	English
Requirements according to examination regulations	None
Recommended require-ments	Basic knowledge of inorganic, organic and physical chemis-try
Coursework / module ex-amination / partial assess-ments	Partial assessment: Presentation (1 CP). Scientific talk with discussion. Partial assessment: Exam (3 CP). Written or oral examina-tion. Possibilities of repetition and rotation according to PO. The type of examination will be announced by notice at the latest two weeks after the start of the course.
Learning objectives	The students expand their knowledge in the field of solid state and materials chemistry with regard to structural princi-ples, structure-property concepts, functionalisation and rele-vant analytical methods for the characterisation of porous in-organic-organic solid state materials. The special focus is on

	coordination networks and coordination polymers. The students can apply their knowledge and use it to develop new ideas.
Learning outcomes and competencies	Upon successful completion of the module, students will be able to, – explain basic and advanced principles on the material class of coordination networks. – explain the laws of solid state and materials chemistry with regard to structural principles, structure-property concepts and functionalisation and apply them independently to new problems. – use acquired knowledge of analytical methods for the characterisation of porous solid-state materials to critically evaluate experimental data and design their own experiments. – link the theoretical knowledge gained in the module on network topology, functionalisation, porosity, host-guest interaction, phase transformations, characterisation methods with other chemical, physical and material science concepts and use it to solve new scientific questions in an interdisciplinary way.
Content	1. Coordination chemistry (transition and main group metals and lanthanoids) 2. Topological description of network structures 3. Coordination networks and polymers 4. Gas adsorption and specific surface area 5. Flexibility, dynamics and phase transformations 6. Structure-property principles 7. Principles of gas storage and separation 8. Morphology and microstructure 9. Physical charactarization methods 10. Reticular synthesis 11. Host-Guest-Chemistry
Media forms	Powerpoint presentations, electronic scripts/publications, blackboard pictures
Literature	*Solid State Chemistry: An Introduction,* L. E. Smart, E. A. Moore, CRC Press, 2012, ISBN: 9781439847909. *Anorganische Strukturchemie*, U. Müller, Vieweg+Teubner Verlag, 2004, ISBN: 978-3-322-99855-2 *The Chemistry of Metal-Organic Frameworks*, S. Kaskel, Wiley-VCH, 2016, ISBN: 978-3-527-33874-0. "Hybrid porous solids: past, present, future", G. Férey, *Chem. Soc. Rev.* **2008**, *37*, 191-214. "Soft porous crystals", S. Horike, S. Shimomura, S. Kitagawa, *Nat. Chem.* **2009,** *1*, 695-704. "The chemistry and applications of metal-organic frameworks", H. Furukawa, K. E. Cordova, M. O'Keeffe, O. M. Yaghi, *Science* **2013,** *341*, 1230444.

Module name	Compulsory elective lecture **Introduction to Materials Chemistry**
Abbreviation	MWV

Interval of offer annual	**Duration** 1 semester	**Semester of study** B. Sc. 5 or 6 M. Sc.1 to 4	**Credits** 4	**Curriculum assignment** B.Sc. Chemie B.Sc. Chemische Biologie M.Sc. Chemistry Subject: AC Major subject: M. M. M.Sc. Chemical Biology Subject: SoC

Module structure

No.	**Course**	**Type**	**CP**	**SWS**	**Presence time**	**Selfstudy**
1	Introduction to Materials Chemistry	V	3	2	30 h	60 h
2	Exercise for Introduction to Materials Chemistry	Ü	1	1	15 h	15 h
		Total	4	3	45 h	75 h

Person responsible for the module	Prof. Dr. Sebastian Henke
Lecturer(s)	Prof. Dr. Sebastian Henke and coworkers
Language	English
Requirements according to examination regulations	None
Recommended require-ments	Basic knowledge of inorganic, organic and physical chemis-try
Coursework / module ex-amination / partial assess-ments	Partial assessment: Student talk (1 CP). Scientific talk with discussion. Partial assessment: Examination (3 CP). Written or oral ex-amination. Repeatability and interval of offer according to examination regulations. The type of examination will be announced two weeks after start of the course at the latest.
Learning objectives	The students expand their knowledge in the field of solid state and materials chemistry with regard to fundamental structural principles, structure-property concepts, and rele-vant analytical techniques for the characterization of inor-ganic and inorganic-organic solid-state materials. The focus

	is on ionics, semiconductors, metals, zeolites and nano-materials. The students can apply their knowledge and use it to develop new ideas.
Learning outcomes and competences	Upon successful completion of this module, students will be able to, – explain basic and advanced principles of solid state chemistry. – explain the laws of solid state and materials chemistry with regard to structural principles, structure-property concepts and apply them independently to new problems. – use acquired knowledge of analytical methods for the characterization of solid-state materials to critically evaluate experimental data and design their own experiments. – link the theoretical knowledge gained in the module on band structure theory, magnetism, doping, defects, phase transformations, characterization methods with other chemical, physical and material science concepts and use it to solve new scientific questions in an interdisciplinary way.
Content	1. Crystal structures of important inorganic solids 2. Ionic compounds 3. Metals 4. Semiconductors 5. The band structure model 6. p-n-Junction 7. Doping and defects 8. Magnetism 9. Dielectric properties 10. Structure-property principles 11. Characterization techniques in solid state chemistry 12. Nanomaterials, particle size effects 13. Morphology and microstructure
Media forms	Powerpoint presentations, electronic scripts/publications, blackboard pictures
Literature	*Solid State Materials Chemistry*, P. M. Woodward, P. Karen, J. S. O. Evans, T. Vogt, Cambridge University Press, 2021, DOI: 10.1017/9781139025348 *Solid State Chemistry and its Applications*, A. R. West, Wiley, 2014, ISBN: 978-1-119-94294-8 *Solid State Chemistry: An Introduction,* L. E. Smart, E. A. Moore, CRC Press, 2012, ISBN: 9781439847909. *Anorganische Strukturchemie*, U. Müller, Vieweg+Teubner Verlag, 2004, ISBN: 978-3-322-99855-2

Compulsory elective lectures in Organic Chemistry

Module name	Compulsory elective lecture **Pericyclische Reaktionen (Pericyclic Reactions)**			
Abbreviation	MWV			
Interval of offer annual	**Duration** 1 semester	**Semester of study** B. Sc. 5 or 6 M. Sc. 1 to 4	**Credits** 4	**Curriculum assignment** B. Sc. Chemie M. Sc. Chemistry Subject: OC Major subject: M. M.

Module structure

No.	**Course**	**Type**	**CP**	**SWS**	**Presence time**	**Self-study**
1	Pericyclische Reaktionen	V	3	2	30 h	60 h
2	Übungen zu Pericyclische Reaktionen	Ü	1	1	15 h	15 h
		Total	**4**	**3**	**45 h**	**75 h**

Person responsible for the module	Prof. Dr. N. Krause
Lecturer(s)	Prof. Dr. N. Krause
Language	German
Requirements according to examination regulations	None
Recommended require-ments	Erfolgreicher Abschluss der Module MOCa, MOCb und MOC1P
Coursework / module ex-amination / partial assess-ments	Modulprüfung: Mündliche Prüfung oder Klausur, Wiederho-lungsmöglichkeiten und Turnus gemäß PO.
Learning objectives	Die Studierenden erwerben Kenntnisse von grundlegenden Typen pericyclischer Reaktionen. Insbesondere können sie die erlernten Konzepte auf Reaktivitäts- und Selektivitäts-probleme selbstständig anwenden.
Learning outcomes and competencies	Nach der erfolgreichen Beendigung dieses Moduls sind die Studierenden in der Lage, – Grundlagen der Molekülorbital- und Störungstheorie so-wie der Anwendung der Klopman-Salem-Gleichung auf ionische Reaktionen zu erklären. – grundlegenden Typen pericyclischer Reaktionen (Sig-matrope Umlagerungen, Elektrocyclische Reaktionen, Cycloadditionen) zu erläutern.

	– das erworbene Wissen zur Vorhersage des Ergebnisses und des mechanistischen Verlaufs pericyclischer Reaktionen zu nutzen und eigene Synthesen zu planen. – Synthesekonzepte logisch zu analysieren. – bei der Erarbeitung von Lösungsstrategien zu diskutieren, den eigenen Standpunkt angemessen zu vermitteln und mit anderen zusammenzuarbeiten.
Content	1. Einführung: Grundlegende Fragestellungen 2. Molekülorbitale und Grenzorbitale 3. Störungstheorie 4. Die Klopman-Salem-Gleichung 5. Ionische Reaktionen 6. HSAB-Prinzip 7. Sigmatrope Umlagerungen - [1,n]-Wasserstoffverschiebungen - Cope- und Claisen-Umlagerung 8. Elektrocyclische Reaktionen 9. [2+2]-Cycloadditionen 10. [4+2]-Cycloadditionen
Media forms	Tafel und/oder Powerpoint-Präsentation
Literature	I. Fleming, Grenzorbitale und Reaktionen Organischer Verbindungen

Module name	Compulsory elective lecture **Klassische und neuere Synthesemethoden (Classical and New Synthetic Methods)**
Abbreviation	MWV

Interval of offer	**Duration**	**Semester of study**	**Credits**	**Curriculum assignment**
annual	1 semester	B. Sc. 5 or 6 M. Sc. 1 to 4	4	B. Sc. Chemie B. Sc. Chemische Biologie M. Sc. Chemistry Subject: OC Major subject: M. M. M. Sc. Chemical Biology Subject: SoC

Module structure

No.	**Course**	**Type**	**CP**	**SWS**	**Presence time**	**Self-study**
1	Klassische und neuere Synthesemethoden	V	3	2	30 h	60 h
2	Übungen zu Klassische und neuere Synthesemethoden	Ü	1	1	15 h	15 h
	Total		**4**	**3**	**45 h**	**75 h**

Person responsible for the module	Prof. Dr. N. Krause
Lecturer(s)	Prof. Dr. N. Krause
Language	German
Requirements according to examination regulations	None
Recommended requirements	Erfolgreicher Abschluss der Module MOCa und MOCb, MOC1P, MOCc
Coursework / module examination / partial assessments	Mündliche Prüfung oder Klausur am Ende des Moduls in der vorlesungsfreien Zeit. Wiederholungsklausur in der vorlesungsfreien Zeit.
Learning objectives	Die Studierenden erwerben grundlegende Kenntnisse über leistungsfähige und teilweise weniger bekannte Synthesemethoden und können anschließend das erworbene Wissen bei der Syntheseplanung selbstständig anwenden.
Learning outcomes and competencies	Am erfolgreichem Ende dieses Moduls sind die Studierenden in der Lage,

	- die im Modul vermittelten Synthesemethoden und ihren mechanistischen Verlauf zu erläutern und ihre Ergebnisse vorherzusagen. - erworbenes Wissen über Synthesemethoden für die Planung von Synthesen selbstständig zu nutzen. - bei der Erarbeitung von Lösungsstrategien für synthetische Fragestellungen zu diskutieren, den eigenen Standpunkt angemessen zu vermitteln und mit anderen zusammenzuarbeiten.
Content	1. Grob-Fragmentierung 2. Favorskii-Umlagerung 3. Morita-Baylis-Hillman-Reaktion 4. Stereoselektive Radikalreaktionen 5. Nazarov-Cyclisierung
Media forms	Tafel und/oder PowerPoint-Präsentation
Literature	Originalliteratur (Artikel aus Fachzeitschriften)

Module name	Compulsory elective lecture **Synthesewissenschaft I (Science of Synthesis I)**			
Abbreviation	MWV			
Interval of offer annual	**Duration** 1 semester	**Semester of study** B. Sc. 5 or 6 M. Sc. 1 to 4	**Credits** 4	**Curriculum assignment** B. Sc. Chemie B. Sc. Chemische Biologie M. Sc. Chemistry Subject: OC Major subject: M. M. M. Sc. Chemical Biology Subject: SoC

Module structure

No.	**Course**	**Type**	**CP**	**SWS**	**Presence time**	**Self-study**
1	Synthesewissenschaft I	V	3	2	30 h	60 h
2	Übung zu Synthesewissenschaft I	Ü	1	1	15 h	15 h
		Total	4	3	45 h	75 h

Person responsible for the module	Prof. Dr. M. Hiersemann
Lecturer(s)	Prof. Dr. M. Hiersemann
Language	German
Requirements according to examination regulations	None
Recommended require-ments	Erfolgreicher Abschluss von MOCb
Coursework / module ex-amination / partial assess-ments	Schriftliche Modulprüfung
Learning objectives	Die Studierenden erwerben vertiefte Kenntnisse über Methoden zur selektiven Molekülstrukturmanipulation (Synthesewissenschaft) und können dieses Wissen zur Planung von Synthesen anwenden.
Learning outcomes and competencies	Nach dem erfolgreichen Abschluss des Moduls sind die Studierenden in der Lage,

	– Taktiken und Strategien zur selektiven Molekülstrukturmanipulation zu erörtern und deren Vor- und Nachteile für die Lösung synthesewissenschaftlicher Fragestellungen zu benennen. – Möglichkeiten zur Asymmetrischen Synthese mit und ohne asymmetrische Induktion zu erläutern. – vermitteltes Wissen zur Lösung synthetischer und retrosynthetischer Fragestellungen aus den Forschungsgebieten Naturstoffchemie, Wirkstoffstoffchemie und Materialchemie (Chemie der Materialmoleküle) zu nutzen und Synthesen demgemäß zu planen. – organisch-chemische Sachverhalte, einschließlich stereochemischer Modellvorstellungen, korrekt in Wort und Bild darzustellen.
Content	1. Zyklisierungsreaktionen mit Kohlenstoffradikalen 2. nukleophile Substitution am sp^3-Kohlenstoffatom 3. Übergangsmetall-katalysierte Substitution am Aromaten 4. Synthese von C/C-Mehrfachbindungen durch Kondensationsreaktionen 5. Lithiumorganyle 6. Aldoladditionen unter asymmetrischer Induktion 7. Palladium-katalysierte Bindungsbildung: Suzuki-Kreuzkupplung und allylische Alkylierung 8. Metathese mit Rutheniumcarbenkomplexen 9. Metathese mit Rutheniumcarbenkomplexen 10. Kettenverlängerung, Ringexpansion und Ringkontraktion durch nukleophile [1,2]-Umlagerung 11. Claisen-Umlagerungen 12. intramolekulare Diels-Alder-Reaktion 13. 1,2-Difunktionalisierung von C/C-Mehrfachbindungen 14. Fotochemie (Themen im wöchentlichen Wechsel. Die Anpassung der Vorlesungsinhalte an aktuelle Entwicklungen ist vorbehalten.)
Media forms	Unterricht mit Tafel, digitalisierte Vorlesung, digitalisiertes Vorlesungsskript, digitalisierte Übungsaufgaben
Literature	Literaturempfehlung erfolgt im Rahmen der Lehrveranstaltung

Module name		Compulsory elective lecture **Science of Synthesis II**		
Abbreviation		MWV		
Interval of offer annual	**Duration** 1 semester	**Semester of study** B. Sc. 5 or 6 M. Sc. 1 to 4	**Credits** 4	**Curriculum assignment** B. Sc. Chemie B. Sc. Chemische Biologie M. Sc. Chemistry Subject: OC Major subject: M. M. M. Sc. Chemical Biology Subject: SoC

Module structure

No.	**Course**	**Type**	**CP**	**SWS**	**Presence time**	**Self-study**
1	Science of Synthesis II	V	3	2	30 h	60 h
2	Exercise for Science of Synthesis II	Ü	1	1	15 h	15 h
		Total	4	3	45 h	75 h

Person responsible for the module	Prof. Dr. M. Hiersemann
Lecturer(s)	Prof. Dr. M. Hiersemann
Language	English
Requirements according to examination regulations	None
Recommended require-ments	successful completion of MOCb
Coursework / module ex-amination / partial assess-ments	written module exam
Learning objectives	Undergraduates acquire deeper knowledge of methodologies for molecular structure manipulation (science of synthesis). Undergraduates will be able to apply this knowledge for planning syntheses.
Learning outcomes and competencies	After module completion, undergraduates will be able to – discuss tactics and strategies including their advantages and disadvantages for selective molecular structure manipulation.

	– outline opportunities for asymmetric synthesis with and without asymmetric induction. – utilize imparted knowledge to solve synthetic and retro-synthetic problems from different research areas, such as natural products chemistry, drug chemistry and materials chemistry. – use acquired knowledge for planning syntheses – properly present organic chemistry-based content, including stereochemical models, in a written and pictorial manner.
Content	1. cyclization reactions involving carbon-centered radicals 2. palladium-catalyzed bond formation: intramolecular Heck reaction and cross-coupling reaction of enolates 3. synthesis of three-membered rings: cyclopropanation 4. synthesis of five-membered rings: Pauson–Khand reaction 5. synthesis of five-membered rings: Nazarov cyclization 6. synthesis of five- and six-membered rings: intramolecular aldol condensation 7. synthesis of seven-membered rings: Cope rearrangement 8. synthesis of seven-membered rings: rhodium(I)-catalyzed (5+2) cycloaddition 9. 1,3-dipolar cycloaddition of azomethine ylides 10. 1,3-dipolar cycloaddition of nitrones 11. nucleophilic 1,2-rearrangement to a nitrogen atom 12. allylic oxidation 13. photochemical (2+2) cycloaddition (For organizational reasons or for didactic purposes, content may be subject to change)
Media forms	chalkboard teaching, digitized lecture, digitized lecture notes, digitized problem sets, inverted-classroom format
Literature	literature recommendations will be made within the course

Module name	Compulsory elective lecture **Science of Synthesis III**			
Abbreviation	MWV			
Interval of offer annual	**Duration** 1 semester	**Semester of study** B. Sc. 5 or 6 M. Sc. 1 to 4	**Credits** 4	**Curriculum assignment** B. Sc. Chemie B. Sc. Chemische Biologie M. Sc. Chemistry Subject: OC Major Subject: M. M. M. Sc. Chemical Biology Subject: SoC

Module structure

No.	**Course**	**Type**	**CP**	**SWS**	**Presence time**	**Self-study**
1	Science of Synthesis III	V	3	2	30 h	60 h
2	Exercise for Science of Synthesis III	Ü	1	1	15 h	15 h
	Total		4	3	45 h	75 h

Person responsible for the module	Prof. Dr. M. Hiersemann
Lecturer(s)	Prof. Dr. M. Hiersemann
Language	English
Requirements according to examination regulations	None
Recommended require-ments	successful completion of MOCb
Coursework / module ex-amination / partial assess-ments	written module exam
Learning objectives	Undergraduates acquire deeper knowledge of methodologies for molecular structure manipulation (science of synthesis). Undergraduates will be able to apply this knowledge for planning syntheses.
Learning outcomes and competencies	After module completion, undergraduates will be able to – discuss tactics and strategies including their advantages and disadvantages for selective molecular structure manipulation.

	– outline opportunities for asymmetric synthesis with and without asymmetric induction. – utilize imparted knowledge to solve synthetic and retro-synthetic problems from different research areas, such as natural products chemistry, drug chemistry and materials chemistry. – use acquired knowledge for planning syntheses. – properly present organic chemistry-based content, including stereochemical models, in a written and pictorial manner.
Content	1. cyclization reactions involving carbon-centered radicals 2. tolanes and tolanoids 3. Achmatowicz reaction 4. Fischer indole synthesis 5. Pictet−Spengler reaction, Bischler−Napieralski reaction 6. pinacol and semipinacol rearrangement 7. Knoevenagel condensation, Dieckmann condensation 8. Mannich reaction 9. Nicholas reaction 10. carbon-carbon σ-bond formation via C-H insertion 11. cyclization cascades 12. de Mayo reaction (For organizational reasons or for didactic purposes, content may be subject to change)
Media forms	chalkboard teaching, digitized lecture, digitized lecture notes, digitized problem sets, inverted-classroom format
Literature	literature recommendations will be made within the course

Module name	Compulsory elective lecture **Makromolekulare Chemie I (Macromolecular Chemistry I)**
Abbreviation	MWV

Interval of offer annual	**Duration** 1 semester	**Semester of study** B. Sc. 5 or 6 M. Sc. 1 to 4	**Credits** 4	**Curriculum assignment** B. Sc. Chemie B. Sc. Chemische Biologie M. Sc. Chemistry Subject: OC Major subject: M. M. M. Sc. Chemical Biology Subject: SoC

Module structure

No.	Course	Type	CP	SWS	Presence time	Selfstudy
1	Makromolekulare Chemie I	V	3	2	30	60
2	Übungen zu Makromolekulare Chemie I	Ü	1	1	15	15
	Total		**4**	**3**	**45**	**75**

Person responsible for the module	Prof. Dr. R. Weberskirch
Lecturer(s)	Prof. Dr. R. Weberskirch
Language	German
Requirements according to examination regulations	None
Recommended require-ments	Abschluss der Module MACa und MOCa. Solide Kenntnisse der Anorganischen und Organischen Chemie
Coursework / module ex-amination / partial assess-ments	Modulprüfung: Klausur oder mündliche Prüfung, Wiederho-lungsmöglichkeiten und Turnus gemäß PO.
Learning objectives	Die Studierenden erwerben grundlegende Kenntnisse auf dem Gebiet der Makromolekularen Chemie, insbesondere der Methoden der Synthese und Analyse makromolekularer Verbindungen. Sie können die Bedeutung der Stoffklasse der makromolekularen Verbindungen in Technik, Biologie und Medizin erläutern und das Wissen zur Lösung von Auf-gabenstellungen im Grenzbereich von Chemie, Technik und Biowissenschaften anwenden.
Learning outcomes and competencies	Nach der erfolgreichen Beendigung dieses Moduls sind die Studierende in der Lage,

	– die historische Entwicklung des Fachgebiets der Polymerchemie zu erläutern. – die Einteilung der Polymere nach ihrem Herstellungsmechanismus, den Rohstoffen und den Verarbeitungsmethoden zu beschreiben. – grundlegende Begrifflichkeiten der Polymerchemie sicher zu beherrschen und auf Vertreter dieser Stoffklasse anzuwenden. – detaillierte Synthesemechanismen zu Polymerisationen oder Stufenreaktionen an Beispielen zu erklären. – die wichtigsten analytischen Methoden zur Charakterisierung von Polymeren zu erläutern und geeignete analytische Methoden problemorientiert auswählen zu können. – Zusammenhänge zwischen Polymerstruktur und thermischen bzw. mechanischen Eigenschaften der Polymere zu erkennen das Wissen bei der Vorhersage von Materialeigenschaften zu nutzen. – vermitteltes theoretisches Wissen für den Entwurf von Lösungsstrategien zur Bearbeitung praktischer Problemstellungen selbstständig zu nutzen. – sich neues Wissen durch die Sichtung von Originalliteratur (Fachartikel in englischer Sprache) selbstständig zu erarbeiten.
Content	1. Einführung in die Polymerchemie - Oligomere und Polymere - Nomenklatur - historische Entwicklung - Aufbauprinzipien - Konstitution von Polymerketten - Mikrostruktur und Taktizität - Einteilung der Polymere nach Rohstoffen Herstellungsverfahren, Technologie bzw. mechanischen und thermischen Eigenschaften - Thermodynamik von Polymerisationen 2. Synthesemethoden von Polymeren - Ketten- und Stufenreaktionen (Mechanismus und Kinetik) - Freie radikalische Polymerisation und Copolymerisation - Kontrollierte radikalische Polymerisation (z. B. RAFT, ATRP, NMP) - Anionische und kationische Polymerisation - Ziegler-Natta Polymerisation - Polykondensation und –additionsreaktionen (u.a. Polyester, Polyamide, Polyurethane) - Neue Entwicklungen in der Polymerchemie: Enzymatische Synthesen, - Methoden der Polymersynthese: Lösungspolymerisation, Emulsionspolymerisation, Substanzpolymerisation 3. Methoden zur Charakterisierung von Polymeren - Modellvorstellungen zur Größenabschätzung

	eines Polymerknäuels - Spektroskopie an Polymeren (NMR, IR und UV/vis) - Methoden zur Molmassenbestimmung (GPC, Viskosimetrie, Membranosmose, MALDI-TOF, Endgruppenanalyse, Absolut-, Relativ- und Äquivalentmethoden, u. a.) - Thermische Charakterisierung: thermische Übergänge 1. und 2.Ordnung, Glasübergangstemperatur (T_g) von Polymeren; Teilkristallinität in polymeren Festkörpern und strukturelle Voraussetzungen. - Methoden zur Bestimmung des thermischen Verhaltens (Differential Scanning Calorimetrie (DSC); Thermogravimetrie (TGA)) - Mechanische Untersuchung von Polymeren (Zug Dehnungsdiagramme, Dynamisch-mechanische Thermoanalyse, Verlust- und Speichermodul u. a.)
Media forms	Tafel; Folien; PowerPoint-Präsentation, Arbeitsmaterialien online (Inhalt, ausgewählte Folien, Fragen)
Literature	Vorlesungsfolien und aktuelle Literaturverweise

Module name	Compulsory elective lecture **Macromolecular Chemistry II**
Abbreviation	MWV

Interval of offer annual	**Duration** 1 semester	**Semester of study** 1 to 4	**Credits** 4	**Curriculum assignment** M. Sc. Chemistry Subject: OC Major subject: M. M. and E. T. M. Sc. Chemical Biology Subject: SoC

Module structure

No.	**Course**	**Type**	**CP**	**SWS**	**Presence time**	**Self-study**
1	Macromolecular Chemistry II	V	3	2	30	60
2	Exercise for Macromolecular Chemistry II	Ü	1	1	15	15
		Total	**4**	**3**	**45**	**75**

Person responsible for the module	Prof. Dr. Ralf Weberskirch
Lecturer(s)	Prof. Dr. Ralf Weberskirch and Dr. Thomas Rölle
Language	English
Requirements according to examination regulations	None
Recommended require-ments	Solid knowledge of inorganic and organic chemistry and the module "Macromolecular Chemistry I".
Coursework / module ex-amination / partial assess-ments	Written or oral module examination, repeat options and rota-tion according to examination regulations
Learning objectives	Students acquire basic knowledge of the importance of poly-mers in the chemical industry, in medicine and organic elec-tronics and can apply the knowledge to solve tasks in the boundary of chemistry, technology and life sciences.
Learning outcomes and competencies	Upon completion of the module, students will be able to, – name important applications of polymers in medicine and organic electronics – explain the importance of biocompatibility, as well as bio-degradable polymers and hydrogels for application ex-amples from medical technology – develop synthesis strategies for biocompatible materials

	– develop synthesis strategies for (poly)isocyanates and polyols – convey knowledge about the structure of mono- and multilayer films made of TPU and PC & CoEx – teach the basics of holography and how holographic materials work. – describe structural features of conductive polymers and name important classes of polymers – explain the importance of conductive polymers in the applications of solar cells, LEDs and biosensors – independently use theoretical knowledge for the design of solution strategies to deal with practical and interdisciplinary problems. – independently acquire new knowledge by reviewing original literature (technical articles in English).
Content	**1st Part: Polymers in medicine** 1. Requirements profile of a polymer for use in medicine: - Definition of biocompatibility 2. Implants: - Biocompatibility and function - Requirement profiles (e.g. bone cement, intraocular lenses) 3. Concepts of tissue regeneration: - Design criteria for carrier materials (technical production by means of CAD / 3D printing) - Biodegradable polymers and hydrogels 4. Cardiovascular diseases: - What is the meaning of blood compatibility and how can it be solved? 5. Polymers and polymeric nanoparticles for drug delivery and diagnostic applications **2nd Part: Polymers for holography** - Aliphatic NCO chemistry (production, properties, trends incl. bio-based) - Aromatic NCO chemistry, especially for thermoplastic types, properties, production, trends incl. circular economy - Mono- and multilayer films made of TPU and PC & CoEx (chemistry, properties, production) - Basics of holography - Photopolymers for holographic exposure (state of the art, COV technology, applications) **3rd Part: Polymers in org. electronics** 1. Organic versus inorganic semiconductors

	- electronic band structure - conductive polymers through doping - charge transport 2. Synthesis of semiconducting properties, i.e. polyacety-lene, polythiophenes, polyfluorenes etc. and how they be-come conductive. 3. OLED, PLED - Structure and function of an OLED - Materials used - singlet and triplet emitters, low-molecular and polymer emitte - Manufacturing process (OLED versus PLED) 4. Solar cells - Structure and function of Si-based solar cells - Current limitations and approaches to solutions - Polymer-based solar cells (structure, function, limitations and solutions) - Efficiency of solar cells - Advantages and disadvantages of different technologies
Media forms	Blackboard; slides; PowerPoint presentation, working mate-rials online (content, selected slides, questions).
Literature	Recommendation of literature will be made within the scope of the course

Module name		Compulsory elective lecture **Homogenous Catalysis in Organic Synthesis**		
Abbreviation		MWV		
Interval of offer annual	**Duration** 1 semester	**Semester of study** B. Sc. 5 or 6 M. Sc. 1 to 4	**Credits** 4	**Curriculum assignment** B. Sc. Chemie B. Sc. Chemische Biologie M. Sc. Chemistry Subject: OC Major subject: M. M. M. Sc. Chemical Biology Subject: SoC

Module structure

No.	**Course**	**Type**	**CP**	**SWS**	**Presence time**	**Self-study**
1	Homogenous catalysis in organic synthesis	V	3	2	30 h	60 h
2	Exercises for Homogenous catalysis in organic synthesis	Ü	1	1	15 h	15 h
	Total		4	3	45 h	75 h

Person responsible for the module	Prof. Dr. M. M. Hansmann
Lecturer(s)	Prof. Dr. M. M. Hansmann and co-workers
Language	English
Requirements according to examination regulations	None
Recommended requirements	Solid basic knowledge of organic chemistry (successful completion of modules MOCa and MOCb).
Coursework / module examination / partial assessments	Written or oral examination, repeatability and rotation according to examination regulations.
Learning objectives	The students acquire basic, as well as current knowledge in the field of homogenous catalysis and can apply this acquired knowledge to the planning of complex organic molecules.
Learning outcomes and competencies	After successful completion of the course “Homogenous catalysis in organic synthesis”, students will be able to,

	– explain applications of homogeneous catalysis (with and without transition metal) in preparative organic chemistry, – describe the importance of modern catalytic processes, in terms of new bond disconnections, for the synthesis of complex organic compounds, – logically analyze synthesis planning concepts and plan for yourself, – apply acquired knowledge in the synthesis planning of more complex organic molecules, for example for the synthesis of fine chemicals or natural products, – link classical synthesis concepts with catalytic methods and to develop interdisciplinary solution concepts for synthesis planning, – develop solution strategies, discuss, appropriately communicate one's own point of view, and collaborate with others.
Content	Essential concepts of homogeneous catalysis with (first part of the lecture) and without transition metal catalyst (second part) are introduced. Here, emphasis is placed on the application in organic synthesis planning (deepening in the corresponding exercise group). 1. Palladium catalysis (cross-coupling reactions, allylic substitution also with iridium catalysis, Heck reactions, C-N couplings, Pd-TMM chemistry) 2. Tandem reactions 3. Ruthenium catalysis (metathesis: alkene, alkyne, enyne) 4. C-H activation 5. Gold catalysis 6. Cobalt and copper catalysis (click chemistry) 7. Organocatalysis (enamine, Broensted acid catalysis) 8. Frustrated Lewis pair catalysis 9. Photoredox catalysis 10. Main group catalysis and autocatalysis
Media forms	Blackboard, PowerPoint presentations, Zoom.
Literature	1. L. Kürti, B. Czakó, „Strategic applications of named reactions in organic synthesis”, Elsevier Press 2005 (ISBN: 978-0124297852) 2. L. S. Hegedus, B. C. G. Söderberg, „Transition Metals in the Synthesis of Complex Organic Molecules” University Science Books, 2009 (ISBN: 978-1891389597) 3. Organic Synthesis Workbooks (I/II/III), Wiley-VCH

Module name	Compulsory elective lecture **Heterocyclic Chemistry**
Abbreviation	MWV

Interval of offer annual	**Duration** 1 semester	**Semester of study** B. Sc. 5 or 6 M. Sc. 1 to 4	**Credits** 4	**Curriculum assignment** B. Sc. Chemie B. Sc. Chemische Biologie M. Sc. Chemistry Subject: OC Major subject: M. M. and E. T. M. Sc. Chemical Biology Subject: SoC

Module structure

No.	**Course**	**Type**	**CP**	**SWS**	**Presence time**	**Self-study**
1	Heterocyclic Chemistry	V	3	2	30 h	60 h
2	Exercises for Heterocyclic Chemistry	Ü	1	1	15 h	15 h
	Total		4	3	45 h	75 h

Person responsible for the module	Prof. Dr. M. M. Hansmann
Lecturer(s)	Prof. Dr. M. M. Hansmann and co-workers
Language	English
Requirements according to examination regulations	None
Recommended requirements	Solid basic knowledge of organic chemistry (successful completion of modules MOCa and MOCb).
Coursework / module examination / partial assessments	Written or oral examination, repeatability and rotation according to examination regulations.
Learning objectives	The students acquire basic, as well as current knowledge in the field of synthesis, properties and application of heterocycles. They can apply this acquired knowledge to the planning of syntheses of heterocyclic compounds.
Learning outcomes and competencies	After successful completion of the course "Heterocyclic Chemistry", students will be able to, – explain fundamentals and general concepts of heterocycle chemistry,

	– apply acquired knowledge in synthesis planning and for naming more complex heterocycles, – estimate typical reactivities and properties of heterocyclic compounds and make predictions based on their knowledge, – describe relevance of heterocycles e.g. in pharmaceutical chemistry and chemical biology, – link classical synthesis concepts with catalytic methods and develop solution concepts for synthesis planning, – analyze synthesis concepts logically, – develop solution strategies, discuss, appropriately communicate one's own point of view, and collaborate with others.
Content	Emphasis is placed on the following contents: 1. Essential concepts of synthesis, properties, reactivities and applications of heterocycles. 2. Systematic treatment of heterocycles sorted by ring sizes (three rings, four rings etc. up to macrocyclic rings). The systems are sorted with increasing number of heteroatoms (O, N, S etc.). 3. Systematic nomenclature of heterocycles according to the exchange nomenclature and the Hantzsch-Widmann-Patterson nomenclature, among others. 4. Typical synthesis strategies (Paar-Knorr, Hantzsch synthesis, Fischer-Indol, etc.). 5. Besides, excursions are thematized, such as strained hydrocarbons, carbenes, aromaticity, 1,3-dipoles, phosphorus heterocycles, biologically relevant heterocycles or topical issues.
Media forms	Blackboard, PowerPoint presentations, Zoom.
Literature	“Heterocyclic Chemistry” Joule, Mills, Wiley 2010 “The Chemistry of Heterocycles” Speicher, Eicher, Hauptmann, Wiley, 2013

Compulsory elective lectures in Physical Chemistry

Module name	Compulsory elective lecture **Computational Chemistry**
Abbreviation	MWV

Interval of offer annual	**Duration** 1 semester	**Semester of study** 1 to 4	**Credits** 4	**Curriculum assignment** M. Sc. Chemistry Subject: PC Major subject: E. T. and M. M. M. Sc. Chemical Biology Subject: CB

Module structure

No.	**Course**	**Type**	**CP**	**SWS**	**Presence time**	**Self-study**
1	Computational Chemistry	V	3	2	30 h	60 h
2	Exercises for Computational Chemistry	Ü	1	1	15 h	15 h
	Total		4	3	45 h	75 h

Person responsible for the module	Prof. Dr. S. M. Kast
Lecturer(s)	Prof. Dr. S. M. Kast and co-workers
Language	English
Requirements according to examination regulations	None
Recommended require-ments	Sufficient knowledge of mathematics, as taught e.g. in the module Mathematik für Chemiestudierende, is strongly rec-ommended for successful participation. Similar requirements apply to the physical basics, which are covered e.g. in the module Physik für Chemiestudierende.
Coursework / module ex-amination / partial assess-ments	Oral examination, repeatability and rotation according to ex-amination regulations.
Learning objectives	The students acquire knowledge of the fundamentals and relations of quantum mechanics for calculating the proper-ties of chemical systems. They are able to assess the possi-bilities and limits of methods of theoretical and computer-aided chemistry and use them independently in practice.
Learning outcomes and competencies	Upon successful completion of the module, students will be able to

	– explain different calculation and modeling methods for chemical problems, – propose suitable quantum-chemical computational methods for given applications and questions, and estimate the limits of their predictive power and their effort, – select and apply appropriate programming techniques for problem solving, – develop solution strategies, discuss, present their own point of view appropriately orally and in writing and cooperate with others.
Content	1. Basics – Basic quantum-mechanical principles (wave functions, operators, Schrödinger equation) – Basis set expansions and matrix formulation – Calculus of variations – Quantum-mechanical variational principle 2. Principles of molecular orbital (MO) theory – LCAO approach – One-electron molecules – Hückel model – Molecular potential surfaces 3. MO theory for many-electron systems – Antisymmetry (Pauli) principle – Slater determinants – Basis sets – Hartree-Fock approach – Fundamentals of density functional theory – Basics of the treatment of electron correlation – (perturbation theory, "coupled cluster" approach) – Solvent effects – Application examples – Comparison with experimental data
Media forms	Blackboard, PowerPoint presentations, computer programs (e.g. Mathematica)
Literature	F. Jensen, Introduction to Computational Chemistry, 3rd Ed. Wiley, 2017. A. R. Leach, Molecular Modelling: Principles and Applications, 2nd Ed., Pearson, 2001. A. Szabo, N. S. Ostlund, Modern Quantum Chemistry, Dover, 1996.

Module name		Compulsory elective lecture **Biomolecular Modeling**					
Abbreviation		MWV					
Interval of offer annual	**Duration** 1 semester	**Semester of study** 1 to 4	**Credits** 4	**Curriculum assignment** M. Sc. Chemistry Subject: PC Major subject: E. T. M. Sc. Chemical Biology Subject: CB / BMM			
Module structure							
No.	**Course**		**Type**	**CP**	**SWS**	**Presence time**	**Self-study**
1	Biomolecular Modeling		V	3	2	30 h	60 h
2	Exercises for Biomolecular Modeling		Ü	1	1	15 h	15 h
			Total	4	3	45 h	75 h
Person responsible for the module		Prof. Dr. S. M. Kast					
Lecturer(s)		Prof. Dr. S. M. Kast and co-workers					
Language		English					
Requirements according to examination regulations		None					
Recommended require-ments		Sufficient knowledge of mathematics and physics, as taught e.g. in the modules Mathematik für Chemiestudierende and Physik für Chemiestudierende, is strongly recommended for successful participation. Basic knowledge in computational chemistry, which is acquired e.g. in the elective course of the same name, is also advantageous, but is not required.					
Coursework / module ex-amination / partial assess-ments		Oral examination, repeatability and rotation according to PO.					
Learning objectives		The students acquire knowledge of the basics and relations in modellng and simulation techniques for complex bio-molecular systems. They are able to assess computer-as-sisted methods for solving biological-chemical problems with regard to their possibilities and limitations, select and use them independently in practice.					
Learning outcomes and competencies		Upon successful completion of the module, students will be able to,					

	– explain different simulation and modeling methods for biological systems, – propose suitable calculation methods for given applications and questions and to estimate the limits of their predictive power and the effort required, – select and apply appropriate programming techniques for problem solving, – use acquired knowledge to develop methodical solution strategies for biochemical and biophysical problems and to logically analyze the results, – develop solution strategies, discuss, present their own point of view appropriately orally and in writing as well as cooperate with others.
Content	1. Basics – Molecular coordinate systems – Classical mechanics – Statistical mechanics – Principles of Monte Carlo simulation – Principles of molecular dynamics simulations – Optimization methods/vibration analysis 2. Atomic models for biological systems – Intra- and intermolecular potential functions – Potential parametrization – Construction principles of complex molecular models – Efficient calculation methods 3. Calculation of observables – Thermodynamic quantities – Structural variables, distribution functions – Dynamic quantities, time correlation functions – Comparison with experimental data 4. Special simulation techniques – Creation of different ensembles – Free energy simulations – The Potential of Mean Force – Advanced methods 5. Applications – Biological membranes – Protein dynamics – Protein-ligand binding
Media forms	Blackboard, PowerPoint presentations, computer programs (e.g. Mathematica)
Literature	T. Schlick, Molecular Modeling and Simulation: An Interdisciplinary Guide, 2nd Ed., Springer, 2010. F. Jensen, Introduction to Computational Chemistry, 3rd Ed. Wiley, 2017. M. P. Allen, D. J. Tildesley, Computer Simulation of Liquids, Oxford University Press, 1987.

Module name		Compulsory elective lecture **Biophysikalische Methoden (Biophysical Methods)**		
Abbreviation		MWV		
Interval of offer annual	**Duration** 1 semester	**Semester of study** B. Sc. 5 or 6 M. Sc. 1 to 4	**Credits** 4	**Curriculum assignment** B. Sc. Chemie M. Sc. Chemistry Subject: PC Major subject: E. T. M. Sc. Chemical Biology Subject: CB / BioPC

Module structure

No.	**Course**	**Type**	**CP**	**SWS**	**Presence time**	**Self-study**
1	Biophysikalische Methoden	V	3	2	30 h	60 h
2	Übungen zu Biophysikalische Methoden	Ü	1	1	15 h	15 h
		Total	**4**	**3**	**45 h**	**75 h**

Person responsible for the module	Prof. Dr. C. Czeslik
Lecturer(s)	N.N., Prof. Dr. C. Czeslik
Language	German
Requirements according to examination regulations	None
Recommended require-ments	Erfolgreicher Abschluss der Module MPCa und MPCb
Coursework / module ex-amination / partial assess-ments	Modulprüfung: Klausur Wiederholungsmöglichkeiten und Turnus gemäß PO.
Learning objectives	Die Studierenden erlangen Kenntnisse über Grundlagen der biophysikalischen Chemie, sowohl theoretisch als auch bezüglich praktischer Anwendungen, und können sie sicher zur Problemlösung einsetzen.
Learning outcomes and competencies	Nach erfolgreichem Abschluss des Moduls sind die Studierenden in der Lage, – grundlegende biophysikalisch-chemische Konzepte und übliche Methoden der Biophysik zu erklären, – erworbenes theoretisches Wissen bei der Anwendung spektroskopischer Analyseverfahren zu nutzen,

	– mit den vermittelten Grundlagen der Biophysik Lösungsstrategien zur Bearbeitung neuer praktischer Problemstellungen zu entwickeln und die Ergebnisse angemessen mündlich und schriftlich zu präsentieren, – biophysikalisch-chemischer Phänomene logisch zu analysieren, – bei der Erarbeitung von Lösungsstrategien zu diskutieren, den eigenen Standpunkt angemessen zu vermitteln und mit anderen zusammenzuarbeiten.
Content	1. Allgemeine Strukturprinzipien biologischer Makromoleküle – intermolekulare Wechselwirkungskräfte – Selbstorganisation amphiphiler Moleküle – Struktur und Konformation biologischer Makromoleküle 2. Thermisch-kalorische Messverfahren – Differenzscanningkalorimetrie – isotherme Titrationskalorimetrie 3. Kolligative und hydrodynamische Methoden: – Osmometrie – Viskosimetrie – Ultra-Zentrifugation 4. Strukturuntersuchungen: – mikroskopische Verfahren – Lichtstreuung – Röntgen- und Neutronenstreuung 5. Spektroskopische Methoden – UV/VIS-Spektroskopie – CD-Spektroskopie – Fluoreszenzspektroskopie – IR-Spektroskopie – NMR-Spektroskopie – ESR-Spektroskopie
Media forms	Tafel, Beamer (Power Point-Präsentation), Vorlesungsunterlagen als PDF
Literature	R. Winter, F. Noll, C. Czeslik, Methoden der Biophysikalischen Chemie, 2. Aufl., Vieweg+Teubner, 2011 C. Czeslik, H. Seemann, R. Winter, Basiswissen Physikalische Chemie, 4. Aufl., Vieweg+Teubner, 2010.

Module name	Compulsory elective lecture **Structure and Dynamics: NMR Spectroscopy of Proteins**
Abbreviation	MWV

Interval of offer annual	**Duration** 1 semester	**Semester of study** 1 to 4	**Credits** 4	**Curriculum assignment** M. Sc. Chemistry Subject: PC Major subject: E. T. and M. M. M. Sc. Chemical Biology Subject: CB / BioPC

Module structure

No.	**Course**	**Type**	**CP**	**SWS**	**Presence time**	**Self-study**
1	Structure and dynamics: NMR spectroscopy of proteins	V	3	2	30 h	60 h
2	Exercises for Structure and dynamics: NMR spectroscopy of proteins	Ü	1	1	15 h	15 h
		Total	4	3	45 h	75 h

Person responsible for the module	Prof. Dr. Rasmus Linser
Lecturer(s)	Prof. Dr. Rasmus Linser and co-workers
Language	English
Requirements according to examination regulations	None
Recommended requirements	Sufficient knowledge of chemistry and physics, as taught, e. g., in the modules MPCb (lecture Physical Chemistry 3) and MPa (lecture Physics for Chemistry Students 1), is strongly recommended for successful participation. Basic knowledge of biochemistry is also beneficial but not required.
Coursework / module examination / partial assessments	Written or oral examination, repeatability and rotation according to examination regulations. The type of examination will be announced by notice at the latest two weeks after the start of the course.
Learning objectives	Students will gain basic knowledge of NMR spectroscopy on biomolecules. They will be able to evaluate applications and limitations of NMR spectroscopy for resonance assignment, structure, and molecular dynamics and use them for planning their own studies.
Learning outcomes and competencies	Upon successful completion of the module, students will be able to

	– be able to explain the basics of NMR spectroscopy and various methods of studying biomolecules using NMR spectroscopy, – understand and validate published results in the context of NMR spectroscopy and assess the potential applications of the technique for their own biochemical work, – analyze logically the possibilities and limitations of NMR spectroscopy and to consider them when planning own work, – use the acquired knowledge to develop, evaluate and appropriately discuss solution strategies for simple problems in structural biology.
Content	1. Physical basics - vector model - product operator formalism - pulse sequences 2. Applications to large biological molecules - basics of (isotope-labeled) expression of proteins/RNAs - signal assignment using 3D and 4D experiments ("sequential walk") - structure calculation using interatomic distances and angular information - characterization of molecular dynamics via quantification of different relaxation parameters 3. Methodological features of technically refined solid-state NMR (magic angle spinning etc.)
Media forms	Blackboard, PowerPoint presentations, Software demonstrations, Exercise sheets
Literature	John Cavanagh et al.: Protein NMR Spectroscopy. Principles and Practice, James Keeler: Understanding NMR Spectroscopy; Malcom H. Levitt: Spin Dynamics

<table>
<tr><td colspan="2">Module name</td><td colspan="3">Compulsory elective lecture
EPR Spectroscopy</td></tr>
<tr><td colspan="2">Abbreviation</td><td colspan="3">MWV</td></tr>
<tr><td>Interval of offer
annual</td><td>Duration
1 semester</td><td>Semester of study
B. Sc. 5 or 6
M. Sc. 1 to 4</td><td>Credits
4</td><td>Curriculum assignment
B. Sc. Chemie
B. Sc. Chemische Biologie
M. Sc. Chemistry
Subject: PC
Major subject: E. T.
M. Sc. Chemical Biology
Subject: CB / BioPC</td></tr>
</table>

Module structure

No.	Course	Type	CP	SWS	Presence time	Self-study
1	EPR Spectroscopy	V	3	2	30 h	60 h
2	Exercises for EPR Spectroscopy	Ü	1	1	15 h	15 h
		Total	4	3	45 h	75 h

Person responsible for the module	Prof. Dr. Müge Kasanmascheff
Lecturer(s)	Prof. Dr. Müge Kasanmascheff
Language	English
Requirements according to examination regulations	None
Recommended require-ments	Sufficient knowledge of chemistry and physics, such as taught in the modules MPCb (lecture on physical chemistry 3) and MPa (lecture on physics for chemistry students 1), is strongly recommended for successful participation. Basic knowledge of biochemistry is also advantageous, but not re-quired.
Coursework / module ex-amination / partial assess-ments	Module examination: Written or oral exam. The type of ex-amination will be announced by notice latest two weeks after the start of the event. Possibility of repetition and rotation according to PO.
Learning objectives	The students acquire basic knowledge of electron paramag-netic resonance (EPR) spectroscopy and, subsequently, will be able to assess the applications and limits of EPR spec-troscopy to solve biochemical problems.

Learning outcomes and competencies	By successfully completing the module, the students are able to - Explain principles and applications of EPR spectroscopy and logically analyze advantages and limitations of EPR spectroscopy. - Elucidate the importance of radicals and their chemistry in essential enzymes and biomolecules as well as the characterization of metal cofactors by EPR spectroscopy. - Explicate the utilization of spin labels to study structure and function of biomolecules. - Benefit from their acquired basic knowledge and developed solution strategies in selecting EPR experiments and critically analyzing their results. - Evaluate solution strategies, discuss them in a team, convey their own point of view appropriately and together work out a solution for a new problem.
Content	1. Basics - Paramagnetism - Properties of an unpaired electron (electron spin) - Interactions of the electron spin 2. Continuous-wave EPR - Relaxation and saturation - Multi-frequency EPR - Hyperfine coupling in solution - Analysis of EPR spectra 3. Pulsed EPR - Anisotropy in the solid state - Hyperfine coupling in the solid state - Double-resonance methods of EPR spectroscopy 4. EPR in biology - Spin probes – spin labeling to study conformational changes in proteins - Amino acid radicals – tyrosine radicals, essential for life - Metal cofactors – elucidation of the FeMo-cofactor in nitrogenase
Media forms	Blackboard, Powerpoint presentations, slides, exercise sheets
Literature	M. Brustolon, E. Giamello, Electron Paramagnetic Resonance: A Practitioner's Toolkit, Wiley, 2009. A. Lund, M. Shiotani, S. Shimada, Principles and Applications of ESR Spectroscopy, Springer, 2011.

Module name		Compulsory elective lecture **Physikalische Chemie 4 (Physical Chemistry 4)**		
Abbreviation		MWV		
Interval of offer annual	**Duration** 1 semester	**Semester of study** B. Sc. 5 or 6 M. Sc. 1 to 4	**Credits** 4	**Curriculum assignment** B. Sc. Chemische Biologie M. Sc. Chemistry Subject: PC Major subject: E. T. M. Sc. Chemical Biology Subject: SoC

Module structure

No.	**Course**	**Type**	**CP**	**SWS**	**Presence time**	**Self-study**
1	Physikalische Chemie 4	V	3	2	30 h	60 h
2	Übungen zu Physikalische Chemie 4	Ü	1	1	15 h	15 h
		Total	**4**	**3**	**45 h**	**75 h**

Person responsible for the module	Prof. Dr. C. Czeslik
Lecturer(s)	N.N., Prof. Dr. R. Linser, Prof. Dr. S. M. Kast, Prof. Dr. C. Czeslik, Prof. Dr. M. Kasanmascheff
Language	German
Requirements according to examination regulations	None
Recommended require-ments	Erfolgreicher Abschluss der Module MPCa und MPCb
Coursework / module ex-amination / partial assess-ments	Modulprüfung: Klausur, Wiederholungsmöglichkeiten und Turnus gemäß PO.
Learning objectives	Die Studierenden erwerben im Modul grundlegende Kenntnisse auf dem Gebiet der Quantenstatistik und statistischen Thermodynamik und sind in der Lage, einfache Aufgaben und Problemstellungen aus diesen Gebieten selbständig zu analysieren und zu lösen.
Learning outcomes and competencies	Am Ende dieses Moduls sind die Studierenden in der Lage, - erworbene Kenntnisse auf dem Gebiet der Quantenstatistik und statistischen Thermodynamik sowohl theoretisch als auch hinsichtlich ihrer praktischen Anwendung sicher zu beherrschen,

	- vermittelte theoretische Kenntnisse bei der Anwendung spektroskopischer Analyseverfahren zu nutzen, - erworbenes theoretisches Wissen zur Entwicklung von Lösungsstrategien bei der Bearbeitung praktischer Problemstellungen zu verwenden, - grundlegende physikalisch-chemische Phänomene einer logischen Analyse zu unterziehen, - eigene Lösungskonzepte angemessen mündlich und schriftlich zu präsentieren.
Content	1. **Grundlagen der statistischen Mechanik**: - Ensembletheorie, - Boltzmannverteilung, - Zustandssummen, - Zusammenhang mit thermodynamischen Größen, - Gleichverteilungssatz. 2. **Grundlagen der Quantenstatistik:** - Molekülzustandssumme, - Systeme aus ununterscheidbaren Teilchen, - Maxwell-Boltzmann-, Fermi-Dirac- und Bose-Einstein-Statistik. **3. Anwendungen der statistischen Thermodynamik:** - Berechnung chemischer Gleichgewichte, - Absolutberechnung von Reaktionsgeschwindigkeiten, - reale Gase, - Flüssigkeiten, - Wärmekapazität von Festkörpern, - Computersimulationsmethoden (Molekulardynamik- und Monte Carlo-Verfahren).
Media forms	Tafel, Beamer (Power-Point-Präsentation), Vorlesungsunterlagen als PDF
Literature	C. Czeslik, H. Seemann, R. Winter, Basiswissen Physikalische Chemie, Vieweg+Teubner, 4. Auflage, 2010. P. W. Atkins, J. de Paula, J. J. Keeler, Physikalische Chemie, 6. Auflage, Wiley-VCH, 2021. G. Wedler, H.-J. Freund, Lehrbuch der Physikalischen Chemie, 6. Auflage, Wiley-VCH, 2012.

Compulsory elective lectures in Industrial Chemistry

Module name	Compulsory elective lecture **Einführung in die Technische Chemie (Introduction to Industrial Chemistry)**
Abbreviation	MWV

Interval of offer	**Duration**	**Semester of study**	**Credits**	**Curriculum assignment**
annual	1 semester	B. Sc. 5 or 6 M. Sc. 1 to 4	4	B. Sc. Chemie M. Sc. Chemistry Subject: TC Major subject: E. T.

Module structure

No.	Course	Type	CP	SWS	Presence time	Self-study
1	Introduction to Industrial Chemistry	V	4	3	45 h	75 h
	Total		**4**	**3**	**45 h**	**75 h**

Person responsible for the module	Prof. Dr. D. Vogt
Lecturer(s)	Prof. Dr. D. Vogt, Prof. Dr.-Ing. H. Freund / Dr.-Ing. M. Börnhorst
Language	English
Requirements according to examination regulations	None
Recommended requirements	Fundamentals of inorganic, organic, and physical chemistry.
Coursework / module examination / partial assessments	Module examination: written exam. Repeat options and rotation according to examination regulations.
Learning objectives	The students acquire basic knowledge of industrial chemical production using the example of economically significant processes and products, as well as the ability to assess a chemical process not only according to chemical, but also according to engineering science, technical, economical, and ecological aspects.
Learning outcomes and competencies	After successful participation in this module, students will be able to: - recognize the differences between the production of substances in the laboratory and on an industrial scale, and to consider them for application. - apply the basics of thermodynamics, the phase equilibria, reaction kinetics, mass and heat transport, as well

	as mass and heat balancing, to explain the operating principles of the most important chemical reactors and separation processes. - discuss the possible applications of the different basic types of chemical reactors. - explain the function of heterogeneous and homogeneous catalysts and they are relevant reaction mechanisms. - carry out step constructions taking into account phase equilibria and mass balances as a basis for the design of separation processes. - understand the desired function of essential equipment in chemical plants and describe their advantages and disadvantages for specific applications. - describe the chemical process with the help of the process flow diagram. - explain the production of essential inorganic and organic precursors, intermediates, and end products in the chemical industry using process flow diagrams. - work together on an interdisciplinary basis with graduates from chemical engineering and other subject areas enabled by the engineering science knowledge acquired in this course.
Content	Basics 1. basic structure of chemical - production facilities - “Verbundstruktur” of the chemical industry - difference of laboratory and production processes - characterization and representation of chemical processes in flow diagrams 2. Industrial thermodynamics and kinetics 3. Reactors - laboratory stirred tank (discontinuous or semi-continuous) - heat dissipation from reactors - scale up - safety aspects - continuously operated still tank reactor - tubular reactor - still tank reactor cascade - residence time 4. Reactor design and process engineering on the example of the ammonia synthesis (heterogeneous catalysis, uses of ammonia) 5. Mass and heat balancing, basic principles of cost accounting, optimization of chemical plants 6. Distillation - laboratory distillation (discontinuous)

	- Rectification - balancing of a rectification column - McCabe-Thiele method - influence of the reflux ratio - industrial embodiments 7. Other basic thermal operations: - Absorption - Adsorption - Extraction - counter-current principle is a common feature, technical implementation forms (tray- and packed columns) - basic mechanical operations (steering, filtering) - pumps Processes 1. Fossil raw materials (oil, natural gas, coal). 2. Organic base chemicals I (steam cracker). 3. Organic base chemicals II (C2 chemistry). 4. Organic base chemicals III (C3- to C5- and aromatics chemistry). 5. Organic end products I (Polymers). 6. Organic end products II (detergents, dyes, pharmaceuticals, crop protection products). 7. Selected inorganic products: e.g. - sulfuric acid - chlorine - caustic soda - cement - pig iron/steel - aluminium - semiconductor silicon 8. Excursion to a chemical industry plant
Media forms	Blackboard, PowerPoint presentation, graphics of simulation calculations (download option), excursion to a chemical company.
Literature	D.W. Agar, A. Behr, J. Jörissen „Einführung in die Technische Chemie“, Spektrum Akademischer Verlag, Heidelberg, 2010. W. Reschetilowski „Technisch-Chemisches Praktikum“, Wiley-VCH, Weinheim, 2002. Scripts of the practical course in industrial chemistry

<table>
<tr><td colspan="2">Module name</td><td colspan="5">Compulsory elective lecture
Industrielle Prozesse nachwachsender Rohstoffe (Industrial Processes of Renewable Resources)</td></tr>
<tr><td colspan="2">Abbreviation</td><td colspan="5">MWV</td></tr>
<tr><td>Interval of offer
annual</td><td>Duration
1 semester</td><td colspan="2">Semester of study
1 to 4</td><td>Credits
4</td><td colspan="2">Curriculum assignment
M. Sc. Chemistry
Subject: TC
Major subject: E. T.</td></tr>
<tr><td colspan="7">Module structure</td></tr>
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No.	Course	Type	CP	SWS	Presence time	Self-study
1	Industrial Processes of Renewable Resources	V	3	2	30 h	60 h
2	Exercise for Industrial Processes of Renewable Resources	Ü	1	1	15 h	15 h
		Total	**4**	**3**	**45 h**	**75 h**

Person responsible for the module	Prof. Dr. D. Vogt
Lecturer(s)	Dr. T. Seidensticker
Language	English
Requirements according to examination regulations	None
Recommended requirements	None
Coursework / module examination / partial assessments	Active participation in the lecture, written or oral examination, repeat options and rotation according to examination regulations.
Learning objectives	In this module, students acquire knowledge of the most important industrial processes for the conversion of renewable raw materials and will be able to apply them.
Learning outcomes and competencies	After successful participation in this module, students will be able to, - better assess the importance of renewable raw materials in current and future chemical production. - discuss the processing and downstream chemistry of renewable raw materials. - assess the particular advantages, but also the possible disadvantages of renewable raw material

	- compare processes based on petrochemical and renewable raw materials. - describe the technical realisation of implementations with renewable raw materials. - evaluate the ecological and economic characteristics of processes with renewable raw materials.
Content	Industrial aspects (industrial extraction, processing, process comparison based on flow charts, important downstream products) of the following product classes: 1. Fats and oils - Oil types - Oil extraction - Fatty acids - Fatty esters - Fatty alcohols - Fatty amines - Glycerol - Subsequent chemistry of the oleochemicals - 2. Carbohydrates - Sugar - Cellulose - Starch - Chitin/Chitosan - Cyclodextrins 3. Vegetable extracs - Natural rubber - Resins, terpenes - Essential oils - Vitamins etc. This course can be supplemented by the further elective lecture "Industrial Processes of Petrochemical Intermediates".
Media forms	PowerPoint presentation, whiteboard, lecture graphics, Videos, Quizzes, etc.
Literature	A. Behr, T. Seidensticker: "Chemistry of Renewables", Springer 2020 M. Baerns, A. Behr, A. Brehm, J. Gmehling, K.-O. Hinrichsen, H. Hofmann, U. Onken, R. Palkovits, A. Renken: "Technische Chemie", Wiley-VCH, Weinheim, 2nd ed. 2013 (Note: the 3rd completely revised edition is due to appear at the end of 2022)

Module name		Compulsory elective lecture **Industrielle Prozesse petrochemischer Zwischenprodukte (Industrial Processes of Petrochemical Intermediates)**		
Abbreviation		MWV		
Interval of offer annual	**Duration** 1 semester	**Semester of study** 1 to 4	**Credits** 4	**Curriculum assignment** M. Sc. Chemistry Subject: TC Major subject: E. T.

Module structure

No.	**Course**	**Type**	**CP**	**SWS**	**Presence time**	**Selfstudy**
1	Industrial Processes of Petro-chemical Intermediates	V	3	2	30 h	60 h
2	Exercise for Industrial Processes of Petrochemical Intermediates	Ü	1	1	15 h	15 h
		Total	**4**	**3**	**45 h**	**75 h**

Person responsible for the module	Prof. Dr. D. Vogt
Lecturer(s)	Dr. T. Seidensticker
Language	English
Requirements according to examination regulations	None
Recommended requirements	None
Coursework / module examination / partial assessments	Active participation in the lecture, written or oral examination, repeat options and rotation according to examination regulations.
Learning objectives	Within the scope of this module, students acquire knowledge of the most important industrial processes for the production of petrochemical intermediates and will be are able to apply them.
Learning outcomes and competencies	After successful participation in this module, students will be able to: - better assess the importance of petrochemical intermediates in current and future chemical production. - discuss the production and downstream chemistry of petrochemical intermediates.

	- assess the particular advantages, but also the possible disadvantages, of petrochemical intermediates. - compare processes based on petrochemical and renewable raw materials. - describe the industrial realisation of manufacturing processes of petrochemical intermediates. - compare processes using specific individual examples and balance the advantages and disadvantages of certain reaction processes, reactor types, reprocessing steps and recycling methods. - critically discuss questions of safety, environmental protection, energy conservation, selective reaction control, the application of catalysis and economic aspects and classify them in the subject area of industrial chemistry.
Content	Overview of the most important petrochemical processes not yet covered in previous studies, in particular industrial syntheses of organic intermediates such as: 1. Alcohols 2. Aldehydes 3. Ketones 4. Carboxylic acids 5. Ether 6. Epoxies 7. Amines 8. Isocyanates This course can be supplemented by the further elective lecture "Industrial Processes of Renewables".
Media forms	PowerPoint presentation, whiteboard, lecture graphics, Videos, Quizzes, etc.
Literature	M. Baerns, A. Behr, A. Brehm, J. Gmehling, K.-O. Hinrichsen, H. Hofmann, U. Onken, R. Palkovits, A. Renken: "Technische Chemie", Wiley-VCH, Weinheim, 2nd ed. 2013 (Note: the 3rd completely revised edition is due to appear at the end of 2022)

Module Name	Compulsory elective lecture **Industrial Chemistry 2**
Abbreviation	MWV

Interval of offer annual	**Duration** 1 semester	**Semester of study** 1 to 4	**Credits** 4	**Curriculum assignment** M. Sc. Chemistry Subject: TC Major subject: E. T.

Module structure

No.	**Course**	**Type**	**CP**	**SWS**	**Presence time**	**Self-study**
1	Industrial Chemistry 2	V	3	2	30 h	60 h
2	Exercise for Industrial Chemistry 2	Ü	1	1	15 h	15 h
		Total	**4**	**3**	**45 h**	**75 h**

Person responsible for the module	Prof. Dr. D. Vogt
Lecturer(s)	Prof. Dr. D. Vogt
Language	English
Requirements according to examination regulations	None
Recommended require-ments	None
Coursework / module exam-ination / partial assess-ments	Active participation in the lecture, written or oral exami-nation, repeat options and rotation according to exami-nation regulations.
Learning objectives	In this module, students gain knowledge of future-ori-ented principles of sustainable chemical production, es-pecially environmentally friendly, “green” chemistry and process development.
Learning outcomes and competencies	After successful participation in this module, students will be able to: - discuss possibilities of converting raw materials into the products demanded by the market in the chemi-cal industry, taking into account non-technical, i.e. economic or environmental requirements. - link the theoretical basis of the individual process methods with typical examples of application. - combine economic and ecological problems with possible solutions in industrial chemistry. - determine decisive criteria for economically optimal

	processes and to classify the individual processes in the chemical industry in a process network. - evaluate the atomic economy of reactions, select optimal catalysts and their recycling methods, and use alternative raw materials and energies. - correlate petrochemistry and process engineering.
Content	Principles of environmentally friendly “green” chemistry and process development. Important basic rules for the design of a chemical process: 1. availability of reactants 2. toxicity of the by-products 3. reusability of solvents and catalysts 4. alternative raw materials are carbon dioxide, as well as 5. the scale up of processes in miniplants
Media forms	Blackboard, PowerPoint presentation
Literature	M. Baerns, A. Behr, A. Brehm, J. Gmehling, K.-O. Hinrichsen, H. Hofmann, U. Onken, R. Palkovits, A. Renken: „TechnischeChemie“, Wiley-VCH, Weinheim, 2nd Ed. 2013 (note: end of 2022 the 3rd completely revised Ed. will be published!)

Module name	Compulsory elective lecture **Applied Homogeneous Catalysis**			
Abbreviation	MWV			
Interval of offer annual	**Duration** 1 semester	**Semester of study** 1 to 4	**Credits** 4	**Curriculum assignment** M. Sc. Chemistry Subject: TC Major subject: E. T.

Module structure

No.	**Course**	**Type**	**CP**	**SWS**	**Presence time**	**Self-study**
1	Applied Homogeneous Catalysis	V	1.5	1	15 h	30 h
2	Exercise for Applied Homogeneous Catalysis	Ü	1	1	15 h	15 h
3	Homework assignment	Ü	1.5	1	15 h	30 h
		Total	**4**	**3**	**45 h**	**75 h**

Person responsible for the module	Prof. Dr. D. Vogt
Lecturer(s)	Prof. Dr. D. Vogt
Language	English
Requirements according to examination regulations	None
Recommended requirements	Courses on organometallic chemistry or “Introduction to Industrial Catalysis”
Coursework / module examination / partial assessments	Active participation in the lecture, written or oral examination, homework assignment. Repeat options and rotation according to examination regulations.
Learning objectives	In this module, knowledge on the most important industrial applications and processes of homogeneous catalysts is gained. Deeper inside is acquired on the respective reaction mechanisms, catalytic cycles, and ligand control.
Learning outcomes and competencies	After successful participation in this module, students will be able to: - explain the basics of homogeneous catalysis and apply these on problems of industrial syntheses. - explain and apply methods of homogeneous catalysis on catalyst choice and recycling.

	- critically discuss the differences and common features between catalysis on lab scale and in industrial processes. - interact and cooperate in an interdisciplinary fashion with graduates from chemical engineering and other disciplines, using the engineering science knowledge acquired.
Content	1. Methods and possibilities to steer and control as well as economically design industrially important processes using homogeneous catalysis. 2. Typical applications of Homogeneous Catalysis - production of base chemicals, - production of intermediate chemicals - production of fine chemicals and end products 3. Methods of Homogeneous Catalysis - catalysts selection - mechanisms - methods of catalyst recycling 4. Variants of homogeneous transition metal catalysis 5. Choice of metal-ligand combinations
Media forms	Blackboard , PowerPoint presentation
Literature	M. Baerns, A. Behr, A. Brehm, J. Gmehling, K.-O. Hinrichsen, H. Hofmann, U. Onken, R. Palkovits, A. Renken: „Technische Chemie“, Wiley-VCH, Weinheim, 2. Aufl. 2013 (remark: end of 2022 the 3rd, completely revised Ed. Is supposed to be published.) A. Behr, P. Neubert, "Applied Homogeneous Catalysis", Wiley-VCH, **2012**

Module name	Compulsory elective lecture **Value Creation in Chemical Industry**			
Abbreviation	MWV			
Interval of offer annual	**Duration** 1 semester	**Semester of study** 1 to 4	**Credits** 4	**Curriculum assignment** M. Sc. Chemistry Subject: TC Major subject: E. T.

Module structure

No.	**Course**	**Type**	**CP**	**SWS**	**Presence time**	**Self-study**
1	Value Creation in Chemical Industry	V	1.5	1	15 h	30 h
2	Exercise for Value Creation in Chemical Industry	Ü	1	1	15 h	15 h
3	Homework assignment	Ü	1.5	1	15 h	30 h
		Total	**4**	**3**	**45 h**	**75 h**

Person responsible for the module	Prof. Dr. D. Vogt
Lecturer(s)	Dr. habil. A. J. Vorholt
Language	English
Requirements according to examination regulations	None
Recommended require-ments	None
Coursework / module exam-ination / partial assess-ments	Active participation in the lecture; during the exercise students give a presentation on a selected chapter with discussion afterwards. Written or oral examination, homework. Repeat options according to examination regulations.
Learning objectives	In this module, students gain knowledge on the most important dimensions of value creation in the chemical industry. They can use the acquired knowledge to solve simple economical questions.
Learning outcomes and competencies	After successful participation in this module, students will be able to: - understand value creation in the chemical industry, explain methods to increase value creation and to apply those methods to simple problems. - describe value creation chains in the chemical industry, especially related to fossil and renewable feedstocks.

	- explain and evaluate processes and raw materials under consideration of their economical dimensions. - explain and confidently apply managerial tools for the increase of value creation. - recognize and apply economical dimensions in the chemical industry.
Content	1. Economical connections in the chemical industry (connections between raw materials, processes, and economical success) 2. Current developments in the chemical industry and the effects on their economic success 3. current management tools for the increase of value creation - strategic application - operative application
Media forms	Blackboard , PowerPoint presentation
Literature	M. Welge, A. Al-Laham, Strategisches Management. Grundlagen – Prozess – Implementierung, 6. Auflage, Springer Gabler Verlag, Wiesbaden, 2012

Module name		Compulsory elective lecture **Reaction Engineering (Reaktionstechnik 1a+1b)**		
Abbreviation		MWV		
Interval of offer annual	**Duration** 1 semester	**Semester of study** 1 to 4	**Credits** 4	**Curriculum assignment** M.Sc. Chemistry Subject: TC Major subject: E. T.

Module structure

No.	Course	Type	CP	SWS	Presence time	Self-study
1	Reaction Engineering	V	3	2	30 h	60 h
2	Exercise for Reaction Engineering	Ü	1	1	15 h	15 h
	Total		**4**	**3**	**45 h**	**75 h**

Person responsible for the module	Prof. Dr.-Ing. H. Freund
Lecturer(s)	Prof. Dr.-Ing. H. Freund and assistants
Language	German *
Requirements according to examination regulations	None
Recommended require-ments	None
Coursework / module ex-amination / partial assess-ments	Active participation in the lecture. Module examination, oral exam. Repeatability and interval of offer according to exami-nation regulations.
Learning objectives	Students acquire knowledge of reaction engineering, espe-cially in the mathematical analysis of reaction systems and the selection and design of chemical reactors, and can apply this knowledge as needed.
Learning outcomes and competencies	After successful completion of the module, students will be able to, - use the acquired knowledge about the various possibili-ties of chemical reactions and reactors in industrial pro-duction to solve simple problems in the field of reaction engineering. - link the theoretical fundamentals of the individual pro-cess methods with typical application examples.

	- explain the key role of the chemical reactor in an industrial chemical plant and its close interaction with the other plant units. - analyze technical reaction systems and evaluate the influence of physical processes on the reaction process. - describe the possibilities and limitations of mathematical modeling of reactions and reactors and consider the relevant criteria for economically optimal reaction control and reactor performance. - analyze and interpret mass and energy balances with reactive sources and sinks.
Content	1. Mass and energy balances with reaction 2. Reaction networks 3. Kinetics and thermodynamics of chemical reactions 4. Chemical reaction with diffusive mass transport and heat transfer in heterogeneous catalysis 5. Fundamentals of ideal chemical reactors and their conversion and selectivity behavior 6. Residence time distribution of real chemical reactors and the dynamic behavior of chemical reactors 7. Heat management in chemical reactors 8. Acquisition of reaction kinetic data and kinetic modeling
Media forms	Set of slides and additional materials will be published on the designated virtual workspaces
Literature	G. Emig, E. Klemm, Chemische Reaktionstechnik, Springer, Berlin, 6. Aufl. 2017. O. Levenspiel, Chemical Reaction Engineering, John Wiley, 3. Auflage, 1998. H. Scott Fogler, Elements of Chemical Reaction Engineering, Prentice Hall International Edition, London, 5. Auflage, 2016. A. Behr, D. W. Agar, J. Jörissen, A. J. Vorholt, Einführung in die Technische Chemie, Springer, Berlin, 2. Auflage, 2016. M. Baerns, A. Behr, A. Brehm, J. Gmehling, K.-O. Hinrichsen, H. Hofmann, U. Onken, R. Palkovits, A. Renken, Technische Chemie, Wiley-VCH, Weinheim, 2. Aufl. 2013. A. Jess, P. Wasserscheid, Chemical Technology, Wiley-VCH, Weinheim, 2013

* A lecture in English with the same content is offered under the title "Introduction to Process Balancing".

<table>
<tr><td colspan="2">Module name</td><td colspan="6">Compulsory elective lecture
Introduction to Industrial Catalysis</td></tr>
<tr><td colspan="2">Abbreviation</td><td colspan="6">MWV</td></tr>
<tr><td>Interval of offer
annual</td><td>Duration
1 semester</td><td colspan="2">Semester of study
B.Sc. 5 or 6
M. Sc. 1 to 4</td><td colspan="2">Credits
4</td><td colspan="2">Curriculum assignment
B. Sc. Chemie
M. Sc. Chemistry
Subject: TC
Major subject: E. T.</td></tr>
<tr><td colspan="8">Module structure</td></tr>
<tr><td>No.</td><td colspan="2">Course</td><td>Type</td><td>CP</td><td>SWS</td><td>Presence time</td><td>Self-study</td></tr>
<tr><td>1</td><td colspan="2">Introduction to Industrial Catalysis</td><td>V</td><td>3</td><td>2</td><td>30 h</td><td>60 h</td></tr>
<tr><td>2</td><td colspan="2">Exercise for Introduction to Industrial Catalysis</td><td>Ü</td><td>1</td><td>1</td><td>15 h</td><td>15 h</td></tr>
<tr><td colspan="4">Total</td><td>4</td><td>3</td><td>45 h</td><td>75 h</td></tr>
<tr><td colspan="2">Person responsible for the module</td><td colspan="6">Prof. Dr.-Ing. H. Freund</td></tr>
<tr><td colspan="2">Lecturer(s)</td><td colspan="6">Prof. Dr.-Ing. H. Freund, Prof. Dr. D. Vogt</td></tr>
<tr><td colspan="2">Language</td><td colspan="6">German</td></tr>
<tr><td colspan="2">Requirements according to examination regulations</td><td colspan="6">None</td></tr>
<tr><td colspan="2">Recommended requirements</td><td colspan="6">None</td></tr>
<tr><td colspan="2">Coursework / module examination / partial assessments</td><td colspan="6">Written or oral exam, repeat opportunities and rotation according to examination regulations.</td></tr>
<tr><td colspan="2">Learning objectives</td><td colspan="6">Students will learn all the essential basic principles and concepts of homogeneous and heterogeneous catalysis as a key technology of chemical material conversion, both in terms of molecular mechanisms and underlying physico-chemical aspects of industrial application of catalysis.</td></tr>
<tr><td colspan="2">Learning outcomes and competencies</td><td colspan="6">After successful completion of the module, students will be able to:

- describe and discuss the fundamentals of transition metal catalysis and use them for predictions as well as evaluation of catalysts.
- enumerate methods for recycling homogeneous catalysts and explain their principles.</td></tr>
</table>

	- make suggestions for a suitable catalyst and reaction system for an unknown reaction. - describe, using relevant examples, the use of heterogeneous catalysts in the synthesis of major basic chemicals and intermediates, and from these describe generally applicable approaches to heterogeneous catalysis. - explain the importance of catalysis for controlling material flows in the chemical industry, differentiate between heterogeneous and homogeneous catalysts, and compare their advantages and disadvantages. - evaluate the choice of catalyst for different applications by comparing the advantages and disadvantages of different catalyst variants. - use the acquired knowledge to plan selective and material- and waste-saving chemical production.
Content	1. Principles of catalysis a) Heterogeneous catalysis - Microkinetics (Langmuir-Hinshelwood) and macrokinetics (Thiele modulus, heat transfer, internal and external mass transfer) - Rate-determining step of catalytic reactions - Activity, selectivity and characterization of catalysts - Parameters influencing activity and selectivity b) Homogeneous catalysis - Transition metal catalyzed catalytic cycles - Asymmetric catalysis - Ligand and catalyst properties - Catalyst and ligand influences 2. Technical use of catalysts - Recycling of homogeneous catalysts - Comparison of homogeneous, heterogeneous and heterogenized catalysis - Use of heterogeneous catalysts in the synthesis of major base chemicals and intermediates in single and multiphase systems - Advantages and disadvantages of different technologies - Catalyst use with respect to process variants and conditions of important industrial processes - Differences and evaluation of the production of a product with and without catalyst
Media forms	The set of slides for the course and additional materials such as bibliographies and website recommendations will be published on the designated virtual workspaces.
Literature	- A. Behr, P. Neubert, Applied Homogeneous Catalysis, Wiley VCH, 2012

	- P.C.J Kamer, D. Vogt, J.W. Thybaut (Eds.) Contemporary Catalysis – Science, Technology, and Applications, RSC, 2017 - M. Baerns, A. Behr, A. Brehm, J. Gmehling, K. Hinrichsen, H. Hofmann, U. Onken, R. Palkovits, A. Renken, Technische Chemie, Wiley-VCH, Weinheim, 2. Auflage, 2013 - A. Behr, D. W. Agar, J. Jörissen, A. J. Vorholt, Einführung in die Technische Chemie, Springer, Berlin, 2. Auflage, 2016 - A. Jess, P. Wasserscheid, Chemical Technology, Wiley-VCH, Weinheim, 2. Auflage, 2013

Compulsory elective lectures in Medicinal Chemistry

Module name		Compulsory elective lecture **Medicinal Chemistry 1**					
Abbreviation		MWV					
Interval of offer annual	**Duration** 1 semester	**Semester of study** 1 to 4		**Credits** 4	**Curriculum assignment** M. Sc. Chemistry Subject: SoC M. Sc. Chemical Biology Subject: MC		
Module structure							
No.	**Course**		**Type**	**CP**	**SWS**	**Presence time**	**Self-study**
1	Medicinal Chemistry 1		V	3	2	30 h	60 h
2	Exercise for Medicinal Chemistry 1		Ü	1	1	15 h	15 h
			Total	**4**	**3**	**45 h**	**75 h**

Person responsible for the module	Prof. Dr. D. Rauh
Lecturer(s)	Prof. Dr. D. Rauh, Dr. M. Beck
Language	English
Requirements according to examination regulations	None
Recommended requirements	Knowledge of bioorganic chemistry and organic chemistry
Coursework / module examination / partial assessments	Written exam, retake options and rotation according to examination regulations.
Learning objectives	The students acquire basic knowledge of the terminology of medicinal chemistry, the factors influencing pharmacokinetic as well as pharmacodynamic properties and the understanding of the design process of new pharmacologically active substances in drug research.
Learning outcomes and competencies	By successfully completing this module, students will be able to, - explain basic principles of protein-ligand interaction and modern drug discovery. - comprehend structure-based, rational and computer-based methods for the development of active substances.

	- explain factors that influence the interplay of pharmacokinetics and pharmacodynamics and understand the possibilities for influencing these processes through chemical modification and apply them in problem solving. - develop interdisciplinary solution strategies for practical problems at the interface between chemistry, pharmacology and biophysics for basic research and biomedical applications. - discuss, communicate their own point of view appropriately and cooperate with others when developing solution strategies.
Content	1. Fundamentals of protein-ligand interaction: - Methods for understanding protein-ligand interactions as a basis for the rational design of W agents. 2. Basic concepts of medicinal/pharmaceutical chemistry: - Definition of active substance - Drug substance and medicinal product, how do active substances work? - Phase I-IV clinical trials 3. Basic concepts of the description of pharmacokinetics: - LADME concept and terms - Application routes 4. Independent pharmacokinetic characteristics: - Understanding of clearance parameters, - Volume of distribution - Bioavailability - Half-life - Elimination 5. Structural properties and possibilities for optimising pharmacokinetic properties: - Lipinsky Rules and Innovations - Metabolic processes - Prediction of ADME properties on the basis of calculated parameters 6. Prediction of human PK properties: - Transporter properties - Microsomal stability - Caco 2 assay - Scaling methods 7. Structure-based drug design and computer methods of modern drug discovery: - Visualisation of physicochemical properties of active substances - molecular modelling - virtual screening - Database searches

	8. Case studies: - Factor Xa inhibitors - MMP inhibitors - Kinase inhibitors - Lipid 2 antagonists - PDE5 inhibitors - Adenosine agonists - sGC stimulators - sGC activators - DPP4 inhibitors
Media forms	Blackboard pictures, Powerpoint presentation, online script (accompanying), synthesis exercises
Literature	Case Studies, Wiley-VCH; Wirkstoffdesign - Entwurf und Wirkung von Arzneistoffen, G. Klebe, Spektrum-Verlag; current original literature

Module name		Compulsory elective lecture **Medicinal Chemistry 2**					
Abbreviation		MWV					
Interval of offer annual	**Duration** 1 semester	**Semester of study** 1 to 4	**Credits** 4	**Curriculum assignment** M. Sc. Chemistry Subject: SoC M. Sc. Chemical Biology Subject: MC			
Module structure							
No.	**Course**		**Type**	**CP**	**SWS**	**Presence time**	**Self-study**
1	Medicinal Chemistry 2		V	3	2	30 h	60 h
2	Exercise for Medicinal Chemistry 2		Ü	1	1	15 h	15 h
			Total	**4**	**3**	**45 h**	**75 h**

Person responsible for the module	Prof. Dr. D. Rauh
Lecturer(s)	Dr. P. Nussbaumer, Dr. H. Haning, Dr. L. Urner
Language	English
Requirements according to examination regulations	None
Recommended require-ments	Knowledge of bioorganic chemistry and organic chemistry
Coursework / module ex-amination / partial assess-ments	Written exam, retake options and rotation according to examination regulations.
Learning objectives	The students acquire basic knowledge of the terminology of medicinal chemistry, technologies for drug identification; exemplary biologics (oligonucleotides, antibodies), properties of enzyme inhibitors, basic knowledge of the industrial pharmaceutical research process as well as of optimisation cycles and can confidently apply this knowledge in solving tasks from medicinal chemistry.
Learning outcomes and competencies	By successfully completing this module, students will be able to, - explain the processes of pharmaceutical research and industrial applications. - understand the underlying principles for the action of biological drugs - understand different technologies for drug identification

	- describe different types of enzyme inhibition and to draw conclusions about possible consequences of enzyme inhibition from chemical structural features. - develop interdisciplinary solution strategies for practical problems at the interface between chemistry, pharmacology and biophysics for basic research and biomedical applications. - discuss, communicate their own point of view appropriately and cooperate with others when developing solution strategies.
Content	1. History of drug research and discovery: - Active plant ingredients - Aspirin - Process of synthesis of the active substance 2. Targets for pharmacologically active agents: - Distribution of target classes for commercial agents 3. Protein-ligand interactions: - Significance of the individual energy contributions - Strength of different types of interaction 4. Enzyme inhibitors: - Types of enzyme inhibition and their kinetic description - Types of enzyme inhibition and their kinetic description - Mechanisms of different protease types - Proteasome and proteasome inhibitors 5. Industrial pharmaceutical research: - Screening process - Screening by selection - Computational chemistry methods in the hit finding and hit-to-lead process - Optimisation cycles 6. Case studies: - Factor Xa inhibitors - MMP inhibitors - Kinase inhibitors - Lipid 2 antagonists - PDE5 inhibitors - sGC stimulators - sGC activators - DPP4 inhibitors 7. Biological drugs such as oligonucleotides and antibodies
Media forms	Blackboard pictures, Powerpoint presentation, online script (accompanying), synthesis exercises
Literature	Case Studies, Wiley-VCH; current original literature

Module name		Compulsory elective lecture **Design and Synthesis of Bioactive Substances and Drugs**		
Abbreviation		MWV		
Interval of offer annual	**Duration** 1 semester	**Semester of study** 1 to 4	**Credits** 4	**Curriculum assignment** M. Sc. Chemistry Subject: SoC M. Sc. Chemical Biology Subject: MC

Module structure

No.	**Course**	**Type**	**CP**	**SWS**	**Presence time**	**Self-study**
1	Design and synthesis of bioactive substances and drugs	V	3	2	30 h	60 h
2	Exercises for Design and synthesis of bioactive substances and drugs	Ü	1	1	15 h	15 h
	Total		**4**	**3**	**45 h**	**75 h**

Person responsible for the module	Prof. Dr. D. Rauh
Lecturer(s)	Dr. L. Urner
Language	English
Requirements according to examination regulations	None
Recommended requirements	Solid knowledge of organic chemistry, bioorganic chemistry and biochemistry; basics of medicinal chemistry helpful (Med. Chem. 1).
Coursework / module examination / partial assessments	Graded written exam, retake options and rotation according to examination regulations.
Learning objectives	Students gain knowledge of modern methods of drug synthesis and drug identification and can confidently apply the acquired knowledge in theory and practice.
Learning outcomes and competencies	By successfully completing this module, students will be able to, - explain basic aspects of drug design. - explain modern methods of active ingredient identification.

	- use acquired knowledge about different approaches to the synthesis of active ingredients and active ingredient libraries to plan simple active ingredient syntheses - use interdisciplinary theoretical knowledge within drug design, drug synthesis and drug identification to solve medicinal chemistry problems.
Content	1. Drug design and structure selection. - Definition of terms, databases for the medicinal chemist - Criteria for structure selection, exclusion criteria, "drug qualities". - Concepts of biology-oriented synthesis (BIOS), diversity-oriented synthesis (DOS). 2. Special techniques in drug discovery. - New high-throughput screening formats: Modern combinatorial synthesis and encoded libraries - Phenotypic assays 3. Medicinal chemistry aspects of organic synthesis. - Overview of the most commonly used reactions by the medicinal chemist - Bioisosterism in drug design - Synthesis and SAR of selected drug-relevant (= privileged) classes of substances: e.g. benzodiazepines, purines, 1,4-dihydropyridines - Green medicinal chemistry, modern methods for the generation of focused SAR libraries (e.g. continuous flow synthesis) - Case Study: peptidomimetics - Research versus process synthesis of drugs, case studies
Media forms	Blackboard pictures, Powerpoint presentation, online script (accompanying), synthesis exercises
Literature	- Klebe, G. "Drug design" (2nd edition). - Steinhilber, Schubert-Zsilavecz, Roth "Medicinal Chemistry" (2nd Edition) - Patrick, G. "Medicinal Chemistry" (5th Edition) - Current original literature and review articles on special topics of the lecture

Module name		Compulsory elective lecture **Applied Computer Methods in Life Sciences**		
Abbreviation		MWV		
Interval of offer annual	**Duration** 1 semester	**Semester of study** 1 to 4	**Credits** 4	**Curriculum assignment** M. Sc. Chemical Biology Subject: MC M. Sc. Chemistry Subject: SoC

Module structure

No.	**Course**	**Type**	**CP**	**SWS**	**Presence time**	**Self-study**
1	Applied Computer Methods in Life Sciences	S	4	2	30 h	90 h
		Total	4	2	**30 h**	**90 h**

Person responsible for the module	Prof. Dr. Michael E. Beck
Lecturer(s)	Prof. Dr. Michael E. Beck
Language	English
Requirements according to examination regulations	None
Recommended require-ments	Medicinal Chemistry 1 and 2; basic knowledge of mathe-matics, physics and physical chemistry; possibly (but not mandatory) modules “Computational Chemistry” and “Bio-molecular Modeling”. Introduction to data science in the field of chemistry and chemical biology.
Coursework / module exam-ination / partial assess-ments	1. Each participant prepares and delivers a seminar lecture based on a given topic and answers questions in a subse-quent discussion. 2. Active participation in the discussions on the presenta-tions of the other seminar participants. The module grade is made up of the grades for the presen-tation (40% presentation materials (“slides”), 40% oral part of the presentation) and participation in the discussions (weighting 20%). Attendance at this seminar is mandatory for the following reasons: 1. Each student gives a presentation followed by a discus-sion; this enters into the grading. 2. The learning objective of participating constructively and actively in discussions is graded as well.

	3. Points 1 and 2 require an actively participating audience. Maximum tolerable absences: 1-2 working days, exclusively with a certificate. The choice of presentation media (blackboard, Powerpoint, etc.) is free and lies within the responsibility of the presenter. The lecturer is responsible for ensuring that the resources to be used are actually available and technically working during the presentation.
Learning objectives	The students gain insights into applications, strengths and weaknesses of current computer-aided methods in the life sciences and improve their skills in constructively conducted scientific discourse.
Learning outcomes and competences	After successful completion of this module, students are enabled to - autonomously familiarize themselves with a new field of work in the field of computer methods of drug research using literature. - deal critically (in a constructive sense) with the scientific primary literature and to compare it with other sources. - present the knowledge gained in the form of a scientific lecture in English with presentation of the core questions, the theoretical background, the relationship to the experiment, the results, as well as critical discussion and classification in connection with other work. - share knowledge with others and participate actively and constructively in scientific discourse.
Content	Using examples from literature, applications and recent developments of computer methods in the life sciences are illustrated.
Media forms	Oral presentation and discussion. In principle, all forms of media available in the seminar room are permitted as means of presentation (from free presentations to blackboards to PowerPoint).
Literature	Scientific literature illustrating applications and developments of computational methods in the life sciences.

Compulsory elective lectures in Molecular Cell Biology

Module name			Compulsory Elective Lecture **Systems Biology**			
Abbreviation			MWV			
Interval of offer annual	**Duration** 1 semester		**Semester of study** 1 to 4	**Credits** 4	**Curriculum assignment** M. Sc. Chemical Biology Subject: ZB	
Module structure						
No.	**Course**	**Type**	**CP**	**SWS**	**Presence time**	**Self-study**
1	Systems Biology	V	3	2	30 h	60 h
2	Exercises for Systems Biology	Ü	1	1	15 h	15 h
		Total	**4**	**3**	**45 h**	**75 h**

Person responsible for the module	Prof. Dr. P. Bastiaens
Lecturer(s)	Prof. Dr. P. Bastiaens, Dr. P. Bieling, Dr. L. Dehmelt, Dr. M. Schmick, Dr. C. Schröter
Language	English
Requirements according to examination regulations	None
Recommended require-ments	Chemical Biology Bachelor modules in Cell Biology and Mathematics
Coursework / module exam-ination / partial assess-ments	Written examination, repeatability and rotation according to examination regulations.
Learning objectives	Students are taught the connection between the biochemistry of protein dynamics and interactions at the nanometer scale and (self-)organization of multicellular assemblies, on the multidisciplinary background of energy minimization, evolution and exploitation of energy-driven self-organization and information processing in signaling processes in living (mammalian) cells and organisms.
Learning outcomes and competencies	Upon successful completion of the module, students will be able to, – explain concepts of systems biology on the common basis of molecular biology, cell biology, biochemistry, biophysics as well as mathematics. – quantitatively explain cellular behaviors in the context of signal transduction, network dynamics and self-organization.

	– analyze current issues in molecular biology, cell biology, microscopy and micro-spectroscopy based on systems biology approaches. – critically handle and evaluate primary literature and experimental data.
Content	1. Flow equilibrium, (non-)equilibrium state and self-organization in living systems 2. Computer-aided data analysis of biological experiments 3. Cellular information processing in application and theory of biochemical signaling networks 4. Synthetic biology and the systems biochemistry of the cytoskeleton 5. Self-organization of microtubules and organizing principles of cell motility and morphogenesis 6. Systems Biology of development: from single cells to cell populations
Media Forms	Powerpoint presentation; via Moodle: skripts, exercise sheets and relevant literature as pdf
Literature	Primary specialist literature

<table>
<tr><td colspan="3">Module name</td><td colspan="6">Compulsory elective lecture
Experimental Cell Biology</td></tr>
<tr><td colspan="3">Abbreviation</td><td colspan="6">MWV</td></tr>
<tr><td colspan="2">Interval of offer
annual</td><td>Duration
1 semester</td><td colspan="2">Semester of study
1 to 4</td><td>Credits
4</td><td colspan="3">Curriculum assignment
M. Sc. Chemical Biology
Subject: ZB
M. Sc. Chemistry
Subject: SoC</td></tr>
<tr><td colspan="9">Module structure</td></tr>
<tr><td>No.</td><td colspan="2">Course</td><td>Type</td><td>CP</td><td>SWS</td><td>Presence time</td><td colspan="2">Selfstudy</td></tr>
<tr><td>1</td><td colspan="2">Experimental Cell Biology</td><td>V</td><td>3</td><td>2</td><td>30 h</td><td colspan="2">60 h</td></tr>
<tr><td>2</td><td colspan="2">Exercises for Experimental Cell Biology</td><td>Ü</td><td>1</td><td>1</td><td>15 h</td><td colspan="2">15 h</td></tr>
<tr><td colspan="4">Total</td><td>4</td><td>3</td><td>45 h</td><td colspan="2">75 h</td></tr>
<tr><td colspan="3">Person responsible for the module</td><td colspan="6">Prof. Dr. P. Bastiaens</td></tr>
<tr><td colspan="3">Lecturer(s)</td><td colspan="6">PD Dr. L. Dehmelt</td></tr>
<tr><td colspan="3">Language</td><td colspan="6">English</td></tr>
<tr><td colspan="3">Requirements according to examination regulations</td><td colspan="6">None</td></tr>
<tr><td colspan="3">Recommended require-ments</td><td colspan="6">Basic knowledge of cell biology, equivalent to the curriculum of the cell biology module taught during Bachelor’s studies at the TU Dortmund.</td></tr>
<tr><td colspan="3">Coursework / module ex-amination / partial assess-ments</td><td colspan="6">Written test or oral examination, repeatability and rotation according to examination regulations.</td></tr>
<tr><td colspan="3">Learning objectives</td><td colspan="6">The students acquire a basic understanding of cellular and molecular mechanisms in eukaryotic cells and how the knowledge to achieve this understanding can be extracted experimentally.</td></tr>
<tr><td colspan="3">Learning outcomes and competencies</td><td colspan="6">Upon successful completion of the module, students will be able to,
– evaluate the consequences for experimental investiga-tions that result from complexity and variability of biologi-cal systems.
– identify suitable strategies to manipulate and analyze cells based on knowledge of biological and biochemical techniques.</td></tr>
</table>

	– extract information about molecular mechanisms in cells by selecting appropriate experimental strategies. – evaluate confidence and validity of information that was acquired via experimental measurements. – discuss scientific problems with peers using correct technical terminology both orally and in writing.
Content	1. Interpreting measurements of biological systems: - Complexity in biology - Variability in biology - Confirmative and exploratory approach - Logic of experimental analysis and the scientific method - Applied statistics 2. Methods in cell biology - Isolation of cells and cell components - Analysis of cell structure and function - Inhibition of mRNA transcripts via RNA interference - Methods for specific manipulation of protein function - Methods for gene manipulation - Acute perturbation methods - Optogenetics - Reconstitution of cellular processes *in vitro* 3. Examples for experimental cell biology - Intracellular organization - Cell communication - Developmental biology - Neurobiology - Organization of the nucleus - Epigenetics
Media forms	PowerPoint presentations, pdf documents provided via the internet
Literature	1. Bruce Alberts, Alexander Johnson, Julian Lewis, Martin Raff, Keith Roberts, and Peter Walter. Molecular Biology of the Cell, 5th edition, 2008, Garland science, NewYork 2. Specific scientific literature (articles in scientific journals)

Module name	Compulsory elective lecture **Fundamental Immunology**			
Abbreviation	MWV			
Interval of offer annual	**Duration** 1 semester	**Semester of study** 1 to 4	**Credits**	**Curriculum assignment** M. Sc. Chemical Biology Subject: ZB

Module structure

No.	**Course**	**Type**	**CP**	**SWS**	**Presence time**	**Selfstudy**
1	Fundamental Immunology	V	3	2	30 h	60 h
2	Exercises for Fundamental Immunology	Ü	1	1	15 h	15 h
		Total	4	3	45 h	75 h

Person responsible for the module	Prof. Dr. Carsten Watzl
Lecturer(s)	Prof. Dr. C. Watzl, Dr. Doris Urlaub
Language	English
Requirements according to examination regulations	None
Recommended requirements	Basic knowledge of cell biology comparable to courses on cell biology in the bachelor's degree program in chemical biology.
Coursework / module examination / partial assessments	Written exam, retake options and rotation according to examination regulations.
Learning objectives	Students gain basic knowledge about the components and functions of the immune system. Furthermore, they gain knowledge to understand immunological analysis methods and therapeutic approaches. They gain basic knowledge about signal transduction processes in immune cells.
Learning outcomes and competencies	By successfully completing this module, students will be able to, - understand the different cell types and organs of the immune system and their functions based on their knowledge acquired in the course. - understand the interaction of the different components of the immune system in a successful immune response.

	- understand and evaluate experimental approaches for the investigation of immunological processes. - explain various manipulations of the immune system for therapeutic purposes. - present scientific facts in technically correct terms in speech and in writing and to discuss them with others.
Content	1. organs and cell types of the immune system 2. immunological processes during viral or bacterial infections 3. immunological effector mechanisms of infection control 4. basics of immunological anti-tumor response 5. novel immunologic therapeutic approaches - therapy with monoclonal antibodies, - cell therapy, - immunosuppressive drugs, - bone marrow transplantation 6. basics of signal transduction in immune cells - Signal transduction of cytokines, - T cell receptor, - inhibitory receptors
Media forms	Powerpoint presentation, online script (accompanying)
Literature	Janeway's Immunobiology, Publisher: Taylor & Francis Ltd.; 10th edition. Cellular and Molecular Immunology, Publisher: Saunders W.B.; 8th edition.

Module name	Compulsory elective lecture **Tissue Engineering**
Abbreviation	MWV

Interval of offer annual	**Duration** 1 semester	**Semester of study** 1 to 4	**Credits** 4	**Curriculum assignment** M. Sc. Chemical Biology Subject: ZB

Module structure

No.	**Course**	**Type**	**CP**	**SWS**	**Presence time**	**Selfstudy**
1	Tissue Engineering	V	3	2	30	60
2	Exercise for Tissue Engineering	Ü	1	1	15	15
		Total	**4**	**3**	**45**	**75**

Person responsible for the module	Prof. Dr. B. Trappmann
Lecturer(s)	Prof. Dr. B. Trappmann
Language	English
Requirements according to examination regulations	None
Recommended require-ments	Basic knowledge of cell biology, comparable to courses on cell biology in the Bachelor's degree program in chemical biology. Basic knowledge on biochemistry.
Coursework / module ex-amination / partial assess-ments	Coursework: seminar presentation, module examination: oral or written examination.
Learning objectives	Students acquire an overview over the different approaches to fabricate living tissues, and their applications in clinical settings (e.g. in the regeneration of damaged organ sites) and basic biomedical research (e.g. in testing of new drugs). They are able to apply their knowledge for new ex-periments, in scientific discussions and the assessment of literature in that field.
Learning outcomes and competencies	After module completion, students will be able to - explain basic design principles in tissue engineering and regenerative medicine - understand the criteria for choosing an appropriate com-bination of cell source, scaffolds and bioreactors to en-gineer specific tissues

	- apply tissue engineering principles to address clinical problems - demonstrate knowledge of already existing clinical applications of tissue engineering and their limitations - independently familiarize themselves with a biomedical topic/problem in a scientific manner - present complex interdisciplinary biomedical topics in spoken and written language using the correct scientific terminology
Content	1. Basic principles of tissue engineering 2. Biomaterials in tissue engineering – Scaffolds: design, materials, fabrication and characterization 3. Cell source: isolation, expansion, differentiation 4. In vitro control of tissue development – Microfluidic platforms – Principles of bioreactor design 5. Gene therapy 6. Current applications – Skin – Heart – Bone – Muscle – Nervous system 7. Fundamentals of drug delivery 8. In vivo transplantation of engineered tissues 9. Clinical translation 10. Applications of engineered tissues in drug testing/ replacement of animal models 11. Current challenges of tissue engineering and outlook on future possibilities
Media forms	Powerpoint presentations, chalkboard teaching, research papers
Literature	Literature recommendations will be made during the course

Module name	Compulsory elective lecture **Current Topics in Cell Biology**
Abbreviation	MWV

Interval of offer annual	**Duration** 1 semester	**Semester of study** 1 to 4	**Credits** 4	**Curriculum assignment** M. Sc. Chemical Biology Subject: ZB

Module structure

No.	**Course**	**Type**	**CP**	**SWS**	**Presence time**	**Selfstudy**
1	Current Topics in Cell Biology	V	3	2	30	60
2	Seminar for Current Topics in Cell Biology	S	1	1	15	15
		Total	**4**	**3**	**45**	**75**

Person responsible for the module	Prof. Dr. B. Pfander
Lecturer(s)	Prof. Dr. B. Pfander
Language	English
Requirements according to examination regulations	None
Recommended requirements	Basic knowledge of cell biology, comparable to courses on cell biology in the Bachelor's degree program in chemical biology. Basic knowledge on biochemistry.
Coursework / module examination / partial assessments	Module examination: presentation of a research paper in the seminar with discussion. Attendance of seminars is compulsory, as teaching and learning content will be acquired through presentations of the current literature and discussions. Therefore, the learning objectives can only be achieved through regular participation. Presence on all but max. 3 seminars is required for successful participation.
Learning objectives	With this module, students acquire the principal ability to deal with cell biological topics using the scientific literature. Based on primary research articles they will be able to acquire the knowledge to critically judge new development in the field of cell biology, to present it to others and to form an informed opinion.
Learning outcomes and competencies	After module completion, students will be able to – acquire the ability to effectively read and work with the current scientific literature in the field of cell biology

	– develop strategies for presenting the research work of others – from hypothesis to conclusion – confidently present cell biological topics in spoken and written language using the correct scientific terminology – put the content of articles from selected research papers and research work of others into context – independently familiarize themselves with a current topic in cell biology – understand in detail specific functions in the cell including the flow of the genetic information, cell signalling and how DNA - the carrier of the genetic information - is maintained – explain the theoretical background of modern cell biological methods - from application to analysis of develop design strategies for biomedical applications at the interface of chemistry, materials science and cell biology – formulate relevant questions for cell biological research
Content	Insights into current topics and methods in cell biology from the following fields: 1. From DNA to protein – the flow of the genetic information 2. Cellular Signalling – from signals to responses 3. Genome Maintenance and architecture of the nucleus
Media forms	Powerpoint presentations, chalkboard teaching
Literature	Literature recommendations will be made during the course

Module name			Compulsory elective lecture **Genome Cell Biology**					
Abbreviation			MWV					
Interval of offer annual		**Duration** 1 semester	**Semester of study** M. Sc. 1 to 4		**Credits** 4	**Curriculum assignment** M. Sc. Chemical Biology Subject: ZB		
Module structure								
No.	**Course**		**Type**	**CP**	**SWS**	**Presence time**	**Self-study**	
1	Genome Cell Biology		V	3	2	30	60	
2	Exercise for Genome Cell Biology		S	1	1	15	15	
			Total	**4**	**3**	**45**	**75**	

Person responsible for the module	Prof. Dr. B. Pfander
Lecturer(s)	Prof. Dr. B. Pfander
Language	English
Requirements according to examination regulations	None
Recommended require-ments	Basic knowledge of cell biology, comparable to courses on cell biology in the Bachelor's degree program in chemical biology. Basic knowledge on biochemistry.
Coursework / module exam-ination / partial assess-ments	Module examination: oral or written examination
Learning objectives	With this module, students acquire an in-depth view of the cell biology of the nucleus – from cell cycle signaling to DNA repair. They also learn the principles of state-of-the-art methodology to approach the questions of genome cell biology – from next-generation sequencing to genome edit-ing, and they are able to apply their knowledge.
Learning outcomes and competencies	After module completion, students will be able to - understand basic and advanced concepts of genome cell biology including the flow of the genetic information, DNA replication and genome integrity and how DNA - the carrier of the genetic information - is maintained - explain the principal challenges for the inheritance of the genetic information, genome maintenance and ge-nome integrity as well as biological solutions towards these challenges

	- apply principles of genetics, genomics and cell biological methods to address problems in genome cell biology - demonstrate knowledge of recent developments in the field of genome cell biology and formulate relevant research questions - independently familiarize themselves with advanced topics in cell biology
Content	1. DNA, Chromosomes and Genomes 2. The flux of the genetic information – from DNA to protein 3. The Nucleus – a cellular compartment devoted to maintaining the genetic information 4. The Cell Cycle 5. DNA Replication and Genome Maintenance 6. DNA Damage and Signalling 7. DNA Recombination 8. Genomics and Next Generation Sequencing 9. NGS Methods to analyze genome integrity 10. Genome Editing
Media forms	Powerpoint presentations, chalkboard teaching
Literature	Alberts et al., “Molecular Biology of the Cell” 6th Edition; Additional literature recommendations will be made during the course

Compulsory elective lectures in Chemical Biology

Module name	Compulsory elective lecture **Cryo-Electron Microscopy**
Abbreviation	MWV

Interval of offer annual	**Duration** 1 semester	**Semester of study** 1 to 4	**Credits** 4	**Curriculum assignment** M. Sc. Chemical Biology Subject: CB

Module structure

No.	**Course**	**Type**	**CP**	**SWS**	**Presence time**	**Self-study**
1	Cryo-Electron Microscopy	V	3	2	30 h	60 h
2	Exercises for Cryo-Electron Micros-copy	Ü	1	1	15 h	15 h
	Total		**4**	**3**	**45 h**	**75 h**

Person responsible for the module	Prof. Dr. S. Raunser
Lecturer(s)	Prof. Dr. S. Raunser, Dr. S. Pospich, Dr. S. Tacke, Dr. T. Raisch, Dr. T. Wagner
Language	English
Requirements according to examination regula-tions	None
Recommended require-ments	None
Coursework / module ex-amination / partial assess-ments	Written exam, repeat options according to examination regu-lations.
Learning objectives	Students acquire basic knowledge of protein and cell struc-ture determination by electron microscopy, as well as critical analysis and interpretation of electron microscopy data.
Learning outcomes and competencies	By successfully completing this module, students will be able to, – explain and classify the importance of structural biology, especially electron microscopy, for the topics of biochem-istry and biomedicine. – describe the theoretical basics of electron microscopy. – explain the different methods of electron microscopy and to be able to select problem-oriented.

	– describe details of specimen preparation and to name approaches for optimization. – deal critically with electron microscopic data.
Content	1. Theory of electron microscopy - Brief history - Physical basics of image formation - Methods of electron microscopy • SEM/TEM/STEM • Single particle electron microscopy • Electron tomography • Correlative electron microscopy • Microcrystal electron diffraction - Instrumentation and current development - Data collection 2. Sample preparation and optimization - Sample requirements - Preparation methods • Room temperature methods • Cryofixation methods (Cryo-EM/Cryo-ET/ HPF/FIB) - Evaluation and optimization of samples 3. Image processing - Single particle analysis - Reconstruction of tomograms - Subtomogram averaging - Limitations and current development - Insight into protein structure modeling 4. critical analysis and evaluation of electron microscopy data and studies
Media forms	Powerpoint presentation, online script (accompanying)
Literature	1. J. Frank (2006) Three-dimensional Electron Microscopy of Macromolecular Assemblies, Oxford Univ Pr 978-0-1951-8218-7 2. J. Frank (2006) Electron Tomography, Springer 978-0387-31234-7 3. L. Reimer (2008) Transmission Electron Microscopy, Springer 978-0-3875-0499-5 4. https://cryo-em-course.caltech.edu/overview

Module name	Compulsory elective lecture **Post-Translational Modification of Proteins**			
Abbreviation	MWV			
Interval of offer annual	**Duration** 1 semester	**Semester of study** 1 to 4	**Credits** 4	**Curriculum assignment** M. Sc. Chemical biology Subject: CB

Module structure

No.	**Course**	**Type**	**CP**	**SWS**	**Presence time**	**Self-study**
1	Post-translational modification of proteins	V	3	2	30 h	60 h
2	Exercises for Post-translational modification of proteins	Ü	1	1	15 h	15 h
	Total		**4**	**3**	**45 h**	**75 h**

Person responsible for the module	Dr. M. Gersch
Lecturer(s)	Dr. M. Gersch, Dr. K. Kliza
Language	English
Requirements according to examination regulations	None
Recommended requirements	Solid basic knowledge of biochemistry (Stryer, Voet & Voet, Lehninger) and organic chemistry (Clayden)
Coursework / module examination / partial assessments	Voluntary course work: On application, the completion of exercises can be included in the module grade as a bonus of 5 %. Module examination, repeat options and rotation according to examination regulations.
Learning objectives	Students gain an overview of the most important post-translational modifications (PTM) and their significance for cellular processes. They learn the chemical background of different mechanisms of PTM and modern biological-chemical research areas and methods.
Learning outcomes and competencies	After successful completion of this module students will be able to – explain mechanisms of protein-modifying enzymes and PTM-recognising proteins. – explain important case studies of the modifications presented. – describe relationships of complex mechanisms of signal transduction.

	– explain and classify the significance of modern methods of protein analytics, chemical biology and structural biology in relation to post-translational modifications. – link biological questions with the underlying chemistry resp. with relevant protein structures. – independently work on a topic by selecting suitable strategies for receiving information. – evaluate validity and safety of information. – present scientific matters correctly in written and spoken language and discuss them with others.
Content	The following post-translational modifications are discussed: 1. methylation 2. phosphorylation 3. acetylation 4. glycosylation 5. lipidation 6. ubiquitination 7. SUMOylation 8. proteolysis 9. hydroxylation 10. polyADP-ribosylation 11. bacterial/viral virulence factors
Media forms	Blackboard pictures, PowerPoint presentation, paper discussions, own notes
Literature	1. The Cell, 5. Ed. Alberts et. al. 2. Reviews and original articles from the current literature

Module name		Compulsory elective lecture **Bioorganic Chemistry II**				
Abbreviation		MWV				
Interval of offer annual	**Duration** 1 semester	**Semester of study** 1 to 4	**Credits** 4	**Curriculum assignment** M. Sc. Chemistry Subject: SoC M. Sc. Chemical Biology Subject: CB		
Module structure						
No.	**Course**	**Type**	**CP**	**SWS**	**Presence time**	**Self-study**
1	Bioorganic chemistry II	V	3	2	30 h	60 h
2	Exercises for Bioorganic chemistry II	Ü	1	1	15 h	15 h
		Total	**4**	**3**	**45 h**	**75 h**
Person responsible for the module		Prof. Dr. H. Mutschler				
Lecturer(s)		University lecturers of chemical biology (for current semester see announcement of chemical biology)				
Language		English				
Requirements according to examination regulations		None				
Recommended requirements		Solid basic knowledge in organic chemistry, bioorganic chemistry and biochemistry				
Coursework / module examination / partial assessments		Graded written exam, possibility to repeat and rotation according to examination regulations.				
Learning objectives		The students acquire advanced knowledge of general principles and methods of bioorganic chemistry and are able to apply this knowledge for the planning of bioorganic synthesis.				
Learning outcomes and competencies		Upon successful completion of the module, students will be able to – explain essential theoretical knowledge about reactions and methods in bioorganic chemistry. – understand the importance of bioorganic chemistry with regard to the subject areas of chemical biology and organic synthesis and to use this understanding to solve interdisciplinary biological-chemical problems.				

	– plan simple bioorganic syntheses. – apply the theoretical knowledge acquired to independently develop suitable strategies for solving biological and chemical problems. – discuss one's own solution strategies, to convey one's own point of view appropriately and to work together with others.
Content	1. Chemistry of carbohydrates - synthesis and properties - biological significance 2. Chemistry of lipids - synthesis and properties - biological significance
Media forms	blackboard (either virtual or physical) structures and diagrams, powerpoint presentations, pdf versions of lecture powerpoints as accompanying scripts, interactive online teaching tools (e.g. Zoom lectures, Kahoot quiz, etc.)
Literature	Thisbe K. Lindhorst: Essentials of Carbohydrate Chemistry and Biochemistry, Wiley-VCH. David Van Vtranken and Gregory Weiss: Introduction to Bioorganic Chemistry and Chemical Biology, Garland Science.

Module name		Compulsory elective lecture **Chemical Epigenetics**					
Abbreviation		MWV					
Interval of offer annual	**Duration** 1 semester	**Semester of study** 1 to 4	**Credits** 4	**Curriculum assignment** M. Sc. Chemical Biology Subject: CB			
Module structure							
No.	**Course**	**Type**	**CP**	**SWS**	**Presence time**	**Self-study**	
1	Chemical Epigenetics	V	3	2	30 h	60 h	
2	Exercises for Chemical Epigenetics	Ü	1	1	15 h	15 h	
	Total		**4**	**3**	**45 h**	**75 h**	

Person responsible for the module	Prof. Dr. Daniel Summerer
Lecturer(s)	Prof. Dr. Daniel Summerer
Language	English
Requirements according to examination regulations	None
Recommended require-ments	Solid basic knowledge of biochemistry and organic chemis-try
Coursework / module ex-amination / partial assess-ments	Seminar lecture (ungraded course work) and oral module examination, repeat options and rotation according to exam-ination regulations.
Learning objectives	Students acquire an overview of epigenetic mechanisms of gene regulation. In particular, they will gain knowledge of the chemical basis of these mechanisms and their effects on cell fate, methods for the synthesis of epigenetically modi-fied proteins and nucleic acids, and their analysis in vitro and in vivo.
Learning outcomes and competencies	By successfully completing this module, students will be able to, – assess epigenetic modifications in DNA, RNA and pro-teins in their biological function. – detail biological mechanisms for the introduction, regula-tory recognition, and removal of such modifications. – know chemical biological methods for the synthesis of epigenetically modified DNA, RNA and proteins and be able to select them according to a given problem.

	– select and evaluate analytical methods for the presence of specific modifications in biomacromolecules. – propose solutions for the study of biomacromolecular interactions in vitro and in vivo, both in individual complexes and at the genome-, transcriptome-, and proteome-wide levels. – independently familiarize themselves with a topic by selecting appropriate strategies for obtaining information. – evaluate validity and safety of information and experimental measurements. – use scientific terms correctly in spoken and written language and discuss them with others.
Content:	**Chemical Epigenetics** 1. Introduction – Genotype and phenotype – Epigenetics - Definitions – Epigenetically controlled processes 2. Genomes and chromatin – Genome sizes – Genome complexity and organization – The human genome – Transcription – Epigenetic regulation of transcription – Eu- and heterochromatin 3. Biology of epigenetic DNA modifications – Types of modifications – Organismic distribution – Biological functions – Mechanisms of introduction – Regulatory recognition and removal in the genome 4. Synthesis of epigenetically modified DNA – DNA solid phase synthesis – Postsynthetic modifications – Array synthesis – Enzymatic modifications – Epigenome - Engineering 5. Analysis of epigenetically modified DNA – Genomic content analysis via LCMS-MS – Hybridization-based methods – PCR methods – Sequencing Concepts – High-throughput sequencing, single-molecule sequencing – Chem. conversion and tagging chemistries 6. Biology of epigenetic protein modifications – Histones + nucleosomes,

	– Mechanisms of introduction, – Regulatory recognition and removal of lysine acetylation, – Methylation, – Other modifications – Nucleosome Remodelling – The histone code 7. Synthesis of epigenetically modified proteins – Peptide solid phase synthesis – Ligation methods – Expansion of the genetic code 8. Analysis of epigenetically modified proteins – Interaction analysis in solution – Footprinting – Nucleoside and amino acid analogs for analysis – Discovery of unknown interaction partners – High-throughput methods for chromatin analysis
Media forms	PowerPoint presentation, blackboard images.
Literature	– Allis, Caparros, Jenuwein, Reinberg, Epigenetics, CSHL, 2015. – Lyle Armstrong, Epigenetics, Garland Science, 2014. – General basic literature in biochemistry and molecular biology (Stryer, Alberts, etc.).

Module name	Compulsory elective lecture **Cell-free Systems**
Abbreviation	MWV

Interval of offer	**Duration**	**Semester of study**	**Credits**	**Curriculum assignment**
annual	1 semester	1 to 4	4	M. Sc. Chemical Biology Subject: CB

Module structure

No.	Course	Type	CP	SWS	Presence time	Self-study
1	Cell-free systems	V	3	2	30 h	60 h
2	Literature seminar	S	1	1	15 h	15 h
	Total		4	3	45 h	75 h

Person responsible for the module	Prof. Dr. Hannes Mutschler
Lecturer(s)	Prof. Dr. Hannes Mutschler
Language	English
Requirements according to examination regulations	None
Recommended require-ments	Solid knowledge of biochemistry and molecular biology
Coursework / module ex-amination / partial assess-ments	Journal club (ungraded course work), oral or written module examination.
Learning objectives	The students will acquire an overview of the possible applications of cell-free systems in basic research, synthetic biology including the production and engineering of biosensors, therapeutics, metabolites and proteins. In particular, they will gain knowledge about the possible applications of different cell-free expression systems and will be able to apply the knowledge to solve problems in synthetic biology.
Learning outcomes and competencies	By successfully completing this module, students will be able to: – assess the importance of cell-free biology in biotechnology, biomedicine and basic research. – explain methods and applications of cell-free systems, especially cell-free expression systems.

	– describe the design and generation of artificial biosystems and to be able to assess their potential, for example in molecular diagnostics or basic research. – independently familiarize themselves with a scientific question / topic by selecting appropriate strategies for information acquisition. – evaluate the validity and safety of information and experimental measurements. – present scientific facts in technical language in speech and writing and to discuss them with others.
Content	1. Introduction to the research questions and applications of cell-free systems 2. Development and use of genetic devices and circuit prototyping 3. Protein and metabolic engineering 4. Engineering of macromolecular assemblies and therapeutics 5. Development of cell-free biosensors and diagnostics 6. Artificial cells and smart materials 7. In vitro evolution in cell-free systems 8. Translation-free protein and nucleic acid acid-based systems 9. Applications of catalytic nucleic acids in cell-free systems 10. Use of cell-free systems to study the origin of life
Media forms	Powerpoint presentations, research papers, online script
Literature	The New Age of Cell-Free Biology, Noireaux and Liu (2020) *Annual Review of Biomedical Engineering*, 22, 51 Silverman *et al.*, Cell-free gene expression: an expanded repertoire of applications. (2020) *Nature Reviews Genetics* 21, 151 Hodgman & Jewett, Cell-free synthetic biology: Thinking outside the cell. (2012) *Metabolic Engineering*, 14, 261 General basic literature of biochemistry and molecular biology (Stryer, Alberts, etc.).

Module name						Compulsory elective lecture **Biomaterials: From Cells to Tissues**
Abbreviation						MWV
Interval of offer annual	**Duration** 1 semester		**Semester of study** 1 to 4	**Credits** 4		**Curriculum assignment** M. Sc. Chemical Biology Subject: CB

Module structure

No.	**Course**	**Type**	**CP**	**SWS**	**Presence time**	**Self-study**
1	Biomaterials: From cells to tissues	V	3	2	30	60
2	Exercise for Biomaterials: From cells to tissues	Ü	1	1	15	15
		Total	**4**	**3**	**45**	**75**

Person responsible for the module	Prof. Dr. B. Trappmann
Lecturer(s)	Prof. Dr. B. Trappmann
Language	English
Requirements according to examination regulations	None
Recommended require-ments	Basic knowledge of cell biology, comparable to courses on cell biology in the Bachelor's program in chemical biology. Basic knowledge on biochemistry.
Coursework / module exami-nation / partial assessments	Coursework: seminar presentation, module examination: oral or written examination.
Learning objectives	Students acquire an overview over the different classes of cell-instructive biomaterials, including their synthesis, functionalization and characterization. In particular, they acquire knowledge on how biomaterials design can be used to control cell function in 2D and 3D environments and apply such principles to design in vitro models of complex multicellular systems.
Learning outcomes and competencies	After module completion, students will be able to – explain basic design principles in modern biomaterials and cell culture scaffolds – understand how properties of biomaterials regulate cell function and apply this knowledge to custom-design biomaterials for specific cell culture applications

	– develop design strategies for biomedical applications at the interface of chemistry, materials science and cell biology – independently familiarize themselves with a biomedical topic/problem in a scientific manner – present complex interdisciplinary biomedical topics in spoken and written language using the correct scientific terminology
Content	1) Introduction to biological tissues – properties at the cellular scale – properties at the macromolecular scale: composition of the extracellular matrix 2) Interactions between cells and their native tissue environment – soluble signals – matrix-bound cues – matrix mechanics – cell-cell interactions 3) Biomaterials and scaffolds: definitions and fundamental properties – biocompatibility, biodegradability, structural and functional support for cells 4) Types of biomaterial scaffolds – natural biomaterials (decellularized tissues, ECM protein hydrogels) – synthetic polymeric biomaterials 5) Scaffold design and biomaterial properties – structure (porosity, fibrous) – mechanical and degradative properties – biochemical composition – topography 6) Scaffold fabrication techniques – hydrogel synthesis and functionalization – techniques to introduce porosity – fiber electrospinning – 3D printing 7) Biomaterials in 2D versus 3D cell culture: applications 8) Regulation of cell function by biomaterial properties – cell-matrix interactions (e.g. cell adhesion, mechanotransduction) – cell migration – stem cell proliferation and differentiation

	9) Towards organ culture: designer matrices for multi-cellular systems 10) Use of biomaterials in vivo
Media forms	Powerpoint presentations, chalkboard teaching
Literature	Literature recommendations will be made during the course

Further compulsory elective lectures

Module name		Compulsory elective lecture **Analytical Chemistry - Water and Soil**		
Abbreviation		MWV		
Interval of offer bi-annual (WiSe even year)	**Duration** 1 semester	**Semester of study** 1 to 4	**Credits** 4	**Curriculum assignment** M. Sc. Chemistry Subject: AC or OC Major subject: M. M. M. Sc. Chemical Biology Subject: SoC

Module structure

No.	**Course**	**Type**	**CP**	**SWS**	**Presence time**	**Self-study**
1	Analytical Chemistry - Water and Soil	V	3	2	30 h	60 h
2	Exercises for Analytical Chemistry - Water and Soil	Ü	1	1	15 h	15 h
		Total	4	3	45 h	75 h

Person responsible for the module	Dr. Sebastian Zühlke
Lecturer(s)	Dr. Sebastian Zühlke
Language	English
Requirements according to examination regulations	None
Recommended requirements	Sufficient knowledge of analytical chemistry and basic knowledge of mathematics is advantageous.
Coursework / module examination / partial assessments	Written or oral module examination. Repeatability and rotation according to examination regulations.
Learning objectives	The students gain an overview of the common methods of water and soil analysis. In particular, the modern sample preparation and separation methods as well as the functioning of the devices and application areas.
Learning outcomes and competencies	Upon completion of the module, students will be able to, – classify basic analytical separation methods and sample preparations of water and soil analysis. – apply knowledge in the field of equipment used and decide on their scope of application (depending on the problem).

	– explain theoretical background of the methods in detail. – determine method characteristics for chromatographic separations. – use acquired theoretical knowledge for the practice-oriented solution of analytical problems. – evaluate validity and safety of experimental measurements. – present scientific facts correctly in spoken and written language and discuss them with others.
Content	1. Environmental analytics in general – Identification and quantitation – Calibration and validation – Chromatographic techniques for sample preparation and analyte separation (GC, LC, SFC, DC, IC) – Detectors for GC and HPLC (MS, HR-MS, IR, DAD, fluorescence, AED) – Stable isotope analysis – ^{14}C analytics – Sampling – Experimental design and evaluation of experiments – Current trends and research methods 2. Water – Turbidity and coloration – Enrichment techniques (SPE, SPME, FFE) – Volatile compounds by means of headspace and purge&trap 3. Soil – Inorganic parameters (AAS, AES, ICP-MS) – Sorption to surfaces/soil – organic sum parameters – Degradation, sorption and mobility of organic pollutants (e.g. PAHs, pesticides) – Extraction methods from solid matrix (ASE, SFE)
Media forms	Powerpoint presentations, electronic scripts, blackboard pictures, other working materials, exercises at computer workstations
Literature	• Georg Schwedt: Taschenatlas der Analytik, Wiley-VCH, 2007 • Niessner, Schäffer: Organic Trace Analysis, Walter de Gruyter GmbH, Berlin/Boston, 2017 • Georg Schwedt: The Essential Guide to Analytical Chemistry, Wiley-VCH, 1997 • Jürgen Schwörbel, Heinz Brendelberger: Einführung in die Limnologie, 9.Auflage, Spektrum Verlag, 2005 • Marc Pansu, Jacques Gautheyrou: Handbook of Soil Analysis, Springer Verlag Berlin, 2006 • Bracher, F. et al.: Arbeitsbuch instrumentelle Analytik, Govi-VerlagGmbH, Eschborn, 2008

	• H.-J. Hübschmann: Handbook of GC/MS: Fundamentals and Applications, Wiley-VCH; 3. Edition, 2015

Module name	Compulsory elective lecture **Umweltchemie (Environmental Chemistry)**
Abbreviation	MWV

Interval of offer	**Duration**	**Semester of study**	**Credits**	**Curriculum assignment**
annual (SoSe)	1 semester	B. Sc. 5 or 6 M. Sc. 1 to 4	4	M. Sc. Chemistry Subject: AC or OC Major subject: M. M. M. Sc. Chemical Biology Subject: SoC B. Sc. Chemie B. Sc. Chemische Biologie „studium oecologicum“

Module structure

No.	Course	Type	CP	SWS	Presence time	Self-study
1	Umweltchemie	V	3	2	30 h	60 h
2	Seminar zu Umweltchemie	S	1	1	15 h	15 h
	Total		4	3	45 h	75 h

Person responsible for the module	Dr. Sebastian Zühlke
Lecturer(s)	Dr. Sebastian Zühlke
Language	German
Requirements according to examination regulations	None
Recommended requirements	Grundkenntnisse in anorganischer und organischer Chemie
Coursework / module examination / partial assessments	Seminarvortrag (unbenotete Studienleistung) sowie Klausur oder mündliche Prüfung am Ende des Moduls, Wiederholungsmöglichkeiten und Turnus gemäß PO
Learning objectives	Die Studierenden erlangen einen Überblick über die grundlegenden Zusammenhänge in den Umweltkompartimenten Wasser, Luft und Boden. Sie sind nach erfolgreichem Abschluss des Moduls fähig, komplexe Prozesse in der Umwelt, im Besonderen die Wechselwirkungen der verschiedenen Umweltkompartimente und der darin enthaltenen Stoffe, sowie deren Auswirkung auf das gesamte Ökosystem einzuordnen.

Learning outcomes and competencies	Die Studierenden sind nach Beendigung des Moduls in der Lage, – grundlegende Zusammenhänge in den Umweltkompartimenten Wasser, Luft und Boden zu erklären. – komplexe Prozesse in der Umwelt einzuordnen. – Wechselwirkungen/Prozesse der verschiedenen Umweltkompartimente und der enthaltenen Stoffe zu beschreiben. – Auswirkungen einzelner Einflüsse auf das gesamte Ökosystem zu erkennen. – vermitteltes theoretisches Wissen anzuwenden, um komplexe umweltchemische Probleme zu erkennen und zu bewerten. – Umweltverhalten von Chemikalien zu verstehen, vorherzusagen und beim wissenschaftlichen Arbeiten zu berücksichtigen – vermitteltes Wissen sicher zu präsentieren und zu diskutieren.
Content	1. Atmosphärenchemie – Aerosole – Ozon – Photochemie – Luftverschmutzung – Treibhauseffekt – Feinstaub – Smog – Abgasreinigung 2. Wasserchemie – Stoffhaushalt der Gewässer – chemische Verschmutzungsindikatoren – physikalische Verhältnisse im Gewässer – Trinkwasseraufbereitung – Abwasserbehandlung – Eintrag und Verhalten von Wasserschadstoffen 3. Bodenchemie – physikalische und chemische Bodenstruktur – Schwermetalle – saurer Regen – Fracking – Sorption, Mobilität und Abbau von organischen Schadstoffen 4. Allgemeine Grundlagen – Zusammensetzung und Bedeutung von Wasser, Boden und Luft – Stoffkreisläufe – Verbleib von organischen Schadstoffen (Distribution, Akkumulation, Abbau) – spezielle Xenobiotika/Stoffklassen (z.B. Pestizide, Arzneimittelrückstände) – neuste Trends und aktuelle Problemverbindungen

Media forms	Powerpoint-Präsentationen, elektronische Skripte, Tafelbilder, online-Tests, weitere Arbeitsmaterialien
Literature	– Claus Bliefert: Umweltchemie, Wiley-VCH Weinheim, 2010 – Jürgen Schwörbel, Heinz Brendelberger: Einführung in die Limnologie, 9.Auflage, Spektrum Verlag, 2005 – Georg Schwedt: Taschenatlas der Umweltchemie, Georg Thieme Verlag Stuttgart, 1996 – Ulrich Gisi: Bodenökologie, Georg Thieme Verlag Stuttgart, 1996 – Karl Fent: Ökotoxikologie: Umweltchemie – Toxikologie – Ökologie, 4.Auflage, Thieme Verlag, 2013

Module name	Compulsory elective lecture **Introduction to Mass Spectrometry**
Abbreviation	MWV

Interval of offer	**Duration**	**Semester of study**	**Credits**	**Curriculum assignment**
bi-annual (WiSe odd year)	1 semester	1 to 4	4	M. Sc. Chemistry Subject: AC or OC Major subject: M. M. M. Sc. Chemical Biology Subject: SoC

Module structure

No.	**Course**	**Type**	**CP**	**SWS**	**Presence time**	**Self-study**
1	Introduction to Mass Spectrometry	V	3	2	30 h	60 h
2	Exercises for Introduction to Mass Spectrometry	Ü	1	1	15 h	15 h
	Total		4	3	45 h	75 h

Person responsible for the module	Dr. Sebastian Zühlke
Lecturer(s)	Dr. Sebastian Zühlke
Language	English
Requirements according to examination regulations	None
Recommended require-ments	Sufficient knowledge of Analytical Chemistry and basic knowledge of mathematics is advantageous.
Coursework / module ex-amination / partial assess-ments	Written or oral module examination. Repeatability and rotation according to examination regula-tions.
Learning objectives	The students gain an overview of mass spectrometry. They acquire knowledge about modern mass spectrometers and their mode of operation as well as their areas of application. In the exercise part, the students learn the practical evalua-tion based on selected data and spectra.
Learning outcomes and competencies	By successfully completing this module, students will be able to, – classify mass spectrometry as a method within the framework of structure elucidation. – explain the basics of mass spectrometry including the necessary theory.

	– use the acquired theoretical knowledge for the practice-oriented solution of mass spectrometric problems by selecting appropriate strategies for obtaining information. – evaluate the validity and safety of information and experimental measurements. – present scientific facts in technical language correctly in speech and writing and discuss them with others.
Content	1. Basics of MS 2. Quadrupoles, ion traps, TOF, Orbitrap, FTICR 3. Ionization techniques for chromatographic coupling (EI, CI, ESI, APCI) 4. MALDI and MALDI imaging 5. Ion mobility 6. Fragmentation reactions of MS 7. IRMS, stable isotopes, radiotracer and radiocarbon method.
Media forms	Powerpoint presentations, blackboard, electronic scripts, online tests, exercises at computer workstations, further working materials
Literature	– Jürgen Gross: Mass Spectrometry, Springer-Verlag, 2017 – Matthias Otto: Analytical Chemistry, Wiley-VCH, 2019 – Schwedt, Schmidt, Schmitz: Analytical Chemistry, Wiley-VCH, 2017. – H.-J. Hübschmann: Handbook of GC/MS, Wiley-VCH, 2009

Module name	Compulsory elective lecture **High Resolution NMR in Chemistry and Chemical Biology**
Abbreviation	MWV

Interval of offer annual	**Duration** 1 semester	**Semester of study** 1 to 4	**Credits** 4	**Curriculum assignment** M. Sc. Chemistry Subject: AC or OC Major subject: M. M. Subject: PC Major subject: E. T. M. Sc. Chemical Biology Subject: SoC

Module structure

No.	**Course**	**Type**	**CP**	**SWS**	**Presence time**	**Self-study**
1	High Resolution NMR in Chemistry and Chemical Biology	V	3	2	30 h	60 h
2	Exercises for High Resolution NMR in Chemistry and Chemical Biology	Ü	1	1	15 h	15 h
		Total	**4**	**3**	**45 h**	**75 h**

Person responsible for the module	Prof. Dr. W. Hiller
Lecturer(s)	Prof. Dr. W. Hiller
Language	English
Requirements according to examination regulations	None
Recommended requirements	none
Coursework / module examination / partial assessments	Oral or written module examination. Possibilities of repetition and rotation according to examination regulations.
Learning objectives	Students acquire basic knowledge of structural analysis using modern multidimensional NMR methods and are able to apply the acquired knowledge to solve simple problems in the study of chemical structures.
Learning outcomes and competencies	By successfully completing this module, students will be able to, – explain advanced and modern NMR methods and select them according to the problem.

	– use the acquired theoretical and practical knowledge for the elaboration of analytical solution strategies based on fundamentals of physics and mathematics for the processing of problems. – derive reasonable structural proposals for the investigated substance from given NMR spectra as well as the corresponding NMR spectra from a given structural formula. – describe the basic apparatus structure of analytical instruments and to explain the importance of key technical elements. – reproduce and apply the methodology of processing of obtained raw data. – combine the obtained analytical results for a substance and draw conclusions on structural properties. – act responsibly in consideration of legal regulations when handling high magnetic fields. – present scientific facts correctly in technical language, both orally and in writing, and to discuss them with others.
Content	**High resolution NMR** 1. basics of NMR – vector model – operator model – chemical shift – signal intensity – direct and indirect nuclear spin coupling 2. multinuclear NMR (e.g. ^{1}H-, ^{2}H-, ^{11}B- ^{19}F-, ^{13}C-, ^{15}N-, ^{17}O-, ^{29}Si-, ^{31}P-, ^{119}Sn-NMR) 3. General classification of chem. shifts, – additivity rules, – influences on chemical shifts and coupling constants. 4. qualitative and quantitative hetero nuclei NMR measurements 5. decoupling methods 6. two-dimensional NMR – fundamentals (absolute value and phase sensitive techniques, homonuclear and heteronuclear techniques). – 2D NMR and – structural analysis 7. processing NMR measurements 8. selective excitation using shaped pulses 9. solvent suppression methods

	10. determination of structures by different NMR methods 11. DOSY (diffusion ordered spectroscopy) for analysis of chemical mixtures and molecular sizes 12. NMR characterization of polymers – microstructure – chemical composition – molecular dynamics 13. coupling of HPLC and NMR
Media forms	Powerpoint presentation, board diagrams, slides, visual aids: tour of NMR lab.
Literature	High resolution NMR: - Horst Friebolin, One- and two-dimensional NMR spectroscopy, Wiley-VCH, 1998. - T.Claridge, High-Resolution NMR Techniques in Organic Chemistry, Pergamon, 1999 - S.Berger, S.Braun, 200 and more NMR Experiments, Wiley-VCH, 2004 - Terence Mitchell, Burkhard Costisella, NMR- From Spectra to Structures, Springer-Verlag, 2007 - James Keeler, Understanding NMR Spectroscopy, John Wiley & Sons Ltd. 2005

Module name		Compulsory elective lecture **Chemikalienrecht und Arbeitsschutz (Chemical Law and Occupation Safety)**		
Abbreviation		MWV		
Interval of offer annual	**Duration** 1	**Semester of study** B. Sc. 5 or 6 M. Sc. 1 to 4	**Credits** 4	**Curriculum assignment** B. Sc. Chemie B. Sc. Chemische Biologie M. Sc. Chemistry Subject: SoN M. Sc. Chemical Biology Subject: SoN

Modulstruktur

No.	**Course**	**Type**	**CP**	**SWS**	**Presence time**	**Self-study**
1	Chemikalienrecht und Arbeitsschutz	V	3	2	30 h	60 h
2	Übungen zu Chemikalienrecht und Arbeitsschutz	Ü	1	1	15 h	15 h
		Summe	**4**	**3**	**45 h**	**75 h**

Person responsible for the module	N.N.
Lecturer(s)	Dr. Vivien Lange
Language	German
Requirements according to examination regulations	None
Recommended requirements	None
Coursework / module examination / partial assessments	Studienleistung: Projektarbeit/Hausarbeit/Präsentation. Modulprüfung: Klausur. Wiederholungsmöglichkeiten und Turnus gemäß PO.
Learning objectives	Die Studierenden vertiefen durch das Modul ihre Grundkenntnisse der Toxikologie, welche sie im Modul Rechtskunde und Toxikologie für Chemiker (MTO) erworben haben. Sie erwerben Kenntnisse zu verschiedenen Aspekten des Chemikalienrechts, der Chemikaliensicherheit und des Arbeitsschutzes. Sie können durch den erfolgreichen Abschluss dieser Veranstaltung durch Bestehen der Klausur die *eingeschränkte Sachkunde* gemäß ChemVerbotsV auf

	die Sachkunde für das Inverkehrbringen giftiger und sehr giftiger Biozidprodukte und Pflanzenschutzmittel erweitern (Erwerb der *umfassenden Sachkunde*).
Learning outcomes and competencies	Durch die erfolgreiche Beendigung dieses Moduls sind die Studierende in der Lage: – Grundansätze der toxikologischen Stoffbewertung zu erläutern (im Rahmen des Erwerbs der erweiterten Sachkunde) und auf Fallbeispiele anzuwenden. – Prinzipien der Gefährdungsbeurteilung von Arbeitsplätzen zu erklären und diese problemorientiert anwenden zu können. – Bedeutung der Toxikologie bezüglich der Themenfelder Ökonomie und Ökologie zu diskutieren. – erworbenes Wissen zur Erarbeitung von Lösungsstrategien unter Berücksichtigung gesetzlicher Bestimmungen (Arbeitsschutz- und Umweltgesetzgebung) für die Bearbeitung praktischer Problemstellungen in Form von Fallbeispielen zu nutzen. – bei der Erarbeitung von Lösungsstrategien zu diskutieren, den eigenen Standpunkt angemessen zu vermitteln und mit anderen zusammenzuarbeiten.
Content	Die Vorlesung soll die Inhalte der Veranstaltung „Rechtskunde und Toxikologie für Chemiker" (Modul MTO, 1. Semester) vertiefen und erweitern: 1. Vertiefung der Grundkenntnisse in der regulatorischen Toxikologie und Chemikalienrecht, insbesondere Biozid- und Pflanzenschutzmittelrecht. 2. Vertiefung der Grundkenntnisse auf dem Gebiet des Arbeitsschutzes bei Chemikalien.
Media forms	PowerPoint-Präsentation, Tafelbilder
Literature	

Module name	Compulsory elective lecture **Innovation Management in the Chemical Industry**					
Abbreviation	MWV					
Interval of offer annual	**Duration** 1 semester	**Semester of study** 1 to 4	**Credits** 4	**Curriculum assignment** M. Sc. Chemistry Fach: SoN M. Sc. Chemical Biology Fach: SoN		
Module structure						
No.	**Course**	**Type**	**CP**	**SWS**	**Presence time**	**Self-study**
1	Innovation Management in the Chemical Industry	V	3	2	30 h	60 h
2	Exercises for Innovation Management in the Chemical Industry	Ü	1	1	15 h	15 h
	Total		**4**	**3**	**45 h**	**75 h**

Person responsible for the module	Prof. Dr. R. Weberskirch
Lecturer(s)	Dr. Thomas Rölle
Language	English
Requirements according to examination regulations	None
Recommended requirements	Successful completion of MOCb
Coursework / module examination / partial assessments	Oral or written module examination.
Learning objectives	Undergraduates acquire deeper knowledge about all basic principles and essential concepts of industrial chemistry and their key role in chemical conversion. Based on this, the students get to know the most important aspects of innovation management in the field of industrial chemistry and will be able to apply it.
Learning outcomes and competencies	After module completion, undergraduates will be able to – recognize and discuss the tools for analysis and evaluation of research and development projects – utilize imparted knowledge to solve problems in project management, technology assessment, intellectual property (IP) management, governance and leadership

Content	The lecture and the associated exercises are based on the common methods for evaluating projects against the background of the available resources in the (industrial) environment. Selected suitable and relevant manufacturing processes will be presented in the first third and their background will be used to teach innovation management afterwards in the subsequent two thirds of the course. Based on the well-known process, specific innovation management tools like potential identification, their evaluating etc. will be explained and applied.
Media forms	chalkboard teaching, digitized lecture, digitized lecture notes, digitized problem sets
Literature	Literature recommendations will be made within the course

Module name	Compulsory elective lecture **Vocational Training Courses (Berufsqualifizierende Veranstaltungen)**
Abbreviation	MWV

Interval of offer annual	**Duration** 1 semester	**Semester of study** B. Sc. 5 or 6 M. Sc. 1 to 4	**Credits** 4	**Curriculum assignment** B. Sc Chemie B. Sc. Chemische Biologie M. Sc. Chemistry Subject: SoN M. Sc. Chemical Biology Subject: SoN

Module structure

No.	**Course**	**Type**	**CP**	**SWS**	**Presence time**	**Self-study**
1	Vocational training course as specified by the department	V/Ü	4	3	45 h	75 h
		Total	4	3	45 h	75 h

Person responsible for the module	Dr. Markus Schürmann
Lecturer(s)	Miscellaneous lecturers. The approved courses are published by notice each semester.
Language	English, German
Requirements according to examination regulations	None
Recommended requirements	Students should be in the final phase of their bachelor's degree program and should be able to assess which competencies are important for later professional life. The prerequisites for the courses are different. For specialized courses, previous knowledge may be required.
Coursework / module examination / partial assessments	Module examination: Examination form as specified in the course or as specified on the notice board.
Learning objectives	Students acquire knowledge and competencies, which are important for later professional life.
Learning outcomes and competencies	Upon successful completion of this module, students will be able to: – deal constructively with the subject cultures of other disciplines. – apply the acquired theoretical knowledge in practice in the analysis and solution of problems.

	– present results orally and in writing in an appropriate way. – work in an interdisciplinary manner with interdisciplinary cooperation with interdisciplinary cooperation. – collaborate interdisciplinary through knowledge of other subjects
Content	Each semester, the Department of Chemistry and Chemical Biology publishes a list of courses that may be considered for vocational training. At least 4 credits must be acquired. If less than 4 credits are awarded for a course, then a further course must be attended, and a total of 4 credits are awarded. The contents of the courses may be: – statistical methods – soft skills – management methods – labor sciences – private law – conflict management – quality management – polymers – toxicology – chemicals law – marketing – economics – presentation – topics from the field of application of chemical products in bio- and chemical engineering – etc. More detailed information on the courses can be found in the module manuals of the respective faculties. In the case of courses that are not announced but might be considered as elective vocational training courses, approval can be granted upon application to the Examination Committee.
Media forms	Blackboard and/or PowerPoint presentation and others. (depending on lecturer)
Literature	Will be announced by the corresponding lecturer.

Module name	Compulsory elective lecture **Further Courses in Chemistry / Natural Sciences (Weitere chemische / naturwissenschaftliche Studien)**
Abbreviation	MWV

Interval of offer annual	**Duration** 1 semester	**Semester of study** 1 to 4	**Credits** 4	**Curriculum assignment** M. Sc. Chemistry Subject: SoN M. Sc. Chemical Biology Subject: SoN

Module structure

No.	Course	Type	CP	SWS	Presence time	Self-study
1	Further Course in Chemistry or Natural Sciences	V/Ü	4	3	45 h	75 h
	Total		4	3	35 h	75 h

Person responsible for the module	Dr. Markus Schürmann
Lecturer(s)	Miscellaneous lecturers. The approved courses and the corresponding lecturers are published by notice each semester.
Language	English,German
Requirements according to examination regulations	None
Recommended requirements	Additional prerequisites may be necessary for participation in subject-specific courses in the field of chemistry or natural sciences. It may be necessary to discuss with the lecturer whether the relevant prerequisites for the course are met.
Coursework / module examination / partial assessments	Mode of examination as specified in the course or in the module manual.
Learning objectives	Students acquire advanced knowledge and competences in other natural sciences, in chemistry or industrial chemistry from outside the Department of Chemistry and Chemical Biology, which are important for professional life or interdisciplinary research.
Learning outcomes and competencies	Upon successful completion of this module, students will be able to: – engage with the cultures of other subjects or faculties and to use the gained experience and insights in later professional collaboration.

	– use the acquired theoretical knowledge and competences for solving problems in professional practice. – present results appropriately in technical language, both verbally and in writing. – discuss scientific issues in a scientific manner. The competencies depend on the chosen course.
Content	Students of the Master's degree program in chemistry can get courses credited for their studies in the fields of natural sciences, industrial chemistry, or chemistry, which are offered by external universities, upon application to the examination board. At least 4 credits must be acquired. If less than 4 credits are awarded for a course, then a further course must be attended, but only a total of 4 credits will be awarded. Contents of the courses can be found in the corresponding module manuals.
Media forms	Blackboard and/or PowerPoint presentation and others. (depending on lecturer)
Literature	Will be announced by the corresponding lecturer.

Compulsory advanced elective laboratory courses

Module name	Compulsory advanced elective laboratory course **Inorganic Chemistry: Supramolecular and Bioinorganic Chemistry**
Abbreviation	MWV

Interval of offer	**Duration**	**Semester of study**	**Credits**	**Curriculum assignment**
By appoint-ment	1 semester	1 to 4	9	M. Sc. Chemistry Subject: AC Major subject: M. M. M. Sc. Chemical Biology Subject: SoC

Module structure

No.	Course	Type	CP	SWS	Presence time	Selfstudy
1	Inorganic Chemistry: Supramolecular and Bioinorganic Chemistry	P	6	8	120 h	60 h
2	Seminar for Inorganic Chemistry: Supramolecular and Bioinorganic Chemistry	S	3	2	30 h	60 h
		Total	9	10	150 h	120 h

Person responsible for the module	Prof. Dr. G. Clever
Lecturer(s)	Prof. Dr. G. Clever and scientific co-workers
Language	English
Requirements according to examination regulations	None
Recommended require-ments	None
Coursework / module ex-amination / partial assess-ments	Module examination (“laboratory course project”), consisting of experimental planning, execution and detailed final report (50% of the grade) and oral examination with seminar presentation and concluding discussion of own project work (50% of the grade). The oral examination should be taken no later than 6 months after the start of the internship project. The final report should be submitted to the supervisor no later than 4 months after the start of the internship project. Possibilities of repetition and rotation according to PO. This compulsory elective internship can only be successfully completed once. If another compulsory elective practical course is required in the subject of inorganic chemistry, this must be carried out in another working group.

	The students learn special working methods of inorganic chemistry and apply the acquired knowledge in carrying out their own project work. After completing the module, they present their project results in a seminar talk and show an understanding their contribution to the scientific research projects of the working group.
Learning objectives	After successful completion of this module, students are able to – explain modern working techniques of inorganic chemistry, select them according to synthetic requirements and implement these working techniques practically. – carry out a computer-assisted literature search and assess the relevance, validity and safety of information. – plan synthesis routes, propose alternative synthesis routes and evaluate them in a differentiated manner. – select suitable analytical methods, to explain the limits and possibilities of the respective method, to process, evaluate and interpret the obtained measurement data. – carry out computer-assisted calculations concerning the structure and properties of molecules, to visualize and interpret the results.*) – summarize the topic of a scientific article, research background information independently, present and discuss the contents in a seminar presentation. – independently plan a simple project and carry it out on time, taking into account legal requirements (occupational health and safety and environmental legislation). *) This learning outcome depends on the respective task.
Learning outcomes and competencies	Independently plan and execute scientific experiments, evaluate scientific results obtained, summarize them, place them in the context of previously published findings and document them according to the "rules of good scientific practice".
Content	1) Laboratory internship The topics are oriented towards current research problems and the specific working techniques of the working group. The research topics can come from the following areas, among others: - Coordination chemistry - Supramolecular chemistry - Main group chemistry - Bioinorganic chemistry - Chemistry in water - Inorganic polymers - Metalorganic Chemistry - Computational Chemistry Analytical methods used (selection): 1. Mass spectrometry 2. Ion mobility spectrometry

	3. Infrared spectroscopy 4. UV/VIS spectroscopy 5. Elemental analysis 6. Melting point determination 7. Rotational value determination 8. Refractive index 9. NMR spectroscopy (e.g. of the nuclei 1H, 13C, 31P, 19F, 119Sn, 29Si, 195Pt) 10. Single-crystal structure analysis 11. X-ray powder diffraction 2) Seminars: Seminar presentations on current research results with subsequent discussion.
Media forms	Lab diary, written final report, PowerPoint presentation, blackboard, slides.
Literature	Original literature (articles from peer-reviewed journals), literature recommendations are made during the course depending on subject

Module name		Compulsory advanced elective laboratory course **Inorganic Chemistry: Functional Materials**				
Abbreviation		MWV				
Interval of offer By appoint-ment	**Duration** 1 semester	**Semester of study** 1 to 4	**Credits** 9	**Curriculum assignment** M. Sc. Chemistry Subject: AC Major subject: M. M. M. Sc. Chemical Biology Subject: SoC		
Module structure						
No.	**Course**	**Type**	**CP**	**SWS**	**Presence time**	**Self-study**
1	Inorganic Chemistry: Functional Materi-als	P	6	8	120 h	60 h
2	Seminar for Inorganic Chemistry: Func-tional Materials	S	3	2	30 h	60 h
	Total		9	10	150 h	120 h
Person responsible for the module		Prof. Dr. S. Henke				
Lecturer(s)		Prof. Dr. S. Henke and scientific co-workers				
Language		English				
Requirements according to examination regulations		None				
Recommended require-ments		None				
Coursework / module ex-amination / partial assess-ments		Module examination (“laboratory course project”), consisting of experimental planning, execution and detailed final report (50% of the grade) and oral examination with seminar presentation and concluding discussion of own project work (50% of the grade). The oral examination should be taken no later than 6 months after the start of the internship project. The final re-port should be submitted to the supervisor no later than 4 months after the start of the internship project. Possibilities of repetition and rotation according to PO. This compulsory elective internship can only be successfully completed once. If another compulsory elective practical course is required in the subject of inorganic chemistry, this must be carried out in another working group. The students learn special working methods of inorganic chemistry and apply the acquired knowledge in carrying out				

	their own project work. After completing the module, they present their project results in a seminar talk and show an understanding their contribution to the scientific research projects of the working group.
Learning objectives	After successful completion of this module, students are able to – explain modern working techniques of inorganic chemistry, select them according to synthetic requirements and implement these working techniques practically. – carry out a computer-assisted literature search and assess the relevance, validity and safety of information. – plan synthesis routes, propose alternative synthesis routes and evaluate them in a differentiated manner. – select suitable analytical methods, to explain the limits and possibilities of the respective method, to process, evaluate and interpret the obtained measurement data. – carry out computer-assisted calculations concerning the structure and properties of molecules, to visualize and interpret the results.*) – summarize the topic of a scientific article, research background information independently, present and discuss the contents in a seminar presentation. – independently plan a simple project and carry it out on time, taking into account legal requirements (occupational health and safety and environmental legislation). *) This learning outcome depends on the respective task.
Learning outcomes and competencies	Independently plan and execute scientific experiments, evaluate scientific results obtained, summarize them, place them in the context of previously published findings and document them according to the "rules of good scientific practice".
Content	1) Laboratory internship The topics are oriented towards current research problems and the specific working techniques of the working group. The research topics can come from the following areas, among others: - Coordination chemistry - Supramolecular chemistry - Main group chemistry - Bioinorganic chemistry - Chemistry in water - Inorganic polymers - Metalorganic Chemistry - Computational Chemistry Analytical methods used (selection): 1. Mass spectrometry 2. Ion mobility spectrometry 3. Infrared spectroscopy 4. UV/VIS spectroscopy

	5. Elemental analysis 6. Melting point determination 7. Rotational value determination 8. Refractive index 9. NMR spectroscopy (e.g. of the nuclei 1H, 13C, 31P, 19F, 119Sn, 29Si, 195Pt) 10. Single-crystal structure analysis 11. X-ray powder diffraction 2) Seminars: Seminar presentations on current research results with subsequent discussion.
Media forms	Lab diary, written final report, PowerPoint presentation, blackboard, slides.
Literature	Original literature (articles from peer-reviewed journals), literature recommendations are made during the course depending on subject

<table>
<tr><td colspan="2">Module name</td><td colspan="6">Compulsory advanced elective laboratory course
Inorganic Chemistry: Photoactive Metal Complexes</td></tr>
<tr><td colspan="2">Abbreviation</td><td colspan="6">MWV</td></tr>
<tr><td>Interval of offer
By appoint-ment</td><td>Duration
1 semester</td><td>Semester of study
1 to 4</td><td>Credits
9</td><td colspan="4">Curriculum assignment
M. Sc. Chemistry
Subject: AC
Major subject: M. M. and E. T.
M. Sc. Chemical Biology
Subject: SoC</td></tr>
<tr><td colspan="8">Module structure</td></tr>
<tr><td>No.</td><td colspan="2">Course</td><td>Type</td><td>CP</td><td>SWS</td><td>Presence time</td><td>Self-study</td></tr>
<tr><td>1</td><td colspan="2">Inorganic Chemistry: Photoactive Metal Complexes</td><td>P</td><td>6</td><td>8</td><td>120 h</td><td>60 h</td></tr>
<tr><td>2</td><td colspan="2">Seminar for Inorganic Chemistry: Pho-toactive Metal Complexes</td><td>S</td><td>3</td><td>2</td><td>30 h</td><td>60 h</td></tr>
<tr><td colspan="4">Total</td><td>9</td><td>10</td><td>150 h</td><td>120 h</td></tr>
<tr><td colspan="2">Person responsible for the module</td><td colspan="6">Prof. Dr. A. Steffen</td></tr>
<tr><td colspan="2">Lecturer(s)</td><td colspan="6">Prof. Dr. A. Steffen and scientific co-workers</td></tr>
<tr><td colspan="2">Language</td><td colspan="6">English</td></tr>
<tr><td colspan="2">Requirements according to examination regulations</td><td colspan="6">None</td></tr>
<tr><td colspan="2">Recommended require-ments</td><td colspan="6">None</td></tr>
<tr><td colspan="2">Coursework / module ex-amination / partial assess-ments</td><td colspan="6">Module examination (“laboratory course project”), consisting of experimental planning, execution and detailed final report (50% of the grade) and oral examination with seminar presentation and concluding discussion of own project work (50% of the grade).
The oral examination should be taken no later than 6 months after the start of the internship project. The final re-port should be submitted to the supervisor no later than 4 months after the start of the internship project.
Possibilities of repetition and rotation according to PO.
This compulsory elective internship can only be successfully completed once. If another compulsory elective practical course is required in the subject of inorganic chemistry, this must be carried out in another working group.
The students learn special working methods of inorganic chemistry and apply the acquired knowledge in carrying out</td></tr>
</table>

	their own project work. After completing the module, they present their project results in a seminar talk and show an understanding their contribution to the scientific research projects of the working group.
Learning objectives	After successful completion of this module, students are able to – explain modern working techniques of inorganic chemistry, select them according to synthetic requirements and implement these working techniques practically. – carry out a computer-assisted literature search and assess the relevance, validity and safety of information. – plan synthesis routes, propose alternative synthesis routes and evaluate them in a differentiated manner. – select suitable analytical methods, to explain the limits and possibilities of the respective method, to process, evaluate and interpret the obtained measurement data. – carry out computer-assisted calculations concerning the structure and properties of molecules, to visualize and interpret the results.*) – summarize the topic of a scientific article, research background information independently, present and discuss the contents in a seminar presentation. – independently plan a simple project and carry it out on time, taking into account legal requirements (occupational health and safety and environmental legislation). *) This learning outcome depends on the respective task.
Learning outcomes and competencies	Independently plan and execute scientific experiments, evaluate scientific results obtained, summarize them, place them in the context of previously published findings and document them according to the "rules of good scientific practice".
Content	1) Laboratory internship The topics are oriented towards current research problems and the specific working techniques of the working group. The research topics can come from the following areas, among others: - Coordination chemistry - Supramolecular chemistry - Main group chemistry - Bioinorganic chemistry - Chemistry in water - Inorganic polymers - Metalorganic Chemistry - Computational Chemistry Analytical methods used (selection): 1. Mass spectrometry 2. Ion mobility spectrometry 3. Infrared spectroscopy 4. UV/VIS spectroscopy

	5. Elemental analysis 6. Melting point determination 7. Rotational value determination 8. Refractive index 9. NMR spectroscopy (e.g. of the nuclei 1H, 13C, 31P, 19F, 119Sn, 29Si, 195Pt) 10. Single-crystal structure analysis 11. X-ray powder diffraction 2) Seminars: Seminar presentations on current research results with subsequent discussion.
Media forms	Lab diary, written final report, PowerPoint presentation, blackboard, slides.
Literature	Original literature (articles from peer-reviewed journals), literature recommendations are made during the course depending on subject

Module name		Compulsory advanced elective laboratory course **Inorganic Chemistry: Chemical Synthesis and Catalysis**					
Abbreviation		MWV					
Interval of offer By appoint-ment	**Duration** 1 semester	**Semester of study** 1 to 4	**Credits** 9	**Curriculum assignment** M. Sc. Chemistry Subject: AC Major subject: M. M. M. Sc. Chemical Biology Subject: SoC			
Module structure							
No.	**Course**		**Type**	**CP**	**SWS**	**Presence time**	**Self-study**
1	Inorganic Chemistry: Chemical Synthe-sis and Catalysis		P	6	8	120 h	60 h
2	Seminar for Inorganic Chemistry: Chemical Synthesis and Catalysis		S	3	2	30 h	60 h
			Total	9	10	150 h	120 h
Person responsible for the module		Prof. Dr. C. Strohmann					
Lecturer(s)		Prof. Dr. C. Strohmann and scientific co-workers					
Language		English					
Requirements according to examination regulations		None					
Recommended require-ments		None					
Coursework / module ex-amination / partial assess-ments		Module examination (“laboratory course project”), consisting of experimental planning, execution and detailed final report (50% of the grade) and oral examination with seminar presentation and concluding discussion of own project work (50% of the grade). The oral examination should be taken no later than 6 months after the start of the internship project. The final re-port should be submitted to the supervisor no later than 4 months after the start of the internship project. Possibilities of repetition and rotation according to PO. This compulsory elective internship can only be successfully completed once. If another compulsory elective practical course is required in the subject of inorganic chemistry, this must be carried out in another working group. The students learn special working methods of inorganic chemistry and apply the acquired knowledge in carrying out					

	their own project work. After completing the module, they present their project results in a seminar talk and show an understanding their contribution to the scientific research projects of the working group.
Learning objectives	After successful completion of this module, students are able to – explain modern working techniques of inorganic chemistry, select them according to synthetic requirements and implement these working techniques practically. – carry out a computer-assisted literature search and assess the relevance, validity and safety of information. – plan synthesis routes, propose alternative synthesis routes and evaluate them in a differentiated manner. – select suitable analytical methods, to explain the limits and possibilities of the respective method, to process, evaluate and interpret the obtained measurement data. – carry out computer-assisted calculations concerning the structure and properties of molecules, to visualize and interpret the results.*) – summarize the topic of a scientific article, research background information independently, present and discuss the contents in a seminar presentation. – independently plan a simple project and carry it out on time, taking into account legal requirements (occupational health and safety and environmental legislation). *) This learning outcome depends on the respective task.
Learning outcomes and competencies	Independently plan and execute scientific experiments, evaluate scientific results obtained, summarize them, place them in the context of previously published findings and document them according to the "rules of good scientific practice".
Content	1) Laboratory internship The topics are oriented towards current research problems and the specific working techniques of the working group. The research topics can come from the following areas, among others: - Coordination chemistry - Supramolecular chemistry - Main group chemistry - Bioinorganic chemistry - Chemistry in water - Inorganic polymers - Metalorganic Chemistry - Computational Chemistry Analytical methods used (selection): 1. Mass spectrometry 2. Ion mobility spectrometry 3. Infrared spectroscopy 4. UV/VIS spectroscopy

	5. Elemental analysis 6. Melting point determination 7. Rotational value determination 8. Refractive index 9. NMR spectroscopy (e.g. of the nuclei 1H, 13C, 31P, 19F, 119Sn, 29Si, 195Pt) 10. Single-crystal structure analysis 11. X-ray powder diffraction 2) Seminars: Seminar presentations on current research results with subsequent discussion.
Media forms	Lab diary, written final report, PowerPoint presentation, blackboard, slides.
Literature	Original literature (articles from peer-reviewed journals), literature recommendations are made during the course depending on subject

Module name	Compulsory advanced elective laboratory course **Bioinorganic Chemistry**
Abbreviation	MWV

Interval of offer	**Duration**	**Semester of study**	**Credits**	**Curriculum assignment**
annual	1 semester	1 to 4	9	M. Sc. Chemical Biology Subject: CB/BioAC M. Sc. Chemistry Subject: AC Major subject: M. M.

Module structure

No.	**Course**	**Type**	**CP**	**SWS**	**Presence time**	**Self-study**
1	Bioinorganic Chemistry	P	6	8	120 h	60 h
2	Seminar for Bioinorganic Chemistry	S	3	2	30 h	60 h
		Total	9	10	150 h	120 h

Person responsible for the module	Prof. Dr. G. Clever
Lecturer(s)	Prof. Dr. G. Clever, Prof. Dr. A. Steffen, Prof. Dr. C. Strohmann, Prof. Dr. S. Henke und wiss. Mitarbeiter*innen
Language	English
Requirements according to examination regulations	None
Recommended requirements	Successful completion of the course: Bioinorganic Chemistry (elective lecture)
Coursework / module examination / partial assessments	Module examination ("laboratory course project"), consisting of experimental planning, execution and detailed final report (50% of the grade) and examination presentation on a given topic and subsequent discussion (50% of the grade). The examination presentation should be given no later than 6 months after the start of the internship project. The final report should be submitted to the supervisor no later than 4 months after the start of the internship project. Possibilities of repetition and rotation according to PO. Attendance at the seminar (absences of more than 10% can only be tolerated in justified exceptional cases, e.g. due to illness evidenced by a doctor's certificate), Attendance is compulsory for the practical course, as the learning objective can only be achieved by working on the apparatus and experimental equipment available there. In the case of justified absences, e.g. due to illness evidenced

	by a doctor's certificate, 10% of the practical (max. two experimental days) can be compensated by repetition. In case of longer absences, the entire internship must be repeated. Details can be found in the current internship regulations.
Learning objectives	The students learn special working methods of bioinorganic chemistry and can apply the acquired knowledge practically. They can present a scientific problem from the field of bioinorganic chemistry in a seminar lecture and place it in the context of bioinorganic chemistry.
Learning outcomes and competencies	After successful completion of this module, the students are able to, – describe the modern working techniques of bioinorganic chemistry, select them according to the synthetic requirements and implement these working techniques practically. – carry out a modern computer-assisted literature research. – carry out chemical syntheses taking into account environmental and safety regulations, to evaluate them and to document them according to the "rules of good scientific practice". – select suitable analytical methods, to be able to explain the limits and possibilities of the respective method, to process, evaluate and interpret the obtained measurement data. – work with samples of biological origin such as DNA and proteins in dilute aqueous solutions and to combine this with methods of synthetic inorganic chemistry and various analytical methods. – evaluate and discuss the results of thermodynamic and kinetic investigations graphically and mathematically. – approach the computer-aided processing, visualization and interpretation of biopolymer and metal complex crystal or NMR structures and calculated models with different software packages. – summarize the scientific results obtained in the form of a written paper and to be able to place them in the context of previously published findings. – understand the subject matter of a scientific subfield.
Content	Practical course The topics are based on classical examples and current research problems in bioinorganic chemistry as well as on specific working techniques of the working groups of bioinorganic and chemical biology. In particular, topics from the following areas can be treated: 1. understanding and analysis of primary, secondary (tertiary, quaternary) structures of DNA and proteins

	2. application of optical spectroscopy methods such as UV-Vis, fluorescence and circular dichroism as well as other techniques (e.g. ESR) 3. synthesis of transition metal complexes that imitate bio-inorganic functional elements or interact with biological structures 4. study in particular of the physiologically relevant metals iron, copper, manganese, nickel and zinc 5. thermodynamic and kinetic consideration of ligand exchange processes 6. interaction of bioinorganic compounds with small bio-relevant molecules such as NO, CO and O2 7. biorelevant redox processes 8. importance of non-covalent interactions in relation to bio-inorganic issues 9. extraction of bioinorganic relevant compounds from natural materials and comparison with synthetic analogues 10. application of different computer programs for processing, visualization and evaluation of bioinorganic structures and models Seminars: Seminar presentations on selected topics, methods or technical articles with subsequent discussion.
Media forms	Lab diary, written final report, PowerPoint presentation, blackboard, slides.
Literature	Original literature (articles from peer-reviewed journals), literature recommendations are made during the course depending on subject

<table>
<tr><td colspan="3">Module name</td><td colspan="5">Compulsory advanced elective laboratory course
Analytical Chemistry: Water and Soil</td></tr>
<tr><td colspan="3">Abbreviation</td><td colspan="5">MPR</td></tr>
<tr><td colspan="2">Interval of offer
annual</td><td>Duration
1 semester</td><td colspan="2">Semester of study
1 to 4</td><td>Credits
9</td><td colspan="2">Curriculum assignment
M. Sc. Chemistry
Subject: AC or OC
Major subject: M. M.</td></tr>
<tr><td colspan="8">Module structure</td></tr>
<tr><td>No.</td><td colspan="2">Course</td><td>Type</td><td>CP</td><td>SWS</td><td>Presence time</td><td>Self-study</td></tr>
<tr><td>1</td><td colspan="2">Analytical Chemistry: Water and Soil</td><td>P</td><td>6</td><td>8</td><td>120 h</td><td>60 h</td></tr>
<tr><td>2</td><td colspan="2">Seminar for Analytical Chemistry: Water and Soil</td><td>S</td><td>3</td><td>2</td><td>30 h</td><td>60 h</td></tr>
<tr><td colspan="4" align="right">Total</td><td>9</td><td>10</td><td>150 h</td><td>120 h</td></tr>
<tr><td colspan="3">Person responsible for the module</td><td colspan="5">Dr. Sebastian Zühlke</td></tr>
<tr><td colspan="3">Lecturer(s)</td><td colspan="5">Dr. Sebastian Zühlke</td></tr>
<tr><td colspan="3">Language</td><td colspan="5">English</td></tr>
<tr><td colspan="3">Requirements according to examination regulations</td><td colspan="5">None</td></tr>
<tr><td colspan="3">Recommended requirements</td><td colspan="5">Participation in the module Analytical Chemistry - Water and Soil I or Introduction to Mass Spectrometry.</td></tr>
<tr><td colspan="3">Coursework / module examination / partial assessments</td><td colspan="5">Coursework: Preparing the experimental plan, colloquium before the start of the experiment, carrying out the experiment.
Module examination: final protocol (70%) and presentations (30%)</td></tr>
<tr><td colspan="3">Learning objectives</td><td colspan="5">The students acquire an overview of the common methods of water and soil analysis in practice. They can independently carry out modern sample preparations, separation methods and analyte detections.</td></tr>
<tr><td colspan="3">Learning outcomes and competencies</td><td colspan="5">Upon completion of the module, students will be able to,
– perform basic analytical separation methods and sample preparation of water and soil analysis.
– operate a wide variety of hardware and software devices.
– determine method characteristics for chromatographic separations/spectroscopic detections.</td></tr>
</table>

	– apply acquired theoretical knowledge and subject-specific practical knowledge to solve analytical problems.
Content	1. Sampling and sample preparation for water and soil 2. Enrichment and extraction techniques - SPE - SPME - LSE - Sonication - ASE 3. Chromatographic techniques - GC - HPLC - IC detector coupling (MS, tandem-MS, HR-MS, DAD) 4. Qualitative and quantitative evaluation of the study results. 5. Design/conduct experiments on the degradation/fate of organic pollutants in water and soil.
Media forms	script, PowerPoint presentations at seminars, control of in-strumental analysis devices via software, evaluations at own computer workstations, further working materials
Literature	• Niessner, Schäffer: Organic Trace Analysis, Walter de Gruyter GmbH, Berlin/Boston, 2017 • Georg Schwedt: The Essential Guide to Analytical Chemistry, Wiley-VCH, 1997 • Georg Schwedt: Taschenatlas der Analytik, Wiley-VCH, 2007 • Bracher, F. et al.: Arbeitsbuch instrumentelle Analytik, Govi-VerlagGmbH, Eschborn, 2008 • H.-J. Hübschmann: Handbook of GC/MS: Fundamen-tals and Applications, Wiley-VCH; 3. Edition, 2015Georg Schwedt: Analytical Chemistry, Wiley-VCH, 2008

Module name	Compulsory advanced elective laboratory course **Analytical Chemistry: NMR Spectroscopy**
Abbreviation	MPR

Interval of offer annual	**Duration** 1 semester	**Semester of study** 1 to 4	**Credits** 9	**Curriculum assignment** M. Sc. Chemistry Subject: AC or OC Major subject: M. M. Subject: PC Major subject: E. T. M. Sc. Chemical Biology Subject: SoC

Module structure

No.	Course	Type	CP	SWS	Presence time	Self-study
1	Analytical Chemistry: NMR Spectroscopy	P	6	8	120 h	60 h
2	Seminar for Analytical Chemistry: NMR Spectroscopy	S	3	2	30 h	60 h
	Total		**9**	**10**	**150 h**	**120 h**

Person responsible for the module	Prof. Dr. W. Hiller
Lecturer(s)	Prof. Dr. W. Hiller
Language	English
Requirements according to examination regulations	None
Recommended requirements	Elective lecture High Resolution NMR
Coursework / module examination / partial assessments	Partial assessment: Laboratory performance. Experiments with graded experimental protocols (6 CP) Partial assessment: Examination. Presentation with discussion in the final colloquium (3 CP) For the internship there is the obligation to perform the above mentioned services within the given period of time. In case of justified absences, e.g. due to illness evidenced by a medical certificate, 10 % of the internship (max. three trial days) can be compensated by repetition. In case of longer absences, the entire internship must be repeated. Possibilities of repetition and rotation according to examination regulations.

Learning objectives	The students acquire basic knowledge of modern one- and multidimensional NMR methods as well as the latest NMR equipment. They will be able to perform sample preparation, different measurement methods, processing of measurement data, spectra display and spectra interpretation independently.
Learning outcomes and competencies	By successful completion of this module, students will be able to, – explain advanced and modern NMR methods and to be able to select them according to the problem. – operate hardware and software independently. – prepare samples for NMR analysis. – use acquired theoretical and practical knowledge to develop analytical solution strategies based on basic physics and mathematics to solve problems. – perform basic NMR measurement methods on the instrument independently to derive meaningful structural suggestions or characterizations for the investigated substances from given NMR spectra. – act responsibly under consideration of the legal regulations when handling high magnetic fields. – summarize scientific results obtained in the form of a written paper and to be able to place them in the context of previously published findings. – summarize the topic of a scientific article, to research background information independently and to present and discuss the contents in a seminar presentation.
Content:	<u>Internship</u> The topics are based on classical examples and current research problems of the working groups of organic, inorganic and physical chemistry and chemical biology. Appropriate samples and experiments will be prepared to solve the problems. The following topics are selected for this purpose: 1. manual and automatic operation of an NMR instrument including sample preparation. 2. preparation of an NMR experiment by means of tuning, locking, shimming 3. setup of an NMR experiment 4. optimization of the required measurement parameters – pulses, – digitization – resolution – sensitivity – etc. 5. performance of 1D and 2D measurements. 6. T1 and T2 relaxation measurements 7. processing of NMR data – appropriate choice of weighting functions – zerofilling,

	– linear prediction – phase and baseline corrections – integration – etc 8. spectrum display 9. spectrum analysis Seminar Seminar presentations on selected topics, methods or technical papers followed by discussion.
Media forms	Powerpoint presentation, blackboard pictures, slides.
Literature	- T.Claridge, High-Resolution NMR Techniques in Organic Chemistry, Pergamon, 1999 - S.Berger, S.Braun, 200 and more NMR Experiments, Wiley-VCH, 2004 - H.Friebolin, One- and Two-dimensional NMR Spectroscopy, Wiley-VCH, 1998 - User manuals - Technical literature

<table>
<tr><td colspan="2">Module name</td><td colspan="5">Compulsory advanced elective laboratory course
Organic Chemistry: Molecular Chemistry</td></tr>
<tr><td colspan="2">Abbreviation</td><td colspan="5">MPR</td></tr>
<tr><td>Interval of offer
By appoint-ment</td><td>Duration
1 semester</td><td>Semester of study
1 to 4</td><td>Credits
9</td><td colspan="3">Curriculum assignment
M. Sc. Chemistry
Subject: OC
Major subject: M. M. and E. T.
M. Sc. Chemical Biology
Subject: SoC</td></tr>
</table>

Module structure

No.	Course	Type	CP	SWS	Presence time	Self-study
1	Organic chemistry: Molecular chemistry	P	7	8	120 h	90 h
2	Seminar for Organic chemistry: Molecular chemistry	S	2	2	30 h	30 h
		Total	**9**	**10**	**150 h**	**120 h**

Person responsible for the module	Prof. Dr. M. M. Hansmann
Lecturer(s)	Prof. Dr. M. M. Hansmann and co-workers
Language	English
Requirements according to examination regulations	None
Recommended requirements	None
Coursework / module examination / partial assessments	Module examination (“laboratory course project”), consisting of experiment design, experimentation and a detailed final report (70% of total grade) as well as exam presentation followed by a practical course project-based discussion (30% of total grade) The exam presentation should be given no later than 6 months after the start of the practical course. Since the exam presentation is related to the practical course, the final report should be submitted at least 6 weeks before the exam presentation. Repeat options and rotation according to the examination regulations.

	The elective practical course can only be successfully completed once. If a further elective practical course in organic chemistry is required, this must be carried out in a different working group.
Learning objectives	While participating in a working group-based research project with an appropriate level of difficulty, the students will gain theoretical and technical skills for planning, conducting and documenting experiments in the context of synthetic organic chemistry. The students learn how to apply the latest research methods, how to self-reliantly process a synthetic project, how to evaluate the obtained results related to the literature and how to summarize their results in a written report as well as an oral presentation. In the seminar, the students acquire knowledge about current areas of organic molecular chemistry and present their exam presentation in the group seminar.
Learning outcomes and competencies	Upon successful completion of this module, students will be able - to choose and apply modern experimental working techniques in organic chemistry, to select them according to synthetic requirements and to implement these working techniques in practice. - to safely implement special working techniques in the areas of organic, metalorganic and main group chemistry as well as of photochemistry, electrochemistry and asymmetric synthesis. - to safely carry out procedures for the isolation, purification and characterisation of low-molecular organic compounds. - to apply modern analytical and spectroscopic methods. This may include electrochemical or spectroscopic methods, such as NMR, EPR, UV-Vis/NIR, CV, spectroelectrochemistry, etc. - to conduct a computer-assisted literature search and to evaluate the importance and the viability of literature precedents. - to plan self-reliantly synthetic routes, to propose alternative synthetic routes and to evaluate their prospects of success in terms of scientific risk management. - to conduct experiments self-reliantly considering environmental as well as safety regulations and to evaluate and document them according to the "rules of good scientific practice". - to select suitable analytical methods, to evaluate limitations and capabilities of each method, and to process, analyze, and interpret the analytical data obtained. - to classify scientific results obtained in the context of the current state of knowledge. - to summarise the obtained scientific results in form of a written report that meets the requirements of a scientific publication - to present scientific results obtained in form of an oral presentation.

	- to self-reliantly plan and conduct a project with an appropriate level of difficulty, while considering legal requirements (occupational health and safety and environmental legislation). - to discuss solution strategies for synthetic challenges, convey one's point of view adequately and work in a team. - to summarise the topic of a scientific publication, to research background information independently and to present and discuss the contents in a seminar presentation.
Content	Experimental contribution to a current synthetic issue from the research topic of molecular chemistry, e.g. of new organic redox systems and their application in photo redox catalysis and organic batteries, of structurally and electronically unusual organic compounds (e.g. ylidically polarized olefins, unsaturated diazo compounds), of new main group compounds, organic radicals and diradicals. The topic of the practical course is based on current research topics of the working group. The exam presentation summarizes and interprets the main experimental results obtained, interprets them and presents the resulting conclusions.
Media forms	handwritten laboratory notebook; written report; PowerPoint presentation; chalkboard-assisted discussion of scientific issues
Literature	literature recommendations will be made within the course

<table>
<tr><td colspan="2">Module name</td><td colspan="6">Compulsory advanced elective laboratory course
Organic Chemistry: Science of Synthesis in Theory and Practice</td></tr>
<tr><td colspan="2">Abbreviation</td><td colspan="6">MPR</td></tr>
<tr><td>Interval of offer
By appointment</td><td>Duration
1 semester</td><td>Semester of study
1 to 4</td><td>Credits
9</td><td colspan="4">Curriculum assignment
M. Sc. Chemistry
Subject: OC
Major subject: M. M.
M. Sc. Chemical Biology
Subject: SoC</td></tr>
<tr><td colspan="8">Module structure</td></tr>
<tr><td>No.</td><td colspan="2">Course</td><td>Type</td><td>CP</td><td>SWS</td><td>Presence time</td><td>Selfstudy</td></tr>
<tr><td>1</td><td colspan="2">Organic chemistry: science of synthesis in theory and practice</td><td>P</td><td>7</td><td>8</td><td>120 h</td><td>90 h</td></tr>
<tr><td>2</td><td colspan="2">Seminar for Organic chemistry: science of synthesis in theory and practice</td><td>S</td><td>2</td><td>2</td><td>30 h</td><td>30 h</td></tr>
<tr><td colspan="4">Total</td><td>9</td><td>10</td><td>150 h</td><td>120 h</td></tr>
<tr><td colspan="2">Person responsible for the module</td><td colspan="6">Prof. Dr. M. Hiersemann</td></tr>
<tr><td colspan="2">Lecturer(s)</td><td colspan="6">Prof. Dr. M. Hiersemann and co-workers</td></tr>
<tr><td colspan="2">Language</td><td colspan="6">English</td></tr>
<tr><td colspan="2">Requirements according to examination regulations</td><td colspan="6">None</td></tr>
<tr><td colspan="2">Recommended requirements</td><td colspan="6">None</td></tr>
<tr><td colspan="2">Coursework / module examination / partial assessments</td><td colspan="6">Module examination (“laboratory course project”), consisting of experiment design, experimentation and a detailed final report (70% of total grade) as well as exam presentation followed by a practical course project-based discussion (30% of total grade)

The exam presentation should be given no later than 6 months after the start of the practical course. Since the exam presentation is related to the practical course, the final report should be submitted at least 6 weeks before the exam presentation.

Repeat options and rotation according to the examination regulations.</td></tr>
</table>

	The elective practical course can only be successfully completed once. If a further elective practical course in organic chemistry is required, this must be carried out in a different working group.
Learning objectives	While participating in a working group-based research project with an appropriate level of difficulty, undergraduates will gain theoretical and technical skills for planning, conducting and documenting experiments in context of a target-molecule synthesis. The learning goals will be achieved by dealing with synthetic challenges from research areas such as natural product synthesis, functional molecules synthesis or development of synthetic method. During group seminars, undergraduates actively participate in the scientific discourse on current research topics in science of synthesis. Undergraduates give their exam presentation in the group seminar.
Learning outcomes and competencies	Upon successful module completion, undergraduates will be able to - choose and apply modern experimental working techniques from the field of organic chemistry, when facing a synthetic issue. Experimental work with hazardous compounds under different conditions is mastered. This includes working under moisture and air-free conditions, under high and low temperatures as well as under fine vacuum. Special working techniques from the field of metalorganic chemistry, element organic chemistry, photochemistry and asymmetric synthesis are acquired. Techniques for the isolation, purification and characterization of small molecular organic compounds are mastered. - conduct a computer-assisted literature search and to evaluate the importance and the viability of literature precedents. - plan self-reliantly synthetic routes based on acquired knowledge of retrosynthesis and reaction mechanisms. - propose alternative synthetic routes and evaluate their prospects of success in terms of scientific risk management. - conduct experiments self-reliantly, while considering environmental and safety regulations, evaluate and document them according to the "rules of good scientific practice" - select appropriate analytical methods, evaluate limitations and capabilities of each method, and process, analyze, and interpret the analytical data obtained. - classify scientific results obtained in the context of the current state of knowledge. - summarize the scientific results obtained in form of a report, which meets the requirements of a scientific publication. - present scientific results obtained in form of an oral presentation.

	- self-reliantly plan and conduct a project with an appropriate level of difficulty, while considering legal requirements (occupational health and safety and environmental legislation). - discuss solution strategies for synthetic challenges, convey one's point of view adequately and work in a team.
Content	Experimental contribution to a current synthetic issue from the research topic of target molecule-oriented synthesis or synthetic method development. The topic of the practical course is based on current research topics of the working group. The exam presentation summarizes and interprets the main experimental results obtained, interprets them and presents the resulting conclusions.
Media forms	handwritten laboratory notebook; written report; PowerPoint presentation; chalkboard-assisted discussion of scientific issues
Literature	literature recommendations will be made within the course

<table>
<tr><td colspan="2">Module name</td><td colspan="3">Compulsory advanced elective laboratory course
Organic Chemistry: Sustainable Synthesis</td></tr>
<tr><td colspan="2">Abbreviation</td><td colspan="3">MPR</td></tr>
<tr><td>Interval of offer
By appoint-ment</td><td>Duration
1 semester</td><td>Semester of study
1 to 4</td><td>Credits
9</td><td>Curriculum assignment
M. Sc. Chemistry
Subject: OC
Major subject: M. M.
M. Sc. Chemical Biology
Subject: SoC</td></tr>
</table>

<table>
<tr><td colspan="8">Module structure</td></tr>
<tr><td>No.</td><td>Course</td><td>Type</td><td>CP</td><td>SWS</td><td>Presence time</td><td>Selfstudy</td></tr>
<tr><td>1</td><td>Organic Chemistry: Sustainable Syn-thesis</td><td>P</td><td>7</td><td>8</td><td>120 h</td><td>90 h</td></tr>
<tr><td>2</td><td>Seminar for Organic Chemistry: Sus-tainable Synthesis</td><td>S</td><td>2</td><td>2</td><td>30 h</td><td>30 h</td></tr>
<tr><td colspan="3">Total</td><td>9</td><td>10</td><td>150 h</td><td>120 h</td></tr>
</table>

<table>
<tr><td>Person responsible for the module</td><td>Prof. Dr. N. Krause</td></tr>
<tr><td>Lecturer(s)</td><td>Prof. Dr. N. Krause and co-workers</td></tr>
<tr><td>Language</td><td>English</td></tr>
<tr><td>Requirements according to examination regulations</td><td>None</td></tr>
<tr><td>Recommended require-ments</td><td>None</td></tr>
<tr><td>Coursework / module ex-amination / partial assess-ments</td><td>Module examination (“laboratory course project”), consisting of experiment design, experimentation and a detailed final report (70% of total grade) as well as exam presentation fol-lowed by a practical course project-based discussion (30% of total grade)

The exam presentation should be given no later than 6 months after the start of the practical course. Since the exam presentation is related to the practical course, the final report should be submitted at least 6 weeks before the exam presentation.

Repeat options and rotation according to the examination regulations.</td></tr>
</table>

	The elective practical course can only be successfully completed once. If a further elective practical course in organic chemistry is required, this must be carried out in a different working group.
Learning objectives	While participating in a working group-based research project with an appropriate level of difficulty, undergraduates will gain theoretical and technical skills for planning, conducting and documenting experiments in the context of synthetic organic chemistry. The students learn how to apply the latest research methods, how to independently process a synthetic project, how to evaluate the obtained results related to the literature and how to summarize their results in a protocol. In the seminar, the students acquire knowledge about current areas of synthetic organic chemistry and present their exam presentation in the group seminar.
Learning outcomes and competencies	Upon successful completion of this module, students will be able - to choose and apply modern experimental working techniques in organic chemistry, to select them according to synthetic requirements and to implement these working techniques in practice. - to safely implement special working techniques in the area of sustainable synthesis chemistry and to safely carry out procedures for the isolation, purification and characterisation of low-molecular organic compounds. - to conduct a computer-assisted literature search and to evaluate the importance and the viability of literature precedents. - to plan self-reliantly synthetic routes, to propose alternative synthetic routes and to evaluate their prospects of success in terms of scientific risk management. - to conduct experiments self-reliantly considering environmental as well as safety regulations and to evaluate and document them according to the "rules of good scientific practice". - to select suitable analytical methods, to evaluate limitations and capabilities of each method, and to process, analyze, and interpret the analytical data obtained. - to classify scientific results obtained in the context of the current state of knowledge. - to summarise the obtained scientific results in form of a written report that meets the requirements of a scientific publication - to present scientific results obtained in form of an oral presentation. - to self-reliantly plan and conduct a project with an appropriate level of difficulty, while considering legal requirements (occupational health and safety and environmental legislation). - to discuss solution strategies for synthetic challenges, convey one’s point of view adequately and work in a team.

	- to summarise the topic of a scientific publication, to research background information independently and to present and discuss the contents in a seminar presentation.
Content	Experimental contribution to a current synthetic issue from the research topic of sustainable synthesis. The topic of the practical course is based on current research topics of the working group. The exam presentation summarizes and interprets the main experimental results obtained, interprets them and presents the resulting conclusions.
Media forms	handwritten laboratory notebook; written report; PowerPoint presentation; chalkboard-assisted discussion of scientific issues
Literature	literature recommendations will be made within the course

Module name	Compulsory advanced elective laboratory course **Organic Chemistry: Synthesis and Characterization of Polymers**			
Abbreviation	MPR			
Interval of offer By appoint-ment	**Duration** 1 semester	**Semester of study** 1 to 4	**Credits** 9	**Curriculum assignment** M. Sc. Chemistry Subject: OC Major subject: M. M. M. Sc. Chemical Biology Subject: SoC

Module structure

No.	**Course**	**Type**	**CP**	**SWS**	**Presence time**	**Self-study**
1	Organic Chemistry: Synthesis and Characterization of Polymers	P	7	8	120 h	90 h
2	Seminar for Organic Chemistry: Synthesis and Characterization of Polymers	S	2	2	30 h	30 h
	Total		**9**	**10**	**150 h**	**120 h**

Person responsible for the module	Prof. Dr. R. Weberskirch
Lecturer(s)	Prof. Dr. R. Weberskirch and co-workers
Language	English
Requirements according to examination regulations	None
Recommended require-ments	None
Coursework / module ex-amination / partial assess-ments	Module examination (“laboratory course project”), consisting of experiment design, experimentation and a detailed final report (70% of total grade) as well as exam presentation followed by a practical course project-based discussion (30% of total grade) The exam presentation should be given no later than 6 months after the start of the practical course. Since the exam presentation is related to the practical course, the final report should be submitted at least 6 weeks before the exam presentation. Repeat options and rotation according to the examination regulations.

	The elective practical course can only be successfully completed once. If a further elective practical course in organic chemistry is required, this must be carried out in a different working group.
Learning objectives	While participating in a working group-based research project with an appropriate level of difficulty, the students will gain theoretical and technical skills for planning, conducting and documenting experiments in the context of synthetic polymer chemistry. The students learn how to apply the latest research methods, how to independently process a synthetic project, how to evaluate the obtained results related to the literature and how to summarize their results in a protocol. In the seminar, the students acquire knowledge about current areas of synthetic polymer chemistry and present their exam presentation in the group seminar.
Learning outcomes and competencies	Upon successful completion of this module, students will be able - to choose and apply modern experimental working techniques in synthetic polymer chemistry, to select them according to synthetic requirements and to implement these working techniques in practice. - experimental work with hazardous substances under exclusion of air and moisture, under high and low temperature conditions and in fine vacuum is mastered. - to safely implement special working techniques in the area of polymer synthesis and to safely carry out procedures for the isolation, purification and characterisation of low-molecular organic as well as of polymeric compounds. - to conduct a computer-assisted literature search and to evaluate the importance and the viability of literature precedents. - to plan self-reliantly synthetic routes, to propose alternative synthetic routes and to evaluate their prospects of success in terms of scientific risk management. - to conduct experiments self-reliantly considering environmental as well as safety regulations and to evaluate and document them according to the "rules of good scientific practice". - to select suitable analytical methods, to evaluate limitations and capabilities of each method, and to process, analyze, and interpret the analytical data obtained. - to classify scientific results obtained in the context of the current state of knowledge in polymer chemistry. - to summarise the obtained scientific results in form of a written report that meets the requirements of a scientific publication - to present scientific results obtained in form of an oral presentation.

	- to self-reliantly plan and conduct a project with an appropriate level of difficulty, while considering legal requirements (occupational health and safety and environmental legislation). - to discuss solution strategies for synthetic challenges in polymer chemistry, convey one's point of view adequately and work in a team. - to summarise the topic of a scientific publication, to research background information independently and to present and discuss the contents in a seminar presentation.
Content	Experimental contribution to a current synthetic issue from the research topic of polymer chemistry. The topic of the practical course is based on current research topics of the working group. The exam presentation summarizes and interprets the main experimental results obtained, interprets them and presents the resulting conclusions.
Media forms	handwritten laboratory notebook; written report; PowerPoint presentation; chalkboard-assisted discussion of scientific issues
Literature	literature recommendations will be made within the course

Module name	Compulsory advanced elective laboratory course **Physical Chemistry 1: Biophysical Methods**			
Abbreviation	MPR			
Interval of offer annual (WiSe)	**Duration** 1 semester	**Semester of study** 1 to 4	**Credits** 9	**Curriculum assignment** M. Sc. Chemistry Subject: PC Major subject: E. T. M. Sc. Chemical Biology Subject: CB / BioPC

Module structure

No.	Course	Type	CP	SWS	Presence time	Self-study
1	Physical Chemistry 1: Biophysical Methods	P	6	8	120 h	60 h
2	Seminar for Physical Chemistry 1: Biophysical Methods	S	3	2	30 h	60 h
		Total	**9**	**10**	**150 h**	**120 h**

Person responsible for the module	Prof. Dr. C. Czeslik
Lecturer(s)	N.N., Prof. Dr. S. M. Kast, Prof. Dr. C. Czeslik, Prof. Dr. S. Raunser
Language	English
Requirements according to examination regulations	None
Recommended requirements	Basic knowledge in biophysical chemistry, attendance of at least one PC lecture in the Master's degree program.
Coursework / module examination / partial assessments	Module examination ("laboratory course project") consisting of a graded student talk with discussion in the seminar (30%), and the successful participation in the laboratory course, submission of all protocols and a final graded oral exam which is based on the protocols (70%). The talk in the seminar is related to the experiments and aims to deepen the underlying theories, methods and concepts. The oral exam should be taken no later than six months after the beginning of the laboratory course. Prerequisites for taking the exam are final submission of the protocols and presentation of the talk in the seminar. The seminar schedule and the protocol deadlines are announced in the introductory meeting. Personal presence during the performance of the experiments is mandatory. The compulsory attendance also refers

	to the introductory meeting, which includes the safety briefing. Possibilities of repeating the course according to examination regulations ("Prüfungsordnung").
Learning objectives	In the practical course, students learn state-of-the-art working methods in different working groups of physical chemistry. In the seminar, the students present a special topic of physical chemistry in a talk.
Learning outcomes and competencies	After successful completion of this module, students will be able to - explain state-of-the-art physico-chemical working methods and, in conjunction with the knowledge gained in the special lectures, use this knowledge to plan and carry out research experiments independently. - analyze physical-chemical problems logically and to implement them in suitable experimental setups. - correctly evaluate, present, and critically interpret the data obtained during experiments. - elaborate the obtained scientific results in the form of experimental protocols which formally meet the requirements of a scientific publication. - discuss strategies for solutions, communicate the own point of view appropriately and to cooperate with others. - summarize the topic of a scientific article, to research background information independently, to present and discuss the contents in a seminar presentation.
Content	The experiments of the practical course are carried out in different working groups of physical chemistry on modern research instruments. Supervision is provided by scientific staff of the respective research area. Contents of the practical course includes (among others): 1. Fluorescence spectroscopy and microscopy 2. UV/Vis spectroscopy 3. Differential scanning calorimetry 4. Langmuir film balance 5. Molecular dynamics simulations 6. Electron microscopy
Media forms	Scripts describing the experimental tasks, presentation software and projector
Literature	References to special literature are provided in the experimental scripts.

Module name	Compulsory advanced elective laboratory course **Physical Chemistry 2: Biomagnetic Resonance**
Abbreviation	MPR

Interval of offer annual (SoSe)	**Duration** 1 semester	**Semester of study** 1 to 4	**Credits** 9	**Curriculum assignment** M. Sc. Chemistry Subject: PC Major subject: E. T. and M. M. M. Sc. Chemical Biology Subject: CB / BioPC

Module structure

No.	**Course**	**Type**	**CP**	**SWS**	**Presence time**	**Self-study**
1	Physical Chemistry 2: Biomagnetic Resonance	P	6	8	120 h	60 h
2	Seminar for Physical Chemistry 2: Bio-magnetic Resonance	S	3	2	30 h	60 h
		Total	**9**	**10**	**150 h**	**120 h**

Person responsible for the module	Prof. Dr. C. Czeslik
Lecturer(s)	Prof. Dr. R. Linser, Prof. Dr. M. Kasanmascheff, Prof. Dr. S. M. Kast
Language	English
Requirements according to examination regulations	None
Recommended require-ments	Basic knowledge in biophysical chemistry, attendance of at least one PC lecture in the Master's degree program.
Coursework / module ex-amination / partial assess-ments	Module examination ("laboratory course project") consisting of a graded student talk with discussion in the seminar (30%), and the successful participation in the laboratory course, submission of all protocols and a final graded oral exam which is based on the protocols (70%). The talk in the seminar is related to the experiments and aims to deepen the underlying theories, methods and concepts. The oral exam should be taken no later than six months after the be-ginning of the laboratory course. Prerequisites for taking the exam are final submission of the protocols and presentation of the talk in the seminar. The seminar schedule and the protocol deadlines are announced in the introductory meet-ing. Personal presence during the performance of the experi-ments is mandatory. The compulsory attendance also refers

	to the introductory meeting, which includes the safety briefing. Possibilities of repeating the course according to examination regulations ("Prüfungsordnung").
Learning objectives	In the practical course, students learn state-of-the-art working methods in different working groups of physical chemistry. In the seminar, the students present a special topic of physical chemistry in a talk.
Learning outcomes and competencies	After successful completion of this module, students will be able to - explain state-of-the-art physico-chemical working methods and, in conjunction with the knowledge gained in the special lectures, use this knowledge to plan and carry out research experiments independently. - analyze physical-chemical problems logically and to implement them in suitable experimental setups. - correctly evaluate, present, and critically interpret the data obtained during experiments. - elaborate the obtained scientific results in the form of experimental protocols which formally meet the requirements of a scientific publication. - discuss strategies for solutions, communicate the own point of view appropriately and to cooperate with others. - summarize the topic of a scientific article, to research background information independently, to present and discuss the contents in a seminar presentation.
Content	The experiments of the practical course are carried out in different working groups of physical chemistry on modern research instruments. Supervision is provided by scientific staff of the respective research area. Contents of the practical course includes (among others): 1. NMR spectroscopy - 2D NMR spectra - Relaxation - Resonance assignment in NMR of proteins 2. EPR spectroscopy - Hyperfine interaction - Influence of molecular motion and solvent 3. Computational chemistry - Quantum chemical calculations - Solvation phenomena - Simulation methods
Media forms	Scripts describing the experimental tasks, presentation software and projector
Literature	References to special literature are provided in the experimental scripts.

Module name	Compulsory advanced elective laboratory course **Physical Chemistry 3: Biomolecular Modeling**
Abbreviation	MPR

Interval of offer By appointment	**Duration** 1 semester	**Semester of study** 1 to 4	**Credits** 9	**Curriculum assignment** M. Sc. Chemistry Subject: PC Major subject: E. T. M. Sc. Chemical Biology Subject: CB / BMM

Module structure

No.	**Course**	**Type**	**CP**	**SWS**	**Presence time**	**Self-study**
1	Physical Chemistry 3: Biomolecular Modeling	P	6	8	120 h	60 h
2	Seminar for Physical Chemistry 3: Biomolecular Modeling	S	3	2	30 h	60 h
		Total	**9**	**10**	**150 h**	**120 h**

Person responsible for the module	Prof. Dr. S. M. Kast
Lecturer(s)	Prof. Dr. S. M. Kast and co-workers
Language	English
Requirements according to examination regulations	None
Recommended requirements	Programming skills, successful completion of the courses "Computational Chemistry" and/or "Biomolecular Modeling" (elective courses)
Coursework / module examination / partial assessments	Module examination (“laboratory course project”) consisting of a graded student talk with discussion in the seminar (30%), and the successful participation in the laboratory course, submission of all protocols and a final graded oral exam which is based on the protocols (70%). The talk in the seminar is related to the experiments and aims to deepen the underlying theories, methods and concepts. The oral exam should be taken no later than six months after the beginning of the laboratory course. Prerequisites for taking the exam are final submission of the protocols and presentation of the talk in the seminar. The seminar schedule and the protocol deadlines are announced in the introductory meeting. Personal presence during the performance of the experiments is mandatory. The compulsory attendance also refers

	to the introductory meeting, which includes the safety briefing. Possibilities of repeating the course according to examination regulations ("Prüfungsordnung").
Learning objectives	In the practical course, students learn the latest methods and techniques in the field of theory and computer-assisted modeling of molecular systems and their application to biological-chemical problems. For this purpose, the students work on concrete problems that are related to the current topics of the work group. In the course of the seminar, the individual students work on a current sub-area of theory and present the results in a seminar lecture.
Learning outcomes and competencies	Upon successful completion of this module, students will be able to - select the appropriate theoretical methods for a given problem and independently assess the possibilities and limitations of different modeling methods, especially for biochemical and biophysical problems, - logically analyze physical-chemical problems and implement them in suitable modeling procedures, - master the programming techniques necessary for the use of the modeling methods taught, - correctly evaluate, present and critically evaluate and interpret the data obtained from modeling, - conduct a computer-based literature search and assess the validity and reliability of information, - to place the scientific results obtained in the context of the already published findings in physical chemistry and to summarize the scientific results obtained in the form of a written paper that meets the requirements of a scientific publication and to present them orally, - communicate their own point of view appropriately when developing solution strategies and to discuss and cooperate with others.
Content	The topics are oriented along the lines of the current problems of the work group. The methods used and to be discussed in the seminar can fall into the following areas, among others: 1. Handling atomic structure data 2. Homology modeling 3. Geometry optimization 4. Vibrational analysis 5. Molecular dynamics simulation 6. Monte-Carlo simulation 7. Coarse-grained models 8. Solvation modeling 9. Quantum-chemical calculations 10. Data analysis and modeling 11. Organization of complex modeling workflows
Media forms	Scripts describing the tasks, presentation software and projector

Literature	T. Schlick, Molecular Modeling and Simulation: An Interdisciplinary Guide, 2nd Ed., Springer, 2010. F. Jensen, Introduction to Computational Chemistry, 3rd Ed., Wiley, 2017. Selected articles from scientific journals.

Module name	Compulsory advanced elective laboratory course **Industrial Chemistry 1**			
Abbreviation	MPR			
Interval of offer By appoint-ment	**Duration** 1 semester	**Semester of study** 1 to 4	**Credits** 9	**Curriculum assignment** M. Sc. Chemistry Subject: TC Major subject: E. T.

Module structure

No.	Course	Type	CP	SWS	Presence time	Self-study
1	Industrial Chemistry 1	P	7	8	120 h	90 h
2	Seminar for Industrial Chemistry 1	S	2	2	30 h	30 h
	Total		**9**	**10**	**150 h**	**120 h**

Person responsible for the module	Prof. Dr. D. Vogt
Lecturer(s)	Prof. Dr.-Ing. H. Freund, Dr. T. Seidensticker, Prof. Dr. D. Vogt,
Language	English
Requirements according to examination regula-tions	None
Recommended require-ments	None
Coursework / module ex-amination / partial as-sessments	Module examination (“laboratory course project”) including experimental design and execution, presentation (ungraded) and written report (graded). Possibility of repetition according to examination regulations.
Learning objectives	In this advanced practical course the students learn the concrete scientific work at the chair of industrial chemistry, participating in ongoing research within own small research project and evaluate the results based on contemporary literature.
Learning outcomes and competencies	After successful participation in this module, students will be able to: - explain and elucidate modern chemical technological working methods and use them in connection to the knowledge obtained in the courses for the independent planning and execution of research experiments.

	- understand and evaluate current publications from the field of Industrial Chemistry and Chemical Technology. - implement modern concepts of chemical technology in experimental setups and plans. - critically evaluate, interpret and present the data obtained in the experiments. - place observations into the context and state-of-the-art of industrial chemistry. - work out the obtained scientific results in the form of a research report, which formally satisfies the requirements of a scientific publication. - take part in the discussion on problem-solving strategies and to properly elucidate the own point of view. - interdisciplinary cooperate with chemical engineers and graduates of other disciplines.
Content	The work is carried out in the research lab. A small, self-contained question from a current research area is worked on, in order to get acquainted with all connected chemical, operative, experimental, and analytical aspects of research carried out in Industrial Chemistry. Topics in question are: 1. Chair of Industrial Chemistry: - Homogeneous Catalysis, - Conversion of renewables - Tandem reactions 2. Chair of Reaction Engineering and Catalysis: - Heterogeneous Catalysis, - Reaction Engineering
Media forms	Reports; discussions
Literature	Selected articles from scientific journals on the subject of research

Module name	Compulsory advanced elective laboratory course **Industrial Chemistry 2**			
Abbreviation	MPR			
Interval of offer By appoint-ment	**Duration** 1 semester	**Semester of study** 1 to 4	**Credits** 9	**Curriculum assignment** M. Sc. Chemistry Subject: TC Major subject: E. T.

Module structure

No.	Course	Type	CP	SWS	Presence time	Self-study
1	Industrial Chemistry 2	P	7	8	120 h	90 h
2	Seminar for Industrial Chemistry 2	S	2	2	30 h	30 h
	Total		**9**	**10**	**150 h**	**120 h**

Person responsible for the module	Prof. Dr. D. Vogt
Lecturer(s)	Prof. Dr.-Ing. H. Freund, Dr. T. Seidensticker, Prof. Dr. D. Vogt,
Language	English
Requirements according to examination regula-tions	None
Recommended require-ments	None
Coursework / module ex-amination / partial as-sessments	Module examination (“laboratory course project”) including experimental design and execution, presentation (ungraded) and written report (graded). Possibility of repetition according to examination regulations.
Learning objectives	The compulsory elective lab course 2 supplements lab course 1 and is therefore carried out in a different subject area. In this advanced practical course the students learn the con-crete scientific work at the chair of industrial chemistry, partic-ipating in ongoing research within own small research project and evaluate the results based on contemporary literature.
Learning outcomes and competencies	After successful participation in this module, students will be able to: - explain and elucidate modern chemical technological working methods and use them in connection to the

	knowledge obtained in the courses for the independent planning and execution of research experiments. - understand and evaluate current publications from the field of Industrial Chemistry and Chemical Technology. - implement modern concepts of chemical technology in experimental setups and plans. - critically evaluate, interpret and present the data obtained in the experiments. - place observations into the context and state-of-the-art of industrial chemistry. - work out the obtained scientific results in the form of a research report, which formally satisfies the requirements of a scientific publication. - take part in the discussion on problem-solving strategies and to properly elucidate the own point of view. - interdisciplinary cooperate with chemical engineers and graduates of other disciplines.
Content	The work is carried out in the research lab. A small, self-contained question from a current research area is worked on, in order to get acquainted with all connected chemical, operative, experimental, and analytical aspects of research carried out in Industrial Chemistry. Topics in question are: 1. Chair of Industrial Chemistry: – Homogeneous Catalysis, – Conversion of renewables – Tandem reactions 2. Chair of Reaction Engineering and Catalysis: – Heterogeneous Catalysis, – Reaction Engineering
Media forms	Reports; discussions
Literature	Selected articles from scientific journals on the subject of research

Module name	Compulsory advanced elective laboratory course **Medicinal chemistry**
Abbreviation	MPR

Interval of offer annual	**Duration** 1 semester	**Semester of study** 1 to 4	**Credits** 9	**Curriculum assignment** M. Sc. Chemistry Subject: SoC M. Sc. Chemical Biology Subject: MC

Module structure

No.	**Course**	**Type**	**CP**	**SWS**	**Presence time**	**Self-study**
1	Medicinal Chemistry	P	6	8	120 h	60 h
2	Seminar for Medicinal chemistry	S	3	2	30 h	60 h
		Total	**9**	**10**	**150 h**	**120 h**

Person responsible for the module	Prof. Dr. D. Rauh
Lecturer(s)	Prof. Dr. D. Rauh, Dr. M. Müller, Prof. Dr. S. Brakmann, Dr. L. Urner, research assistants
Language	English
Requirements according to examination regulations	Students of the Master's degree program in Chemistry can only take part in the practical course upon application.
Recommended requirements	Attendance of the lectures "Medicinal Chemistry 1 and 2", "Design and Synthesis of Bioactive Substances and Drugs", "Applied Computer Methods in Life Sciences" or "Biomolecular Modeling".
Coursework / module examination / partial assessments	Experimental protocols, final oral examination. Attendance is compulsory for the practical course, as the learning objective can only be achieved by hands-on experience with the experimental equipment available. In the case of justified absences, e.g. due to illness certified by a doctor's attestation, 10% of the practical course (max. two days) can be compensated by repetition. In case of longer absences, the entire practical course must be repeated.
Learning objectives	Students learn basic knowledge of the most important methods in medicinal chemistry as well as the application of this knowledge.
Learning outcomes and competencies	By successfully completing this module, students will be able to

	– critically evaluate the significance of small bioactive molecules within the areas of chemical biology, biotechnology and biomedicine. – link computer-based methods with chemical and biological questions. – conduct a database search and independently apply computer-based methods for rational drug design. – independently carry out the analytics of small molecules using NMR and LC-MS and evaluate the data obtained. – plan and carry out syntheses and testing of enzyme inhibitors. – independently carry out work in the laboratory taking into account environmental and safety regulations as well as GMP and GLP rules, evaluate and document it in accordance with the "rules of good scientific practice". – generate and analyse/validate structural models of protein:ligand complexes.
Content	1. *Practical methods of drug synthesis* – Identification and assessment of the purity of small molecules by NMR and LC-MS – Synthesis (especially of drug-relevant heterocycles) and purification of an inhibitor, characterisation of the compound by LC-MS and NMR 2. *Computer-aided drug design* – Database research and virtual synthesis to create a molecule library – Molecular Docking of the library – Pharmacophore-based virtual screening – Research of molecules in various databases important for medicinal chemistry (BindingDB, Pubchem, Pubchem Bioassay, ChEMBL, TTD) 3. *X-ray crystallography in medicinal chemistry* – Validation and visualisation of X-ray crystal structures from the Protein Data Bank (PDB) – Crystallisation of proteins and protein:ligand complexes by co-crystallisation and soaking
Media forms	Blackboard, slides, PowerPoint presentation, online script (accompanying), public online databases
Literature	Accompanying (online) script, current original literature

Module name	Compulsory advanced elective laboratory course **Bioorganic Chemistry II**			
Abbreviation	MPR			
Interval of offer annual	**Duration** 1 semester	**Semester of study** 1 to 4	**Credits** 9	**Curriculum assignment** M. Sc. Chemical Biology Subject: CB / BioOC

Module structure

No.	**Course**	**Type**	**CP**	**SWS**	**Presence time**	**Self-study**
1	Bioorganic Chemistry II	P	6	8	120 h	60 h
2	Seminar for Bioorganic Chemistry II	S	3	2	30 h	60 h
		Total	**9**	**10**	**150 h**	**120 h**

Person responsible for the module	Dr. M. Bührmann
Lecturer(s)	Dr. M. Bührmann, university teachers of Chemical Biology
Language	English
Requirements according to examination regulations	None
Recommended require-ments	Basic knowledge of bioorganic chemistry according to the lecture Bioorganic Chemistry I and solid basics in organic chemistry and biochemistry
Coursework / module ex-amination / partial assess-ments	Module examination (“laboratory course project”). The pro-ject consists of successful participation in the seminar, com-pletion of the experiments, and submission of all protocols (40 % of the grade) and a final graded oral exam which is based on the theoretical and practical aspects of the course (60 % of the grade). The final submission of the proto-cols, after correction by the laboratory assistants, is a pre-requisite for the oral exam, which will take place within two weeks after the final submission. Repetition options and interval of offer according to the ex-amination regulations (PO). Attendance is compulsory because it is necessary to carry out the experiments on the equipment provided. This com-pulsory attendance refers to the preliminary discussion, which includes the safety briefing, and to the practical exe-cution of the experiments. Four experiments, each lasting one week, must be com-pleted during the laboratory course. Compulsory attendance

	is defined in a way that all four experiments must be successfully completed. If students are absent on individual days, this can only be excused by a medical certificate. If the experiment is completed despite of any excused absence, this practical part will be recognized as successfully passed. If an experiment cannot be completed, it must be made up for at the next opportunity (after submitting a medical certificate). If several experiments cannot be carried out, the entire laboratory course must be repeated at a later date.
Learning objectives	Students acquire in-depth knowledge of the principles and methods of bioorganic chemistry and are able to apply this knowledge confidently in theory and practice.
Learning outcomes and competencies	After successfully completing this module, students will be able to – explain modern working techniques in bioorganic chemistry, select them according to practical requirements and put these working techniques into practice. – carry out a computer-aided literature search and assess the validity and safety of information. – carry out work in the laboratory independently, considering environmental and safety regulations, analyze and document it in accordance with the "rules of good scientific practice". – categorize the scientific results obtained in the context of previously published findings in bioorganic chemistry. – summarize the scientific results obtained in the form of a written paper that meets the requirements of a scientific publication and present them orally. – discuss solution strategies, communicate their own point of view appropriately and collaborate with others.
Content	1. Linking chemical and biological working techniques, questions and ideas 2. Using the expertise of chemistry to answer biological questions 3. Proteome analysis 4. Combinatorial synthesis of substance libraries and proof of biological activity 5. Synthesis and biochemical evaluation of a deubiquitinase inhibitor 6. Bioactive detergents as antibiotics
Media forms	Blackboard, slides, PowerPoint presentations, practical course script
Literature	1. Waldmann, Janning, "Chemical Biology - A Practical Course", Wiley-VCH 2. Waldmann, Janning, "Chemical Biology - Learning through Case Studies", Wiley-VCH

	3. general textbooks on organic chemistry (*e.g.*: Vollhardt, "Organische Chemie", Wiley-VCH) and biochemistry (e.g.: Voet, Voet, "Biochemie", Wiley-VCH)

Module name	Compulsory advanced elective laboratory course **Systems Biology**					
Abbreviation	MPR					
Interval of offer annual	**Duration** 1 Semester	**Semester of study** 1 bis 4	**Credits** 9	**Curriculum assignment** M. Sc. Chemische Biologie Subject: ZB / Systems Biology		
Module structure						
No.	**Course**	**Type**	**CP**	**SWS**	**Presence time**	**Self-study**
1	Systems Biology	P	6	8	120 h	60 h
2	Seminar for Systems Biology	S	3	2	30 h	60 h
	Total		**9**	**10**	**150 h**	**120 h**

Person responsible for the module	Prof. Dr. P. Bastiaens
Lecturer(s)	Prof. Dr. P. Bastiaens, Dr. P. Bieling, Dr. L. Dehmelt, Dr. M. Schmick, Dr. C. Schröter
Language	English
Requirements according to examination regulations	None
Recommended require-ments	Lecture “Systems Biology”. Chemical Biology Bachelor modules in Cell Biology and Mathematics (MMa, MMb)
Coursework / module exam-ination / partial assess-ments	Written examination, repeatability and rotation according to examination regulations.
Learning objectives	Students investigate the connection between the biochem-istry of protein dynamics and interactions on a nanometre scale and the (self-)organisation of multicellular associa-tions in various experiments. Examples of biochemical os-cillators, computer-assisted evaluation of (image) data and simulation of biological systems accompanying experi-ments are emphasised.
Learning outcomes and competencies	Upon successful completion of the module, students will be able to, – analyse current systems biology questions. – explain and classify systems biological processes on the basis of molecular biology, cell biology, biochemis-try, biophysics and mathematics.

	– carry out microscopic measurements on the cellular activity of various proteins and their interactions, analyse them quantitatively and then evaluate them within the framework of mathematical modelling. – explain and apply current methods of molecular biology, cell biology, microscopy and micro-spectroscopy and perform a systems biology analysis of the results. – carry out work in the laboratory independently, taking into account environmental and safety regulations, to evaluate it and to document it in accordance with the "rules of good scientific practice". – communicate the results achieved in a joint presentation in a professional language.
Content	1. Computer-assisted image and data analysis; simulation of biological systems 2. The repressilator as an example of oscillating gene expression 3. Oscillating activity of the Erk protein 4. Reconstitution of molecular motors and polymerizing filaments 5. Excitable systems: the Belousov-Zhabotinsky-reaction and Dictyostelium discoideum
Forms of media	Powerpoint presentation; via Moodle: skripts, exercise sheets, protocols and relevant literature as pdf
Literature	Primary specialist literature

Module name		Compulsory advanced elective laboratory course **Advanced Cell Culture Models**					
Abbreviation		MPR					
Interval of offer annual	**Duration** 1 semester	**Semester of study** 1 to 4	**Credits** 9	**Curriculum assignment** M. Sc. Chemical Biology Subject: ZB			
Module structure							
No.	**Course**		**Type**	**CP**	**SWS**	**Presence time**	**Self-study**
1	Advanced cell culture models		P	6	8	120 h	60 h
2	Seminar for Advanced cell culture models		S	3	2	30 h	60 h
			Total	**9**	**10**	**150 h**	**120 h**

Person responsible for the module	Prof. Dr. B. Trappmann
Lecturer(s)	Prof. Dr. B. Trappmann
Language	English
Requirements according to examination regulations	None
Recommended require-ments	Solid practical knowledge of biochemistry and molecular biology, attendance of the lecture "Biomaterials – from cells to tissues"
Coursework / module exami-nation / partial assessments	Module examination("laboratory course project"): Successful participation in the laboratory course including submission of all protocols (50% of the final grade) and a graded oral final exam (50% of the final grade). Possibilities of repeating the course according to examination regulations. The oral exam should be taken no later than six months after the beginning of the practical course. The final versions of the protocols should be submitted to the supervisor no later than two weeks before the oral exam. Deadlines are announced in the introductory meeting. Personal presence during the performance of the experiments is mandatory. The compulsory attendance also refers to the introductory meeting, which includes the safety briefing. Absent days are excused only by a valid reason. In case of an absence of more than two days, the laboratory course must be repeated at a later date.

Learning objectives	Students will acquire practical experience with setting up and maintaining mammalian cell cultures, with a special focus on sterile working techniques. They will gain knowledge about different kinds of 2D and 3D cell culture models and their applications, and will be able to appy the knowledge to solve questions in cell biology. Importantly, they will learn how to analyze data obtained from cell culture experiments.
Learning outcomes and competencies	After module completion, students will be able to – assess the importance of cell culture models in cell biology and biomedicine – explain and apply basic design principles in modern cell culture scaffolds – understand how properties of biomaterial scaffolds regulate cell function in 2D and 3D and apply this knowledge to custom-design cell culture models to study basic questions in cell biology – independently familiarize themselves with a cell biological/biomedical topic/problem in a scientific manner (e.g. by literature search), and assess the validity/safety of the information – carry out work in a cell culture laboratory independently, considering environmental and safety regulations, and to document obtained results in accordance with the rules of good scientific practice – analyse the data obtained from cell culture experiments, including (confocal) microscope image analysis – present and discuss the scientific results orally and in writing – discuss complex interdisciplinary biomedical topics in spoken and written language using the correct scientific terminology, including discussion in groups
Content	1. Basics of mammalian cell culture with a special focus on sterile work techniques 2. 2D cell culture assays to determine cell proliferation rates 3. Generation of tumor cell spheroids 4. Preparation of natural and synthetic hydrogels as 3D extracellular matrices 5. 3D collagen-based model of tumor cell migration 6. Scratch wound assay to mimic angiogenesis in 2D 7. Microfluidic devices to mimic angiogenesis in 3D 8. Preparation of cells for confocal microscopy imaging, including immunofluorescence stainings 9. Analysis of imaging data using dedicated software (e.g. ImageJ, Imaris)
Media forms	Powerpoint presentations, chalkboard teaching, research papers, online script
Literature	Literature recommendations will be made during the course

Module name	Compulsory advanced elective laboratory course **Advanced Methods of Protein Modification and Structural Analysis**
Abbreviation	MPR

Interval of offer	**Duration**	**Semester of study**	**Credits**	**Curriculum assignment**
annual	1 semester	1 to 4	9	M. Sc. Chemical Biology Subject: CB / Recombinant DNA & Protein expression

Module structure

No.	**Course**	**Type**	**CP**	**SWS**	**Presence time**	**Self-study**
1	Advanced Methods of Protein Modification and Structural Analysis	P	6	8	120 h	60 h
2	Seminar for Advanced Methods of Protein Modification and Structural Analysis	S	3	2	30 h	60h
		Total	**9**	**10**	**150 h**	**120 h**

Person responsible for the module	Prof. Dr. D. Summerer
Lecturer(s)	Prof. Dr. D. Summerer, Prof. Dr. D. Rauh, Dr. M. Müller
Language	English
Requirements according to examination regulations	None
Recommended requirements	Practical expertise in microbiology and biochemistry
Coursework / module examination / partial assessments	Partial assessment: Laboratory performance. Experimental performance, graded protocols (4.5 CP) Partial assessment: Exam. Written entrance examination, graded oral examination (4.5 CP) Repeatability and rotation according to examination regulations.
Learning objectives	The students acquire advanced knowledge of cloning, protein expression, chemical modification, and crystallization, and can apply these independently.
Learning outcomes and competencies	Upon successful completion of this module, students will be able: – to critically assess the important application parameters of protein modification strategies and chose the right modification strategy according to the specific needs of different areas of protein research.

	– to explain and apply advanced molecular biology, biochemistry and structural biology methods for the study of proteins. – to work in the laboratory independently under consideration of environmental and safety regulations and evaluate the results in accordance with the "rules of good scientific practice". – to summarize the obtained scientific results in the form of a written paper, which meets the requirements of a scientific publication. – to conduct a computer-assisted literature search and to assess the validity and reliability of information. – to discuss the development of solution strategies, to communicate one's own point of view appropriately and to cooperate with others.
Content	1. Chemical protein modification I: – Genetic Code Expansion (incorporation of unnatural amino acids by amber-suppression for copper-free click chemistry) – cloning of gene fragments in expression vectors by PCR, restriction digestion/ligation as well as Gibson assembly. – transformation of *E. coli* – protein expression and purification – Fluoresence modification of proteins by different types of copper-free click chemistry – Assessment of reaction kinetics of the employed modification strategies 2. Chemical protein modification II: – Expressed Protein Ligation with Inteins – expression and purification of an intein Fusion construct – formation of the protein thioester – ligation with a fluorescently labeled peptide – analysis of the modified protein 3. Crystallization of a protein: – preparation of the crystallization experiments – recording and evaluation of X-ray diffraction data – determination and interpretation of the crystal structure
Media forms	Internship Script, PowerPoint presentation, blackboard images, slides.
Literature	General: Molecular cloning: A laboratory manual. J. Sambrook, E. F. Fritsch, and T. Maniatis, ISBN 0879695765 <u>Experiment 1</u>: Adding new chemistries to the genetic code. Liu C. C and Schultz P. G., Annu. Rev. Biochem. 2010, 79, 413-44. Expanding and reprogramming the genetic code of cells and animals. Chin, J. W., Annu Rev. Biochem. 2014, 83, 379-408.

	Experiment 2: Chemoselective ligation and modification strategies for peptides and proteins. Hackenberger CP, Schwarzer D., Angew Chem 2008;47(52):10030-74. Experiment 3: Crystallography Made Crystal Clear (Third Edition), Gale Rhodes ISBN: 978-0-12-587073-3 Biomolecular Crystallography, Bernhard Rupp ISBN: 9780815340812

<table>
<tr><td colspan="2">Module name</td><td colspan="7">Compulsory advanced elective laboratory course
Cell-Free Systems</td></tr>
<tr><td colspan="2">Abbreviation</td><td colspan="7">MPR</td></tr>
<tr><td>Interval of offer
annual</td><td>Duration
1 semester</td><td>Semester of study
1 to 4</td><td>Credits
9</td><td colspan="5">Curriculum assignment
M. Sc. Chemical Biology
Subject: CB</td></tr>
<tr><td colspan="9">Module structure</td></tr>
<tr><td>No.</td><td colspan="2">Course</td><td>Type</td><td>CP</td><td>SWS</td><td>Presence time</td><td colspan="2">Self-study</td></tr>
<tr><td>1</td><td colspan="2">Cell-Free Systems</td><td>P</td><td>6</td><td>8</td><td>120 h</td><td colspan="2">60 h</td></tr>
<tr><td>2</td><td colspan="2">Seminar for Cell-Free Systems</td><td>S</td><td>3</td><td>2</td><td>30 h</td><td colspan="2">60 h</td></tr>
<tr><td colspan="4">Total</td><td>9</td><td>10</td><td>150 h</td><td colspan="2">120 h</td></tr>
<tr><td colspan="2">Person responsible for the module</td><td colspan="7">Prof. Dr. Hannes Mutschler</td></tr>
<tr><td colspan="2">Lecturer(s)</td><td colspan="7">Prof. Dr. Hannes Mutschler</td></tr>
<tr><td colspan="2">Language</td><td colspan="7">English</td></tr>
<tr><td colspan="2">Requirements according to examination regulations</td><td colspan="7">None</td></tr>
<tr><td colspan="2">Recommended requirements</td><td colspan="7">Solid practical knowledge of biochemistry and molecular biology, attendance of the lecture “Cell-Free Systems”</td></tr>
<tr><td colspan="2">Coursework / module examination / partial assessments</td><td colspan="7">Modul examination (“Praktikumsprojekt”): Successful participation in the practical course including submission of all protocols (50% of the final grade) and a graded oral or written final exam (50% of the final grade). Possibilities of repeating and recurrence of the course according to examination regulations (“Prüfungsordnung”).

The written/oral exam should be taken no later than four months after the end of the practical course. Since the exam refers to the submitted protocol and experiments, the final version of the protocol should be submitted to the supervisor no later than ten weeks after the end of the practical course.

Personal presence during the performance of the experiments is mandatory. The compulsory attendance also refers to the introductory meeting, which includes the safety briefing. Absent days are excused only by a sick note. In case of an absence of more than two days, the internship must be repeated at a later date.</td></tr>
</table>

Learning objectives	The students will acquire practical experience with handling different cell-free systems tools such as the production, engineering and experimental usage of small molecule and nucleic acid sensors, proteins, catalytic nucleic acids and artificial cells. They will gain knowledge about the in vitro synthesis of the different parts, possible applications of different cell-free expression systems, and will be able to apply the knowledge to solve problems in synthetic biology.
Learning outcomes and competencies	By successfully completing this module, students will be able to: – assess the importance of cell-free biology in biotechnology, biomedicine and basic research. – explain and apply methods and applications of cell-free systems. – describe the design and generation of artificial biosystems and to be able to assess their potential, for example in molecular diagnostics or basic research. – independently familiarize themselves with a scientific question / topic by selecting appropriate strategies for information acquisition. – evaluate the validity and safety of information and experimental measurements. – present scientific facts in technical language and to discuss them with others. – carry out work in the laboratory independently, considering environmental and safety regulations, and to evaluate and document it in accordance with the "Rules of Good Scientific Practice". – summarize the scientific results obtained in the form of a written paper that meets the requirements of a scientific publication. – conduct a computer-assisted literature search and to assess the validity and safety of information. – discuss and appropriately communicate one's own point of view and collaborate with others when developing solution strategies.
Content	1. Preparation of DNA-templates for in-vitro-transcription and / or coupled in-vitro-transcription / translation 2. In-vitro-transcription of RNAs and subsequent preparation and concentration determination 3. Fluorescence-based real-time RNA synthesis and cell-free protein expression using PURE-systems 4. Detection of viral model RNAs from randomized samples using toehold sensors 5. Use of RNA-cleaving DNAzymes for gene silencing in cell-free protein synthesis 6. Preparation of catalytic RNAs (ribozymes) 7. Usage of light-up aptamers as small-molecule biosensors 8. Quantitative ribozyme activity assays using denaturing gel electrophoresis and molecular imaging

	9. Ribozyme activity assays in presence of additives such as peptides 10. Preparation and imaging of artificial cells.
Media forms	Powerpoint & blackboard presentations, research papers, online script
Literature	The New Age of Cell-Free Biology, Noireaux and Liu (2020) *Annual Review of Biomedical Engineering*, 22, 51 Silverman *et al.*, Cell-free gene expression: an expanded repertoire of applications. (2020) *Nature Reviews Genetics* 21, 151 Hodgman & Jewett, Cell-free synthetic biology: Thinking outside the cell. (2012) *Metabolic Engineering*, 14, 261 General basic literature of biochemistry and molecular biology (Stryer, Alberts, etc.).

Major subject seminars

Module name		Major subject seminar **Chemical Biology**					
Abbreviation		MSE					
Interval of offer annual	**Duration** 1 Semester	**Semester of study** 1 to 4	**Credits** 6	**Curriculum assignment** M. Sc. Chemical Biology Subject: CB			
Module structure							
No.	**Course**		**Type**	**CP**	**SWS**	**Presence time**	**Self-study**
1	Chemical biology		S	6	4	60 h	120 h
			Total	**6**	**4**	**60 h**	**120 h**
Person responsible for the module		Dr. M. Gersch					
Lecturer(s)		University lecturers of chemical biology (for current semester see announcement of chemical biology)					
Language		English					
Requirements according to examination regulations		None					
Recommended requirements		Knowledge in biochemistry and bioorganic chemistry as well as cell biology					
Coursework / module examination / partial assessments		Partial assessment: Presentation. Talk on a given topic and performance in the discussion of the presentations (3 CP) Partial assessment: Exam. Written final exam (3 CP)					
Learning objectives		Students acquire basic and advanced knowledge of chemical biology and can apply this for solution of practical problems or development of own ideas.					
Learning results and competencies		By successfully completing this module, students will be able to – describe basic models of chemical biology. – formulate hypotheses for simple questions in chemical biology and to carry out the design of their experimental verification. – analyse case studies on current topics in chemical biology. – critically examine current literature on the topic, both from primary and secondary literature, and place it into the context of current research. – work independently on a current topic from chemical biology and to present the topic in a scientific talk with					

	presentation of the core questions, the experimental approach, the results and to face a critical discussion.
Contents	Current topics from the field of chemical biology, e. g. chemical genetics, epigenetics, target identification or chemical and biochemical modulation of enzyme activities.
Media forms	Power Point presentations, pdf versions of the presentations as accompanying scripts, original publications, books
Literature	H. Waldmann, P. Janning: Chemical Biology – Learning Through Case Studies, Wiley-VCH, 2009. Research publications provided by the lecturers at the beginning of the course.

<table>
<tr><td colspan="2">Module name</td><td colspan="3">Major subject seminar
Medicinal Chemistry: Fundamentals and Strategies in Drug Discovery</td></tr>
<tr><td colspan="2">Abbreviation</td><td colspan="3">MSE</td></tr>
<tr><td>Interval of offer
annual</td><td>Duration
1 semester</td><td>Semester of study
1 to 4</td><td>Credits
6</td><td>Curriculum assignment
M. Sc. Chemical Biology
Subject: MC</td></tr>
</table>

Module structure

No.	Course	Type	CP	SWS	Presence time	Self-study
1	Medicinal Chemistry: Fundamentals and Strategies in Drug Discovery	S	6	4	60 h	120 h
	Total		**6**	**4**	**60 h**	**120 h**

Person responsible for the module	Prof. Dr Daniel Rauh
Lecturer(s)	Prof. Dr Susanne Brakmann, Prof. Dr Daniel Rauh, Dr Matthias Müller
Language	English
Requirements according to examination regulations	None
Recommended require-ments	Fundamentals of biochemistry, cell biology, bioorganic chemistry and medicinal chemistry 1 and 2
Coursework / module ex-amination / partial assess-ments	Partial assessment: Presentation. Seminar presentation based on scientific publications on a given topic and subse-quent discussion (3.5 CP) Partial assessment: Exam. Oral or written final examination (2.5 CP) Possibility of repetition according to examination regulations. <u>Compulsory attendance</u>: Attendance is compulsory for this seminar. Reason: 1. Each student gives a presentation followed by a dis-cussion; this unit is graded. Since the topics build directly on each other, absences directly lead to knowledge deficits. Core statements of the lectures and the discussion are di-rectly relevant for the final examination. 2. One learning objective of the seminar is to give presentations in front of an audience. If the size of the audi-ence is not constant and difficult to calculate, the conditions are not equivalent for all students.

	Maximum tolerable absences: 1-2 working days, with certificate only. The missing knowledge has to be made up for in own work.
Learning objectives	Students gain fundamental knowledge of topics and strategies in modern drug discovery and development such as - synthesis and coding of drug libraries, assay development, - nanoscale detection of molecular interactions, single molecule techniques, DNA and RNA technologies and protein technologies.
Learning outcomes and competencies	By successfully completing this module, students will be able to, – describe current approaches to identifying new active substances and active principles as well as methods for their development or implementation. – explain current techniques for individualisable diagnostics and analytics. – select suitable approaches to drug design, identification and development in a problem-oriented manner. – understand current literature and critically look into a scientific publication, also with the help of secondary literature. – work independently on a current topic of medicinal chemistry and to present the topic in the form of a scientific lecture with presentation of the core questions, the experimental approach and the results as well as to face a critical discussion.
Content	Current topics from the field of 1. Active ingredient research 2. Medicinal chemistry 3. Translational Chemical Biology and Medicine 4. Biotechnology
Media forms	Powerpoint presentation, handout
Literature	Current scientific literature from the field of drug discovery, chemical biology, medicine and biotechnology

Research laboratory courses

Module name	Research laboratory course in the major subject of the Master's thesis **Inorganic Chemistry**
Abbreviation	MVMT

Interval of offer By appointment	**Duration** 1 semester	**Semester of study** 3	**Credits** 10	**Curriculum assignment** M. Sc. Chemistry Subject: AC Major subject: M. M. M. Sc. Chemical Biology Subject: SoC

Module structure

No.	Course	Type	CP	SWS	Presence time	Self-study
1	Inorganic Chemistry	P	7	10	150 h	60 h
2	Seminar for Inorganic Chemistry	S	3	2	30 h	60 h
		Total	**10**	**12**	**180 h**	**120 h**

Person responsible for the module	Prof. Dr. G. Clever
Lecturer(s)	Supervisor of the master thesis
Language	English
Requirements according to examination regulations	Prior successful participation in 4 compulsory advanced elective laboratory courses and at least 2 compulsory elective lectures, which must be part of the major subject for chemistry students. In addition, students must have taken part in the final examinations of at least 4 further compulsory elective lectures.
Recommended requirements	None
Coursework / module examination / partial assessments	Module examination (“Laboratory course project”): consisting of experimental planning, execution and detailed final report (50% of the grade) and oral examination with seminar presentation and concluding discussion of own project work (50% of the grade). The oral examination should be taken no later than 6 months after the start of the internship project. The final report should be submitted to the supervisor no later than 4 months after the start of the internship project. Possibilities of repeating and rotation according to PO.

Learning objectives	The students learn special working methods of inorganic chemistry and apply the acquired knowledge in carrying out their own project work. After completing the module, they can present the results of the project appropriately in a seminar lecture and place them in the context of the scientific research projects of the working group. They can present their results appropriately in the form of a written paper and a lecture in accordance with the usual methodology in chemistry.
Learning outcomes and competencies	After successful completion of this module, students are able to, - explain modern working techniques of inorganic chemistry, select them according to synthetic requirements and implement these working techniques practically. - carry out a computer-assisted literature search and assess the relevance, validity and safety of information. - plan synthesis routes independently, to propose alternative synthesis routes and to evaluate them in a differentiated way. - select suitable analytical methods, to explain the limits and possibilities of the respective method, to process, evaluate and interpret the obtained measurement data. - carry out computer-assisted calculations regarding the structure and properties of molecules, visualize and interpret the results. *) - summarize the topic of a scientific article, research background information independently, present and discuss the contents in a seminar presentation. - independently plan a simple project and carry it out on time, taking into account legal requirements (occupational health and safety and environmental legislation). - evaluate scientific results obtained, summarize them, place them in the context of previously published findings and document them according to the "rules of good scientific practice". *) This learning outcome depends on the respective task.
Content	1) Laboratory internship The topics are oriented towards current research problems and the specific working techniques of the working group. The research topics can come from the following areas, among others: - Coordination chemistry - Supramolecular chemistry - Main group chemistry - Bioinorganic chemistry - Chemistry in water - Inorganic polymers - Metalorganic Chemistry - Computational Chemistry Analytical methods used (selection): 1. Mass spectrometry

	2. Ion mobility spectrometry 3. Infrared spectroscopy 4. UV/VIS spectroscopy 5. Elemental analysis 6. Melting point determination 7. Rotational value determination 8. Refractive index 9. NMR spectroscopy (e.g. of the nuclei 1H, 13C, 31P, 19F, 119Sn, 29Si, 195Pt) 10. Single-crystal structure analysis 11. X-ray powder diffraction 2) Seminars: Seminar presentations on current research results with subsequent discussion.
Media forms	Lab diary, written final report, PowerPoint presentation, blackboard, slides.
Literature	Original literature (articles from peer-reviewed journals), literature recommendations are made during the course depending on subject

Module name	Research laboratory course in the major subject of the Master's thesis **Organic Chemistry**					
Abbreviation	MVMT					
Interval of offer By appointment	**Duration** 1 semester	**Semester of study** 3	**Credits** 10	**Curriculum assignment** M. Sc. Chemistry Subject: OC Major subject: M. M. M. Sc. Chemical Biology Subject: SoC		

Module structure

No.	**Course**	**Type**	**CP**	**SWS**	**Presence time**	**Self-study**
1	Organic Chemistry	P	7	10	150 h	60 h
2	Seminar for Organic Chemistry	S	3	2	30 h	60 h
		Total	**10**	**12**	**180 h**	**120**

Person responsible for the module	Prof. Dr. M. M. Hansmann
Lecturer(s)	Supervisor of the master thesis
Language	English
Requirements according to examination regulations	Prior successful participation in 4 compulsory advanced elective laboratory courses and at least 2 compulsory elective lectures, which must be part of the major subject for chemistry students. In addition, students must have taken part in the final examinations of at least 4 further compulsory elective lectures.
Recommended requirements	None
Coursework / module examination / partial assessments	Module examination (“Laboratory course project”): consisting of experimental planning, execution and detailed final report (70% of the grade) and examination presentation with subsequent discussion of the project (30% of the grade). The presentation should be held no later than 6 months after the start of the internship project. Since the presentation refers to the internship, the final protocol should be handed in to the supervisor at least 6 weeks before the exam presentation. Attendance is compulsory at the seminar session, as this is the only place to learn, practice and refine scientific presentation and discourse in an audience setting. This

	qualification is not only effective for the disputation of the master thesis, but also qualifies for a profession. Possibilities of repeating and rotation according to PO.
Learning objectives	While working on a small, more challenging research project of a research group of the organic chemistry department, students acquire the theoretical and technical skills to independently plan, experimentally perform and document a synthesis sequence in organic synthetic chemistry. During the practical course, students acquire knowledge of special working methods in organic chemistry as well as the latest methods from research and are able to apply them independently. While carrying out the research project, students learn to independently lead such a project to success and evaluate the obtained results based on the literature. They deepen their ability to appropriately summarize, present and discuss their results in the form of a written paper and a presentation according to the methodology commonly used in organic chemistry. In the seminar, students participate in the scientific discourse on current issues in organic chemistry and present their lecture.
Learning outcomes and competencies	After successful completion of this module, students are able to, - explain modern experimental working techniques in organic chemistry, select and evaluate them according to synthetic requirements and implement these working techniques in practice. - safely implement special working techniques from organic synthesis chemistry and to safely carry out procedures for the isolation, purification and characterization of low-molecular organic compounds. - conduct a computer-assisted literature search and evaluate the relevance, validity, and reliability of information. plan synthesis routes independently, propose alternative synthesis routes and evaluate them in a differentiated manner. - perform chemical syntheses independently, considering environmental and safety regulations and to evaluate and document them according to the "rules of good scientific practice". - independently select suitable analytical methods, to explain the limits and possibilities of the specific method, to independently process, analyze and interpret the obtained measurement data. - classify and evaluate the obtained scientific results in the context of already published findings in organic chemistry. - summarize the obtained scientific results in the form of a written paper, which corresponds to the requirements of a scientific publication, to analyze and evaluate the results and to present them orally.

	- independently plan a project and implement it on time, taking into account legal requirements (occupational health and safety and environmental legislation). - propose and discuss solution strategies for problems in organic synthesis chemistry, to communicate one's own point of view appropriately and to cooperate with others. - summarize the topic of a scientific article, to research background information independently and to present and discuss the contents.
Content	Work on a current experimental problem from the research field of an organic chemistry working group. The topic of the research project is based on the research topics and working techniques of the working group. The exam lecture will summarize the main experimental results, interpret them and present the resulting conclusions.
Media forms	Written report; discussions and PowerPoint presentations
Literature	Literature recommendation will be made in the context of the Course

Module name	Research laboratory course in the major subject of the Master's thesis **Physical Chemistry**
Abbreviation	MVMT

Interval of offer	**Duration**	**Semester of study**	**Credits**	**Curriculum assignment**
By appointment	1 semester	3	10	M. Sc. Chemistry Subject: PC Major subject: E. T. M. Sc. Chemical Biology Subject: SoC

Module structure

No.	**Course**	**Type**	**CP**	**SWS**	**Presence time**	**Self-study**
1	Physical Chemistry	P	7	10	150 h	60 h
2	Seminar for Physical Chemistry	S	3	2	30 h	60 h
		Total	10	12	180 h	120 h

Person responsible for the module	Prof. Dr. C. Czeslik
Lecturer(s)	Supervisor of the master thesis
Language	English
Requirements according to examination regulations	Prior successful participation in 4 compulsory advanced elective laboratory courses and at least 2 compulsory elective lectures, which must be part of the major subject for chemistry students. In addition, students must have taken part in the final examinations of at least 4 further compulsory elective lectures.
Recommended requirements	None
Coursework / module examination / partial assessments	Module examination ("Laboratory course project"): Detailed experimental protocol and lecture. Possibilities of repetition and cycle according to examination regulations.
Learning objectives	Within the framework of the laboratory course, which is carried out in a working group of the Physical Chemistry section, the students acquire knowledge of state-of-the-art physical-chemical working methods and are able to apply these independently within the framework of a small research project. They deepen their ability to present their results appropriately in the form of a written paper and a lecture according to the methodology commonly used in chemistry or chemical

	biology. The topic should be in the subject of the master's thesis.
Learning outcomes and competencies	After successful completion of this module, students will be able to - explain state-of-the-art physico-chemical working methods and, in conjunction with the knowledge gained in the special lectures, use this knowledge to plan and carry out research experiments independently. - analyze physico-chemical problems logically and implement them in suitable experimental setups. - correctly evaluate and present the data obtained during the experiments and to critically evaluate and interpret them. - elaborate the scientific results obtained in the form of experimental protocols which formally meet the requirements of a scientific publication. - discuss strategies for solutions, to communicate one's own point of view appropriately and to cooperate with others. - summarize the topic of a scientific article, to research background information independently and to present and discuss the contents in a seminar presentation.
Content	The topic of the research project is based on the research topics and working techniques of the respective working group. The topic should be in the subject of the Master's thesis.
Media forms	Seminar: PowerPoint presentations
Literature	Articles selected for the research project in scientific journals

Module name	Research laboratory course in the major subject of the Master's thesis **Industrial Chemistry**			
Abbreviation	MVMT			
Interval of offer By appointment	**Duration** 1 semester	**Semester of study** 3	**Credits** 10	**Curriculum assignment** M. Sc. Chemistry Subject: TC Major subject: E. T.

Module structure

No.	**Course**	**Type**	**CP**	**SWS**	**Presence time**	**Self-study**
1	Industrial Chemistry	P	7	10	150 h	60 h
2	Seminar for Industrial Chemistry	S	3	2	30 h	60 h
		Total	**10**	**12**	**180 h**	**120 h**

Person responsible for the module	Prof. Dr. D. Vogt
Lecturer(s)	Supervisor of the master thesis
Language	English
Requirements according to examination regulations	Prior successful participation in 4 compulsory advanced elective laboratory courses and at least 2 compulsory elective lectures, which must be part of the major subject for chemistry students. In addition, students must have taken part in the final examinations of at least 4 further compulsory elective lectures.
Recommended requirements	None
Coursework / module examination / partial assessments	Module examination (“Laboratory course project”): active participation in the seminar of the respective chair, written report on the research project. Repeat options and rotation according to examination regulations.
Learning objectives	In this internship, students who have chosen the focus area Industrial Chemistry, acquire the experimental requirements for the successful execution of their master thesis, by working on an appropriate small research project.
Learning outcomes and competencies	After successful participation in this module, students will be able to: - fulfill the theoretical and experimental requirements for a master thesis in Industrial Chemistry.

	- master the planning and execution of a largely independent research project. - realize modern concepts of Industrial Chemistry in experimental setups and experimental planning. - analyze, evaluate, present and critically interpret and discuss data obtained in experiments. - present the results in a report, which formally satisfies the requirements of the scientific publication. - understand and evaluate current publications from the field of Industrial Chemistry and Chemical Technology. - classify observations into the current knowledge of Industrial Chemistry. - take part in the discussion on problem-solving strategies and to properly elucidate the own point of view. - interdisciplinary cooperate with chemical engineers and graduates of other disciplines.
Content	A small, self-contained question from a current research area is worked on, in order to get acquainted with all connected chemical, operative, experimental, and analytical aspects of research carried out in Industrial Chemistry. Topics in question are: 1. Chair of Industrial Chemistry: - Homogeneous Catalysis, - Conversion of renewables - Tandem reactions 2. Chair of Reaction Engineering and Catalysis: - Heterogeneous Catalysis, - Reaction Engineering The topic should be located in the subject area of the master thesis.
Media forms	Reports; discussions
Literature	Selected articles from scientific journals on the subject of research.

<table>
<tr><td colspan="3">Module name</td><td colspan="5">Research laboratory course in the major subject of the Master's thesis
Analytical Chemistry</td></tr>
<tr><td colspan="3">Abbreviation</td><td colspan="5">MVMT</td></tr>
<tr><td>Interval of offer
By appointment</td><td colspan="2">Duration
1 semester</td><td>Semester of study
3</td><td>Credits
10</td><td colspan="3">Curriculum assignment
M. Sc. Chemistry
Subject: AC or OC
Major Subject: M. M.
M. Sc. Chemical Biology
Subject: SoC</td></tr>
<tr><td colspan="8">Module structure</td></tr>
<tr><td>No.</td><td colspan="2">Course</td><td>Type</td><td>CP</td><td>SWS</td><td>Presence time</td><td>Self-study</td></tr>
<tr><td>1</td><td colspan="2">Analytical Chemistry</td><td>P</td><td>7</td><td>10</td><td>150 h</td><td>60 h</td></tr>
<tr><td>2</td><td colspan="2">Seminar for Analytical Chemistry</td><td>S</td><td>3</td><td>2</td><td>30 h</td><td>60 h</td></tr>
<tr><td colspan="4">Total</td><td>10</td><td>12</td><td>180 h</td><td>120 h</td></tr>
<tr><td colspan="3">Person responsible for the module</td><td colspan="5">Dr. S. Zühlke</td></tr>
<tr><td colspan="3">Lecturer(s)</td><td colspan="5">Supervisor of the master thesis</td></tr>
<tr><td colspan="3">Language</td><td colspan="5">English</td></tr>
<tr><td colspan="3">Requirements according to examination regulations</td><td colspan="5">Prior successful participation in 4 compulsory advanced elective laboratory courses and at least 2 compulsory elective lectures, which must be part of the major subject for chemistry students. In addition, students must have taken part in the final examinations of at least 4 further compulsory elective lectures.</td></tr>
<tr><td colspan="3">Recommended requirements</td><td colspan="5">Participation "Analytical Chemistry - Water and Soil" and "Introduction to Mass Spectrometry".</td></tr>
<tr><td colspan="3">Coursework / module examination / partial assessments</td><td colspan="5">Module examination (“Laboratory course project”): Experimental protocol and oral presentation. Repeatability and rotation according to examination regulations.</td></tr>
<tr><td colspan="3">Learning objectives</td><td colspan="5">Students acquire knowledge of modern sample preparation and separation methods as well as the functioning of analytical instruments. They independently carry out small research projects or research sub-projects using common methods of analytical chemistry. They deepen their ability to present their results appropriately in the form of a written paper and a lecture in accordance with the methods commonly used in analytical chemistry.</td></tr>
</table>

Learning outcomes and competencies	Upon successful completion of this module, students will be able to, - use the basic analytical separation methods and sample preparations. - operate the available equipment (especially mass spectrometers) and evaluate the data obtained. - apply the acquired theoretical knowledge and subject-specific practical knowledge for the practical solution of analytical problems from the subfield of analysis of environmental pollutants and natural substances. - place the obtained scientific results in the context of the already published findings in analytical chemistry as well as to summarize the obtained scientific results in the form of a written elaboration which meets the requirements of a scientific publication and to present them orally. - conduct a computerized literature search and assess the validity and certainty of information. - discuss, appropriately communicate one's own point of view, and collaborate with others in developing solution strategies.
Content	The topic is based on current topics from the working group and should be in the subject of the master's thesis.
Media forms	Powerpoint presentations, blackboard, other working materials, evaluations at computer workstations
Literature	Oriented to the particular topic and issued individually.

<table>
<tr><td colspan="2">Module name</td><td colspan="5">Research laboratory course in the major subject of the Master's thesis
Chemical Biology</td></tr>
<tr><td colspan="2">Abbreviation</td><td colspan="5">MVMT</td></tr>
<tr><td>Interval of offer
By appointment</td><td>Duration
1 semester</td><td colspan="2">Semester of study
3</td><td>Credits
10</td><td colspan="2">Curriculum assignment
M. Sc. Chemical Biology
Subject: CB</td></tr>
</table>

Module structure

No.	Course	Type	CP	SWS	Presence time	Self-study
1	Research internship in the major field of Chemical Biology	P	7	10	150 h	60 h
2	Seminar for Chemical Biology	S	3	2	30 h	60 h
	Total		**10**	**12**	**180 h**	**120 h**

Person responsible for the module	Dr. M. Gersch
Lecturer(s)	Supervisor of the master thesis
Language	English
Requirements according to examination regulations	Prior successful participation in 4 compulsory advanced elective laboratory courses and at least 2 compulsory elective lectures, which must be part of the major subject for chemistry students. In addition, students must have taken part in the final examinations of at least 4 further compulsory elective lectures.
Recommended requirements	None
Coursework / module examination / partial assessments	Module examination (“Laboratory course project”). Examination lecture in the main seminar and written elaboration on the processed project. Possibilities of repeating and rotation according to examination regulations.
Learning objectives	Through successful participation in this practical course, which is carried out in a working group of chemical biology, the students acquire knowledge of special working methods of chemical biology. The Students are able to apply the obtained knowledge practically as well as to present the results appropriately in the form of a written elaboration and a lecture, according to the usual methodology in chemical biology.

Learning outcomes and competencies	After successful completion of this module, students are able to, - explain the modern working techniques of chemical biology, select them according to the synthetic requirements and implement these working techniques practically. - know and apply the methods of modern computer-assisted literature research. - plan synthesis routes, propose alternative synthesis routes and evaluate them in a differentiated manner. - carry out chemical syntheses and biological experiments taking into account environmental and safety regulations, to evaluate them and to document them according to the "rules of good scientific practice". - select suitable analytical methods, to be able to explain the limits and possibilities of the respective method, to process, evaluate and interpret the obtained measurement data. - perform computer-assisted calculations concerning the structure and properties of molecules, to visualize and interpret the results. - summarize the obtained scientific results in the form of a written paper and to be able to place them in the context of the already published findings. - present the obtained scientific results in the form of a seminar presentation, to justify the approach and to defend the results in a scientific discussion.
Content	Performance of experimental or theoretical work in the field of chemical biology with, for example, microstructural, biochemical, molecular biological, bioorganic synthetic, cell biological, biophysical, microbiological, and bioinformatics focus.
Media forms	Seminars: PowerPoint presentation, online delivery of the lectures, blackboard images, slides, handouts for the lectures.
Literature	Original literature (articles from scientific journals).

<table>
<tr><td colspan="2">Module name</td><td colspan="6">Research laboratory course in the major subject of the Master's thesis
Molecular Cell Biology</td></tr>
<tr><td colspan="2">Abbreviation</td><td colspan="6">MVMT</td></tr>
<tr><td>Interval of offer
By appointment</td><td>Duration
1 Semester</td><td>Semester of study
3</td><td>Credits
10</td><td colspan="4">Curriculum assignment
M. Sc. Chemical Biology
Subject: ZB</td></tr>
<tr><td colspan="8">Module structure</td></tr>
<tr><td>No.</td><td colspan="2">Course</td><td>Type</td><td>CP</td><td>SWS</td><td>Presence time</td><td>Self-study</td></tr>
<tr><td>1</td><td colspan="2">Molecular Cell Biology</td><td>P</td><td>7</td><td>10</td><td>150 h</td><td>60 h</td></tr>
<tr><td>2</td><td colspan="2">Seminar for Molecular Cell Biology</td><td>S</td><td>3</td><td>2</td><td>30 h</td><td>60 h</td></tr>
<tr><td colspan="4" align="right">Total</td><td>10</td><td>12</td><td>180 h</td><td>120 h</td></tr>
</table>

Person responsible for the module	Prof. Dr. P. Bastiaens
Lecturer(s)	Supervisor of the master thesis
Language	English
Requirements according to examination regulations	Prior successful participation in 4 compulsory advanced elective laboratory courses and at least 2 compulsory elective lectures, which must be part of the major subject for chemistry students. In addition, students must have taken part in the final examinations of at least 4 further compulsory elective lectures.
Recommended requirements	None
Coursework / module examination / partial assessments	Module examination (“Laboratory course project”): Presentation in the staff seminar or written paper on the project worked on, repeat options and rotation according to examination regulations.
Learning objectives	Through successful participation in this practical course, which is carried out in a working group of the chemical biology section, the students acquire knowledge of special working methods of chemical biology and are able to apply them practically. They deepen their ability to present their results appropriately in the form of a written paper and a lecture, according to the usual methodology in chemical biology.

Learning outcomes and competencies	Upon successful completion of the module, students will be able to, - explain the modern working techniques of molecular cell biology, select them according to biological and chemical requirements and implement these working techniques in practice. - carry out computer-assisted literature research. - plan experimental strategies, propose alternatives and evaluate them in a differentiated manner. - carry out biological and biochemical experiments taking into account environmental, genetic engineering and safety regulations, to evaluate them and to document them according to the "rules of good scientific practice". - select suitable analytical methods, to explain the limits and possibilities of the respective method, to process, evaluate and interpret the measurement data obtained. - carry out computer-assisted calculations and evaluations concerning the dynamics, localisation and properties of molecules and molecular reactions, to visualise and interpret the results.*) - summarise the scientific results obtained in the form of a written paper and to place them in the context of the already published findings, or - present the scientific results obtained in the form of a seminar presentation, justify the approach and defend the results in a scientific discussion. *) This learning outcome depends on the chosen working group.
Content	Carrying out experimental and/or theoretical work from the field of molecular cell biology with a focus on cell biological, systems biological, molecular biological, biochemical, biophysical, microstructural and bioinformatics research. The topic should be in the subject of the Master's thesis.
Media forms	Seminars: Powerpoint presentations, Online provision of the lectures, blackboard pictures, slides, handouts for the lectures.
Literature	Primary specialist literature

<table>
<tr><td colspan="3">Module name</td><td colspan="6">Research laboratory course in the major subject of the Master's thesis
Drug Synthesis, Medicinal Chemistry and Structural Biology</td></tr>
<tr><td colspan="3">Abbreviation</td><td colspan="6">MVMT</td></tr>
<tr><td colspan="2">Interval of offer
By appointment</td><td>Duration
1 semester</td><td>Semester of study
3</td><td colspan="2">Credits
10</td><td colspan="3">Curriculum assignment
M. Sc. Chemical Biology
Subject: MC</td></tr>
<tr><td colspan="9">Module structure</td></tr>
<tr><td>No.</td><td colspan="3">Course</td><td>Type</td><td>CP</td><td>SWS</td><td>Presence time</td><td>Self-study</td></tr>
<tr><td>1</td><td colspan="3">Drug Synthesis, Medicinal Chemistry and Structural Biology</td><td>P</td><td>7</td><td>10</td><td>150 h</td><td>60 h</td></tr>
<tr><td>2</td><td colspan="3">Seminar for Drug Synthesis, Medicinal Chemistry and Structural Biology</td><td>S</td><td>3</td><td>2</td><td>30 h</td><td>60 h</td></tr>
<tr><td colspan="5" align="right">Total</td><td>10</td><td>12</td><td>180 h</td><td>120 h</td></tr>
<tr><td colspan="3">Person responsible for the module</td><td colspan="6">Prof. Dr. D. Rauh</td></tr>
<tr><td colspan="3">Lecturer(s)</td><td colspan="6">Supervisor of the master thesis</td></tr>
<tr><td colspan="3">Language</td><td colspan="6">English</td></tr>
<tr><td colspan="3">Requirements according to examination regulations</td><td colspan="6">Prior successful participation in 4 compulsory advanced elective laboratory courses and at least 2 compulsory elective lectures, which must be part of the major subject for chemistry students. In addition, students must have taken part in the final examinations of at least 4 further compulsory elective lectures.</td></tr>
<tr><td colspan="3">Recommended requirements</td><td colspan="6">None</td></tr>
<tr><td colspan="3">Coursework / module examination / partial assessments</td><td colspan="6">Module examination (“Laboratory course project”): Presentation in the main seminar and written paper on the project. Possibility of repetition according to examination regulations.</td></tr>
<tr><td colspan="3">Learning objectives</td><td colspan="6">In the module, which is carried out in a working group of the department for Chemical Biology, the students acquire knowledge about special methods of chemical biology and are able to present their results appropriately in the form of a written assignment and a lecture.</td></tr>
<tr><td colspan="3">Learning outcomes and competencies</td><td colspan="6">By successfully completing this module, the students are able to</td></tr>
</table>

	- describe the modern working techniques of drug discovery and medicinal chemistry, select them according to the synthetic and structural biological requirements and implement these working techniques in practice. - conduct computer-assisted literature searches. - plan synthesis routes, propose alternative synthesis routes and evaluate them in a differentiated manner. - carry out chemical syntheses and biological experiments taking into account environmental and safety regulations, evaluate and document them according to the "rules of good scientific practice". - produce and purify recombinant proteins. - crystallise proteins and protein-ligand complexes and determine their structure. - select suitable analytical methods, explain the limits and possibilities of the respective methods, process, evaluate and interpret the obtained experimental data. - perform computer-based calculations regarding the structure and properties of molecules and proteins, visualise and interpret the results. - summarise the scientific results obtained in the form of a written paper and place them in the context of previously published results. - present the scientific results in the form of a seminar presentation, justify the approach and defend the results in a scientific discussion.
Content	Carrying out experimental or theoretical work in the field of medicinal chemistry and drug research with e.g. biochemical, molecular biological, bioorganic synthetic, cell biological, biophysical, structural biological, microbiological and bioinformatic focus. The topic should correspond to the topic of the master's thesis.
Literature	Original literature (articles from scientific journals).

Master’s thesis and disputation

<table>
<tr><td colspan="2">Module name</td><td colspan="3">Master's thesis (M.Sc. Chemistry)</td></tr>
<tr><td colspan="2">Abbreviation</td><td colspan="3">MMT</td></tr>
<tr><td>Interval of offer
By appointment</td><td>Duration
6 months (regular completion time of the Master’s thesis)</td><td>Semester of study
4</td><td>Credits
30</td><td>Curriculum assignment
M. Sc. Chemistry
Subject: AC or OC
Major subject: M. M.
Subject: PC or TC
Major subject: E. T.</td></tr>
</table>

Module structure

No.	Course	CP
1	Master’s thesis	25
2	Master’s thesis defense	5
	Total	**30**

Person responsible for the module	Dean of Studies
Lecturer(s)	Supervisor of the Master's thesis according to the examination regulations
Language	English, German
Requirements according to examination regulations	In addition to §18 of the examination regulations, the following requirements of §21(3) must be met: - acquisition of 70 credit points - successful completion of all laboratory courses
Recommended requirements	None
Coursework / module examination / partial assessments	Thesis (usually max. 60 DIN A4 pages); department-public disputation with lecture and discussion. Possibility of repetition according to examination regulations.
Learning objectives	The students learn to structure an experimental or theoretical task of appropriate scope from the field of chemistry within a specified period of time and to work on it independently under scientific aspects on the basis of known procedures within the specified period of time and to present it in written form in an appropriate manner from a scientific point of view. Within the disputation, the students are able to show that they can present the project they have carried out themselves in context of the current knowledge, justify the chosen approaches and defend the thesis in a scientific discussion.

Learning outcomes and competencies	By successfully completing this module, students will be able to, - use the acquired theoretical knowledge of chemistry and its neighbouring disciplines to develop strategies for solving practical problems. - comprehensively research and structure scientific literature on a given topic. - plan and carry out a scientific work under guidance and document it according to the "rules of good scientific practice". - prepare experiments and carry them out responsibly in compliance with work and environmental protection rules.*) - process data resulting from calculations or analytical measurements, interpret the results and critically question them. - classify and evaluate the scientific results obtained in the overall context of the already existing (published) findings. - write a scientific paper according to a given scope and formatting in accordance with the methodology used in chemistry. - present the results of the scientific activity in a lecture of limited duration, to justify the approach and to defend it in a discussion within an extended professional framework. - complete tasks independently and on time. - work collegially and responsibly with others in a research laboratory. *) not applicable for purely theoretical work
Content	Carrying out experimental or theoretical work in the field of chemistry with e.g. an inorganic, organic, physicochemical, analytical chemical focus.
Literature	Current scientific literature from the above-mentioned areas.

<table>
<tr><td colspan="2">Module name</td><td colspan="3">Master's thesis (M.Sc. Chemical Biology)</td></tr>
<tr><td colspan="2">Abbreviation</td><td colspan="3">MMT</td></tr>
<tr><td>Interval of offer
By appointment</td><td>Duration
6 months (regular completion time of the Master’s thesis)</td><td>Semester of study
4</td><td>Credits
30</td><td>Curriculum assignment
M. Sc. Chemical Biology</td></tr>
<tr><td colspan="5">Module structure</td></tr>
</table>

No.	Course	CP
1	Master‘s thesis	25
2	Master’s thesis defense	5
	Total	**30**

Person responsible for the module	Dean of Studies
Lecturer(s)	Supervisor of the Master's thesis according to the examination regulations
Language	English, German
Requirements according to examination regulations	In addition to §18 of the examination regulations, the following requirements of §21(3) must be met: - acquisition of 74 credit points - successful completion of all laboratory courses
Recommended requirements	None
Coursework / module examination / partial assessments	Thesis (usually max. 60 DIN A4 pages); department-public disputation with lecture and discussion. Possibility of repetition according to examination regulations.
Learning objectives	The students learn to structure an experimental or theoretical task of appropriate scope from the field of chemical biology within a specified period of time and to work on it independently under scientific aspects on the basis of known procedures within the specified period of time and to present it in written form in an appropriate manner from a scientific point of view. Within the disputation, the students are able to show that they can present the project they have carried out themselves in context of the current knowledge, justify the chosen approaches and defend the thesis in a scientific discussion.

Learning outcomes and competencies	By successfully completing this module, students will be able to, - use the acquired theoretical knowledge of chemical biology and neighbouring disciplines to develop strategies for solving practical problems. - comprehensively research and structure scientific literature on a given topic. - plan and carry out a scientific work under guidance and document it according to the "rules of good scientific practice". - prepare experiments and carry them out responsibly in compliance with work and environmental protection rules.*) - process data material resulting from calculations or analytical measurements, interpret the results and critically question them. - classify and evaluate the scientific results obtained in the overall context of the already existing (published) findings. - write a scientific paper according to a given scope and formatting in accordance with the methodology used in Chemical Biology. - present the results of the scientific activity in a lecture of limited duration, to justify the approach and to defend it in a discussion in an extended professional context. - complete tasks set independently and on time. - work collegially and responsibly with others in a research laboratory. *) not applicable for purely theoretical work
Content	Carrying out experimental or theoretical work in the field of chemical biology with a focus on e.g. microstructure technology, biochemistry, molecular biology, bioorganic synthesis, cell biology, biophysics, structural biology, microbiology and bioinformatics.
Literature	Current scientific literature from the above-mentioned areas.