Master of Science
in
Chemistry

Module Handbook

Compulsory Modules
and
Required Elective Modules

Faculty of Natural Sciences

Gottfried Wilhelm Leibniz Universität

(German Handbook last updated:
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Contents

Master of Science in Chemistry

Preface

The study modules and courses in this handbook are categorised according to 5 classes:

◉ ◎ ◎ ◎ ◎ Module or course is taught entirely in English.

◎ ◉ ◎ ◎ ◎ Module or course is taught bilingually in German and English.

◎ ◎ ◉ ◎ ◎ The language of the module or course is decided on an individual basis at the beginning of the semester.

◎ ◎ ◎ ◉ ◎ Module or course is taught partly in English, but some mandatory part is taught in German.

◎ ◎ ◎ ◎ ◉ Module or course is taught entirely in German.

The code above is used in the headline of each module and in the table of contents and also in front of the course title.

Master of Science in Chemistry

Compulsory Modules

◎ ◎ ◎ ◎ ◉ **Anorganische Chemie: Bindung – Struktur – Eigenschaften / Inorganic Chemistry: Bonding – Structure – Properties**

Module title Inorganic Chemistry: Bonding – Structure – Properties		**Module code**
Degree programme MSc Chemistry		**Module type** Compulsory module
Credit points 6	**Module availability** Winter semester	**Language** German
Area of expertise None	**Recommended semester** 1st semester	**Module duration** 1 semester
Student workload		
180 hours	84 contact hours	96 h independent study
Further use of module None		

1	**Learning objectives** **Aims** Provide a deeper and broader understanding of inorganic chemistry and its applications (for advanced master's students). **The module shall provide the students with the following specialised and key knowledge and skills:** **On successful completion of the module, students are able to** 1. describe and discuss chemical bonding in inorganic solids 2. derive the spectroscopic and electrical conductivity properties of inorganic solids from the band structure of solids 3. develop a deeper understanding of the structures of metals, intermetallic phases and covalently bonded solids 4. understand chemical bonding in inorganic molecular compounds 5. describe and discuss advanced aspects of the chemistry of main group elements 6. understand special aspects of inorganic coordination chemistry 7. understand basic aspects of bioinorganic chemistry
2	**Module content** **Subject-specific content:** **Lecture/ Exercise Inorganic Chemistry: Bonding – Structure – Properties** The band model for describing the electronic properties of solids is derived from crystal orbital theory. This is then used to derive the spectroscopic properties and the electrical conductivity properties of inorganic solids. In addition, details of the structure of metallic solids and intermetallic phases and the structural chemistry of covalently bonded solids are derived. Unusual bonding states in compounds of the main group elements are discussed, as are the more complex structures they form, such as chains, rings or clusters. Fundamentals of the organometallic chemistry of the main and minor group elements are dealt with, again in relation to the bonding conditions. Advanced aspects of f-element chemistry are discussed.

	Fundamentals of the bioinorganic chemistry of the major and minor group elements are discussed. **General content:**
3	**Mode of teaching** ◎ ◎ ◎ ◎ ◉ Lecture Inorganic Chemistry: Bonding – Structure – Properties (4 semester hours) ◎ ◎ ◎ ◎ ◉ Exercise Inorganic Chemistry: Bonding – Structure – Properties (1 semester hour)
4a	**Participation requirements** **Module assessment:** None
4b	**Recommended prior knowledge** None
5	**Requirements for award of credit points** **Coursework:** None **Assessment:** Written examination 120 minutes
6	**Literature** Meyer, Janiak, Gudat, Alsfasser, Riedel. Moderne Anorganische Chemie. 2012 Müller, Anorganische Strukturchemie, 2008 Cox, The Electronic Structure and Chemistry of Solids, 1987 Elschenbroich, Organometallchemie, 2008 Klapötke, Tornieporth-Oetting. Nichtmetallchemie
7	**Further information** **Lecturer(s):** Behrens, Renz, Schneider.
8	**Organisational unit** Faculty of Natural Sciences, Institute for Inorganic Chemistry, Chemistry Teaching Unit; http://www.aci.uni-hannover.de/
9	**Person responsible for module** Behrens

◎ ◎ ◎ ◎ ◉ **Katalyse und Reaktionsmechanismen /**
Catalysis and Reaction Mechanisms

Module title Catalysis and Reaction Mechanisms		**Module code**
Degree programme MSc Chemistry		**Module type** Compulsory module
Credit points 6	**Module availability** Winter semester	**Language** German
Area of expertise None	**Recommended semester** 1st semester	**Module duration** 1 semester
Student workload		
180 hours	84 contact hours	96 h independent study
Further use of module None		

1	**Learning objectives** **Aims** Provide a deeper and broader understanding of catalysis and reaction mechanisms (for advanced master's students). **The module shall provide the students with the following specialised and key knowledge and skills:** **On successful completion of the module, students are able to** 1. use appropriate criteria to evaluate the most important methods for optimising catalysts and catalytic processes. 2. compare and evaluate special catalysts with regard to efficiency, selectivity and ecological impact as well. 3. understand reaction mechanisms as they occur in photochemistry, rearrangement reactions or modern metal-organic reactions. 4. use reaction mechanisms to derive concepts to control the selectivity in syntheses. 5. describe mechanisms and kinetics of important reactions (like zero, first and second order reactions, reactions with pre-equilibrium, consecutive reactions, side reactions). 6. analyse catalytic processes in detail with regard to yield, selectivity, economics and ecological balance. 7. analyse technical processes and establish relations between reaction mechanism, kinetics and reactor.
2	**Module content** **Subject-specific content:** **Lecture/ Exercise Catalysis and Reaction Mechanisms** • fixed catalysts: heterogeneous catalysis including heterogenised molecular catalysts; photocatalysis, constructive and destructive

	• molecular catalysis: homogeneous catalysis, biocatalysis • fundamental terms like conversion, selectivity, yield and turnover number (TON) • application of complex rate equations (for zero, first and second order reactions, consecutive reactions, side reactions and for reactions with pre-equilibrium) to catalysed reactions • groups of catalysed reactions like oxidation, hydrogenation or isomerisation and the respective • systems by means of structural components from microreactor catalysts • modern applications of homogeneous catalysis based on transition metals like gold and ruthenium • reaction mechanisms which are not covered by the basic lectures: photochemistry, rearrangement reactions or modern metal-organic reactions • derivation of concepts to control the selectivity in syntheses which are based on reaction mechanisms • particular mechanistic aspects of homogeneous and heterogeneous catalysis • modern developments in the field of catalysis, e.g. combinatorial research in catalysis, molecular design of enzymatic inorganic catalysts, in-situ techniques for the diagnostics of working catalysts (in operando), membrane-mediated catalysis, fuel cell as catalytic membrane reactor, heterogenisation of homogeneous catalysts, miniaturisation of catalytic technology, atom efficiency, life cycle assessment of catalysts • environmentally relevant catalytic processes: e.g. purification of automobile exhaust gases (three-way, diesel), technical purification of exhaust gases (SCR etc.), catalytic purification of fluids (gases and liquid systems), photooxidation of harmful substances • high selectivity and specificity of enzymatic catalysis and biotransformation by means of showcases, heterogenisation of enzymatic systems • operational safety in catalysis (explosion protection, release of byproducts, handling of nanoparticles, waste management, regeneration and exploitation of used catalysts) • special achievements of Nobel laureate Ertl, who taught and did research at Leibniz University Hannover from 1968 to 1972. He investigated the catalytic oxidation of CO and discovered the mechanism of NH_3 synthesis. **General content:**
3	**Mode of teaching+** ◎ ◎ ◎ ◎ ◉ Lecture Catalysis and Reaction Mechanisms (4 semester hours) ◎ ◎ ◎ ◎ ◉ Exercise Catalysis and Reaction Mechanisms (1 semester hour)
4a	**Participation requirements** **Module assessment:** None
4b	**Recommended prior knowledge** None
5	**Requirements for award of credit points**
	Coursework: None
	Assessment: Written examination 120 minutes

6	**Literature** I. I. Chorkendorff, J.W. Niemantsverdriet, Concepts of modern catalysis and kinetics, Wiley-VCH, 2003. II. J.M. Thomas, W.J. Thomas, Principles and practice of heterogeneous catalysis, Wiley VCH, 2015. III. M. Beller, A. Renken, R.A. van Santen, Catalysis, From principles to applications, Wiley VCH
7	**Further information** **Lecturer(s):** Caro, Renz, Kalesse, Bloh
8	**Organisational unit** Faculty of Natural Sciences, Institute of Physical Chemistry and Electrochemistry, Chemistry Teaching Unit; http://www.pci.uni-hannover.de/
9	**Person responsible for module** Caro

◎ ◉ ◎ ◎ ◎ Stereokontrolle in der chemischen Synthese / Stereocontrol in Chemical Synthesis

<table>
<tr><td colspan="3">Module title Stereocontrol in Chemical Synthesis</td><td>Module code</td></tr>
<tr><td colspan="3">Degree programme MSc Chemistry</td><td>Module type
Compulsory module</td></tr>
<tr><td>Credit points 6</td><td colspan="2">Module availability Winter semester</td><td>Language German</td></tr>
<tr><td>Area of expertise None</td><td colspan="2">Recommended semester 1st semester</td><td>Module duration
1 semester</td></tr>
<tr><td colspan="4">Student workload</td></tr>
<tr><td colspan="2">180 hours</td><td>60 contact hours</td><td>120 h independent study</td></tr>
<tr><td colspan="4">Further use of module
None</td></tr>
<tr><td>1</td><td colspan="3">Learning objectives

Aims
Provide a deeper and broader understanding of stereocontrol and the chemistry of heterocycles and their application (for advanced master's students).

The module shall provide the students with the following specialised and key knowledge and skills:

On successful completion of the module, students are able to

1. analyse complex molecules for their stereochemical elements in a comprehensive context.
2. apply conformational analysis methods to molecules.
3. mechanistically rationalise methods and strategies of stereoselective synthesis with regard to their selectivities.
4. develop retrosyntheses for chiral molecules using the methods learned.
5. plan synthesis strategies for simple to complex chiral molecules and apply suitable methodology to develop them in detail.
6. classify heterocycles and assess their reactivity.
7. classify and postulate general methods of representation for heterocycles.</td></tr>
<tr><td>2</td><td colspan="3">Module content

Subject-specific content:
Lecture Stereocontrol and Asymmetric Synthesis
• Introduction to stereochemistry, non-linear effects
• Methods of stereoselective synthesis (oxidations, reductions, C-C linkages, organometallic compounds) including catalysis (organometallic catalysis, organocatalysis)
• Chiral building blocks (ex chiral pool) for synthesis
• Biotransformations with enzymes and whole cells in the synthesis
• Coupled asymmetric catalysis</td></tr>
</table>

	• Introduction to retrosynthesis. Exercise Stereocontrol and Asymmetric Synthesis Students independently tackle and then discuss exercises accompanying the lecture. The exercises deal with synthesis sequences and related analytical aspects (NMR, MS, IR spectra, EA). The exercises can be solved using the knowledge on synthesis taught in the lecture and by interpreting the analytical data. Lecture Introduction to Heterocyclic Chemistry • Basics of heteroaromaticity • Electronic differences between different heterocycles and stereoelectronic effects in saturated heterocycles • Selected saturated heterocycles – representation, reactivity, occurrence and relevance • General methods for the representation of non-aromatic heterocycles (electrocyclic reactions, nitrenes / carbenes, transition metal catalysis and π-Lewis acids, condensation) • Stereoselective synthetic methods of non-aromatic heterocycles General content:
3	**Mode of teaching** ◎ ◉ ◎ ◎ ◎ Lecture Stereocontrol and Asymmetric Synthesis (2 semester hours) ◎ ◉ ◎ ◎ ◎ Exercise Stereocontrol and Asymmetric Synthesis (1 semester hour) ◎ ◉ ◎ ◎ ◎ Lecture Introduction to Heterocyclic Chemistry (1 semester hour) ◎ ◉ ◎ ◎ ◎ Exercise Introduction to Heterocyclic Chemistry (1 semester hour)
4a	**Participation requirements** **Module assessment:** None
4b	**Recommended prior knowledge** None
5	**Requirements for award of credit points** **Coursework:** None **Assessment:** Written examination 180 minutes
6	**Literature** R. Brückner, Reaktionsmechanismen (Organische Reaktionen, Stereochemie, moderne Synthesemethoden), Spektrum Akademischer Verlag, 2. Aufl., 2003 Clayden, Greeves, Warren & Wothers, Organic Chemistry, Oxford, 2001 K.C. Nicolaou, Classics in Total Synthesis I & II, Wiley-VCH; E. L. Eliel, S. H. Wilen, Stereochemistry of Organic Compounds, John Wiley & Sons 1994. J. A. Joule and K. Mills "Heterocyclic Chemistry" Fifth Edition, Blackwell Publishing 2009
7	**Further information** **Lecturer(s):** Kirschning, Kalesse, Plettenburg, Brönstrup

8	**Organisational unit** Faculty of Natural Sciences, Institute of Organic Chemistry, Chemistry Teaching Unit; http://www.oci.uni-hannover.de
9	**Person responsible for module** Kirschning

◎ ◎ ◎ ◎ ◉ Statistische Modelle und Polymere /
Statistical Models and Polymers

<table>
<tr><td colspan="3">Module title Statistical Models and Polymers</td><td>Module code</td></tr>
<tr><td colspan="3">Degree programme MSc Chemistry</td><td>Module type
Compulsory module</td></tr>
<tr><td>Credit points 6</td><td colspan="2">Module availability Winter semester</td><td>Language German</td></tr>
<tr><td>Area of expertise None</td><td colspan="2">Recommended semester 1st semester</td><td>Module duration
1 semester</td></tr>
<tr><td colspan="4">Student workload</td></tr>
<tr><td colspan="2">180 hours</td><td>84 contact hours</td><td>96 h independent study</td></tr>
<tr><td colspan="4">Further use of module
None</td></tr>
<tr><td>1</td><td colspan="3">Learning objectives

Aims
Provide a deeper and broader understanding of statistical models and polymers and their applications (for advanced master's students).

The module shall provide the students with the following specialised and key knowledge and skills:

On successful completion of the module, students are able to

1. understand thermodynamics from a statistical physics´ point of view.
2. calculate thermodynamic values based on the molecular properties.
3. understand activated complex theory.
4. explain heat capacities.
5. understand defects formation in solid materials.
6. explain chain and coil models in polymer chemistry.
7. explain basic concepts in polymer synthesis and chemistry
8. describe polymers in solution and in the solid state.
9. describe different polymerisation mechanisms and explain their respective characteristic features.
10. choose and apply suitable methods for polymer characterisation.
11. explain and characterise mechanical properties of polymeric materials.</td></tr>
<tr><td>2</td><td colspan="3">Module content

Subject-specific content:
Lecture 1/ Exercise Statistical models
• Boltzmann statistics
• Maxwell distribution
• Canonical and microcanonical ensembles
• Partition functions and thermodynamic potentials derived therefrom</td></tr>
</table>

	• Defects in solid materials • Specific heat • Quantum statistics • Black body radiation • Electrons in solid materials • Theory of kinetics • Collision theory • Transition state theory • Potential energy surface • Chain models • Entropic stabilisation Lecture 2/ Exercise Polymers • Polymer architectures • Biopolymers • Chain models • Entropic effects • Polymers in solution • Analysis of polymers • Solid polymers: crystalline, semi-crystalline and amorphous • Polymerisation mechanisms • Functional polymers • Industrial polymers and processes • Recycling of polymers **General content:** • Methods of mathematical statistics
3	**Mode of teaching** ◎ ◎ ◎ ◎ ◉ Lecture Statistical Models and Polymers (4 semester hours) ◎ ◎ ◎ ◎ ◉ Exercise Statistical Models and Polymers (1 semester hour)
4a	**Participation requirements** **Module assessment:** None
4b	**Recommended prior knowledge** None
5	**Requirements for award of credit points**
	Coursework: None
	Assessment: Written examination 120 minutes

6	**Literature** G. Wedler, Lehrbuch der Physikalischen Chemie, 4. Aufl., Wiley-VCH, Weinheim 1997 P.W. Atkins, Physikalische Chemie, 3. Aufl., Wiley-VCH, Weinheim 2002 Polymere: Synthese, Eigenschaften und Anwendungen, S. Koltzenburg, M. Maskos, O. Nuyken, Springer Spektrum, Berlin
7	**Further information** **Lecturer(s):** Weinhart, König
8	**Organisational unit** Faculty of Natural Sciences, Institute of Physical Chemistry and Electrochemistry, Chemistry Teaching Unit; http://www.pci.uni-hannover.de/
9	**Person responsible for module** Weinhart

◎ ◎ ◎ ◉ ◎ Dynamik und Transport / Dynamics and Transport

<table>
<tr><td colspan="3">Module title Dynamics and Transport</td><td>Module code</td></tr>
<tr><td colspan="3">Degree programme MSc Chemistry</td><td>Module type
Compulsory module</td></tr>
<tr><td>Credit points 6</td><td colspan="2">Module availability Winter semester</td><td>Language German</td></tr>
<tr><td>Area of expertise None</td><td colspan="2">Recommended semester 1st semester</td><td>Module duration
1 semester</td></tr>
<tr><td colspan="4">Student workload</td></tr>
<tr><td>180 hours</td><td colspan="2">84 contact hours</td><td>96 h independent study</td></tr>
<tr><td colspan="4">Further use of module
None</td></tr>
<tr><td>1</td><td colspan="3">Learning objectives

Aims
Provide advanced skills and a deeper and broader understanding of physical chemistry in theory and practice (for advanced master's students).

The module shall provide the students with the following specialised and key knowledge and skills:

On successful completion of the module, students are able to

1. critically scrutinise their results, evaluate and interpret them, and collate them in reports.
2. perform experiments on their own carefully, safely and without risk within a pre-determined time frame and in compliance with occupational safety regulations.
3. make appropriate use of research techniques and utilise suitable scientific techniques to document and present their study.
4. present and defend their most significant results in front of an audience of fellow scientists.</td></tr>
<tr><td>2</td><td colspan="3">Module content

Subject-specific content:
Seminar/ Laboratory exercise Dynamics and Transport
• reaction kinetics and dynamics (stopped-flow)
• electrode kinetics (polarography)
• spectroscopy (Laser-Raman, NMR)
• solid state diffusion (Ag_2S)
• magnetism (Quincke)
• adsorption (BET)
• statistical thermodynamics (Argon-lattice energy)

General content:</td></tr>
</table>

	• General scientific working and presentation techniques: Students learn to quickly familiarise themselves with previously unknown topics and to independently gather and collate information on a well-defined subject. On successful completion of the module, students are able to select and utilise suitable media for their presentation.
3	**Mode of teaching** ◎ ◎ ◎ ◎ ◉ Seminar Dynamics and Transport (1 semester hour) ◎ ◎ ◉ ◎ ◎ Laboratory exercise Dynamics and Transport (4 semester hours)
4a	**Participation requirements** **Module assessment:** None
4b	**Recommended prior knowledge** BSc in Chemistry
5	**Requirements for award of credit points** **Coursework:** Seminar Dynamics and Transport, oral presentation of their work Laboratory exercise Dynamics and Transport **Assessment:** Oral examination 30 minutes
6	**Literature** Descriptions detailing the experiments to be completed during the laboratory exercises are provided. G. Wedler, Lehrbuch der Physikalischen Chemie, 4. Aufl., Wiley-VCH, Weinheim 1997 P.W. Atkins, Physikalische Chemie, 3. Aufl., Wiley-VCH, Weinheim 2002
7	**Further information** **Lecturer(s):** Seminar: Bremm, Grabow, with contributions from all lecturers in the Institute of Physical Chemistry and Electrochemistry Laboratory exercise: Bremm, Grabow
8	**Organisational unit** Faculty of Natural Sciences, Institute of Physical Chemistry and Electrochemistry, Chemistry Teaching Unit; http://www.pci.uni-hannover.de/
9	**Person responsible for module** Grabow

◎ ◎ ◎ ◎ ◎ Masterarbeit mit Vortrag /
Master's Thesis with Presentation

<table>
<tr><td colspan="3">Module title Master's Thesis with Presentation</td><td>Module code</td></tr>
<tr><td colspan="3">Degree programme MSc Chemistry</td><td>Module type
Compulsory module</td></tr>
<tr><td>Credit points 30</td><td colspan="2">Module availability Winter semester or summer semester</td><td>Language German or English</td></tr>
<tr><td>Area of expertise None</td><td colspan="2">Recommended semester 4. Semester</td><td>Module duration
1 semester</td></tr>
<tr><td colspan="4">Student workload</td></tr>
<tr><td colspan="2">900 hours</td><td>800 contact hours</td><td>100 h independent study</td></tr>
<tr><td colspan="4">Further use of module
None</td></tr>
<tr><td>1</td><td colspan="3">Learning objectives

Aims
Provide the advanced and enhanced skills which are needed to independently design and implement a project plan on a well-defined topic within a specified time using scientific methods (for advanced master's students).

The module shall provide the students with the following specialised and key knowledge and skills:

On successful completion of the module, students are able to

1. independently acquire more in-depth knowledge of a new topic, and design and implement a project plan within a longer but limited time frame.
2. develop an advanced chemical topic as instructed, independently acquire more in-depth knowledge of it and independently develop it further within a restricted time frame.
3. develop and evaluate new approaches.
4. provide further perspectives on a selected topic.
5. adopt a systematically structured approach to tackling complex problems and think creatively, innovatively, and in abstract and interdisciplinary terms while solving the problem
6. exploit opportunities for scientific discussion with fellow students and scientists in the research group.
7. critically scrutinise their own results, evaluate them and assess their progress relative to the time frame.
8. perform experiments on their own carefully, safely and without risk, within a limited time frame and in compliance with occupational safety regulations.
9. use scientific methods appropriately.
10. make suitable use of research tools and appropriate scientific methods while writing and presenting the work.
11. critically present and review research results.</td></tr>
</table>

	12. write a scientific report on their own. 13. compile their own key results in a proper written form, present them to an audience of experts and defend them in a seminar. 14. place a selected topic into a scientific context and discuss it. 15. work independently on an advanced level in accordance with the principles of research integrity.
2	**Module content** **Subject-specific content:** Topics related to the specialisations of Materials Chemistry and Nanochemistry or Medicinal and Natural Products Chemistry. **General content:** • General scientific working and presentation techniques: Students learn to quickly familiarise themselves with previously unknown research topics and to independently gather and collate information on a well-defined subject, translate it into experimental work, and present it in a suitable written form. On successful completion of the module, students are able to select and utilise suitable media to present their research results. • Organised and goal-oriented working practices: Students acquire the ability to independently organise the way they work and to meet deadlines, to develop an expedient structure for their work processes and adopt a goal-oriented approach to executing them. • Research integrity: on successful completion of the module, students are familiar with the principles of research integrity.
3	**Mode of teaching** ◎ ◎ ◉ ◎ ◎ Master's Thesis with Presentation
4a	**Participation requirements** None
4b	**Recommended prior knowledge** Advanced knowledge of chemistry
5	**Requirements for award of credit points** 60 Credit points
	Coursework: Theoretical or experimental work
	Assessment: Master's thesis (75%), Oral Assignment (25%)
6	**Literature** Relevant literature will be recommended by the supervising lecturer and also sourced independently by the student.

7	**Further information** Special emphasis is placed on the ability to estimate the time required and on periodic progress checks in the course of the work **Lecturer(s):** Lecturers of the Master of Chemistry degree programme
8	**Organisational unit** Faculty of Natural Sciences, Chemistry Teaching Unit
9	**Person responsible for module** Lecturers of the Master's degree programme in chemistry

Either

Compulsory Modules for the Materials Chemistry and Nanochemistry Specialisation

or

Required Elective Modules for the General Chemistry Study Line

◎ ◎ ◎ ◉ ◎ Anorganische Materialchemie / Inorganic Materials Chemistry

Module title Inorganic Materials Chemistry			**Module code**
Degree programme MSc Chemistry			**Module type** Compulsory module
Credit points 10	**Module availability** Summer semester		**Language** German
Area of expertise None	**Recommended semester** 2nd semester		**Module duration** 2 semesters
Student workload			
300 hours	120 contact hours		180 h independent study
Further use of module None			

1	**Learning objectives** **Aims** Provide advanced skills and a deeper and broader understanding of inorganic materials chemistry in theory and practice (for advanced master's students). **The module shall provide the students with the following specialised and key knowledge and skills:** **On successful completion of the module, students are able to** 1. explain the structure-property-application relationships of important inorganic materials. 2. evaluate different methods of synthesis for the production of inorganic solids and the preparation of inorganic materials with regard to a desired property profile and weigh up their advantages and disadvantages, paying special attention to the morphology. 3. carry out sophisticated practical syntheses of inorganic materials in the laboratory and explain how variations in different reaction parameters affect the outcome of a reaction, especially with regard to the morphology (nanoparticles, powder, single crystal) of the reaction product. They will be able to analytically examine the products using suitable methods. 4. to choose and use adequate media for the presentation
2	**Module content** **Subject-specific content:** **Lecture Inorganic Materials Chemistry** - Chap. I - Magnetic Materials: theory of magnetism, characterization of magnetic behaviour, magnetic materials classes, diamagnets, paramagnets, ferromagnets, antiferromagnets, applications of magnetic materials, data storage, spin-valves, diluted magnetic semiconductors. - Chap. II - Functional Molecules: molecular switches, amphiphiles, surfactants, association colloids, self-assembly, micelles, vesicles, liquid crystals, thermotropic phases. - Chap. III - Nanoparticles and Colloids: colloidal systems, surface thermodynamics, surface

<table>
<tr><td></td><td>tension, DLVO-theory, Hamaker constant, charged surfaces, structure and electronic system of surfaces, surface analysis, synthesis of nanocrystals, quantum size effect, plasmonic effects, superstructures, cooperative effects, photonic materials, metamaterials.
- Chap. IV - Porous Materials: overview, microporous solids, zeolites, pillared clays, MOFs, COFs, adsorption phenomena on external and internal surfaces, physisorption, chemisorption, mesoporous materials, methods of surface modification, macroporous materials, aerogels, anodically etched membraned.

Seminar Inorganic Materials Chemistry
Students prepare presentations based on publications from the recent literature. The publications are then discussed critically.

Laboratory exercise Synthesis of Solids and Preparation of Materials
The experimental course is composed of two parts. The students will learn about different materials classes and the corresponding, advanced synthesis methods based on defined experimental setups (first part). In general, series of experiments are carried out while varying one or more reaction parameters in order to systematically clarify the effect of different reaction regimes on the product properties. The students will apply various analytical methods, which have been introduced in previous courses. The experimental data will be interpreted to probe the expected variation of properties. The second part of the experimental seminar involves the reproduction of experimental procedures published in recent publications from the literature. The product will be characterized and compared to the literature data. If there is a deviation from the reference, possible reasons will be discussed followed by a possible repetition of the experiment under slightly changed conditions.

General content:
General scientific working and presentation techniques: Students learn to quickly familiarise themselves with previously unknown topics and to independently gather and collate information on a well-defined subject.</td></tr>
<tr><td>3</td><td>Mode of teaching
◎ ◎ ◎ ◉ ◎ Lecture Inorganic Materials Chemistry (4 semester hours)
◎ ◎ ◎ ◉ ◎ Seminar Inorganic Materials Chemistry (1 semester hour)
◎ ◎ ◉ ◎ ◎ Laboratory exercise Synthesis of Solids and Preparation of Materials (4 semester hours)</td></tr>
<tr><td>4a</td><td>Participation requirements

Module assessment: None</td></tr>
<tr><td>4b</td><td>Recommended prior knowledge
Advanced knowledge of inorganic chemistry</td></tr>
<tr><td rowspan="3">5</td><td>Requirements for award of credit points</td></tr>
<tr><td>Coursework:
Presentation in the seminar and attendance at the seminar
Laboratory exercise Synthesis of Solids and Preparation of Materials</td></tr>
<tr><td>Assessment: Oral examination 30 minutes</td></tr>
</table>

6	**Literature** **Lecture/Seminar: Inorganic Chemistry of Materials** Smart & Moore: Einführung in die Festkörperchemie U. Müller: Anorganische Strukturchemie A.R. West: Grundlagen der Festkörperchemie U. Schubert, N. Hüsing, Synthesis of Inorganic Materials, Wiley VCH, 2004 Script to Laboratory Exercise Synthesis of Solids and Preparation of Materials Further recommended literature will be announced in the lectures
7	**Further information** **Lecturers:** Behrens, Polarz, Renz, Schaate
8	**Organisational unit** Faculty of Natural Sciences, Institute of Inorganic Chemistry, Chemistry Teaching Unit; http://www.aci.uni-hannover.de/
9	**Person responsible for module** Polarz

◎ ◎ ◎ ◉ ◎ **Physikalische Materialchemie / Physical Chemistry of Materials**

<table>
<tr><td colspan="3">Module title Physical Chemistry of Materials</td><td>Module code</td></tr>
<tr><td colspan="3">Degree programme MSc Chemistry</td><td>Module type
Compulsory module</td></tr>
<tr><td>Credit points 10</td><td colspan="2">Module availability Summer semester</td><td>Language German, English</td></tr>
<tr><td>Area of expertise None</td><td colspan="2">Recommended semester 2nd semester</td><td>Module duration
1 semester</td></tr>
<tr><td colspan="4">Student workload</td></tr>
<tr><td>300 hours</td><td colspan="2">120 contact hours</td><td>180 h independent study</td></tr>
<tr><td colspan="4">Further use of module
MSc Nanotechnology</td></tr>
</table>

<table>
<tr><td>1</td><td>Learning objectives

Aims
Provide advanced skills and a deeper and broader understanding of physical materials chemistry in theory and practice (for advanced master's students).

The module shall provide the students with the following specialised and key knowledge and skills:

On successful completion of the module, students are able to

1. describe the particular properties of solid-state systems as complex functional materials and as nanomaterials with concepts of real space and reciprocal space.
2. recognise the difference to bulk materials if the dimensions of solid-state particles are reduced to a few nanometres or less.
3. recognise potential applications of nanostructured solids and nanoparticle assemblies in devices.
4. describe the functional principles and the physical-chemical properties of solids.
5. understand structure-property relationships in complex materials.
6. recognise current possibilities to optimise selected materials systems.
7. combine the chemical synthesis of materials and the physical-chemical characterisation of their properties.
8. evaluate and suitably present the results of measurements.</td></tr>
<tr><td>2</td><td>Module content

Subject-specific content:
Lecture 1/ Exercise Physical Chemistry of Solids and Nanosystems
• Crystal structure of solids: description of periodic crystals (rigid lattice), Bravais lattices, symmetries, quasicrystals, diffraction methods (electrons, X-rays, neutrons), criteria for constructive interference (Laue, Bragg, Brillouin), atomic form factor, structure factor, reciprocal space, reciprocal lattice, Brillouin zone, Patterson function
• Dynamics of atoms in solids and nanosystems: harmonic approximation of the atom's</td></tr>
</table>

dynamics, Debye-Waller factor, quantisation of lattice vibrations, quasi particles, phonon dispersion, phononic band structure, Einstein model, Debye model, heat capacity, entropy capacity

- Dynamics of electrons in solids and nanosystems: free-electron gas, nearly-free-electron gas in the periodic potential, Bloch waves, electronic band structure, band structure of crystalline and amorphous solids, sp^3 hybridisation, electronic conductors, semiconductors, insulators, p-n junction
- Extended dynamics of atoms in solids and nanosystems: thermodynamics of point defects, diffusion, reactivity, electrochemical potential
- Particular nanosystems: consolidation of concepts with case studies from current research as obtained from peer-reviewed scientific journals.

Lecture 2 Functional Principles of Selected Solid-State Materials

Selected material classes are considered with special focus being placed on structure-property relationships. The train of ideas is from molecule to material to device. The system concept is taught using the following selected materials by way of example:

- "Hard materials": Problems relating to the chemical stability and the nanostructure of hard materials are addressed in relation to the geometry of bulk materials or thin films. The focus is particularly on the mechanical properties of nanostructured materials.
- "Metals": Starting with the model of the metallic bond, properties like electrical conductivity and thermal conductivity, and deformability in conjunction with high mechanical strength are explained.
- "Metallic nanoparticles": Nanoscopic effects like reduction in the melting point, band splitting and the occurrence of localised surface plasmon resonances are explained using the example of metallic nanoparticles.
- "Magnetic materials": Solids with interesting magnetic properties and their typical applications as well as structure-property relationships are presented. The phenomenon of superconductivity and its cause are explained. The phenomenon of superparamagnetism in magnetic nanomaterials is explained and possible applications are discussed.
- "Membrane materials": Porous and dense materials and how they are structured to produce membranes for gas separation are discussed. Fundamental problems of molecular materials are considered in the "molecular electronics" unit. Selected syntheses are presented and ways whereby molecules can self-organise to form "molecular wires" and "switches" are illustrated. Furthermore, aspects of bonding and metrology are discussed.
- "Sensors": Modern gas-sensor technology systems are presented. Of crucial importance here are the electrochemical principles of the detection (e.g. ion conduction) and the description of the requisite complex modular systems.
- "Fuel cells": The structure and operating principles of modern-day fuel cells are explained. The focus is on the functional interaction of the different components.
- "Batteries": Concepts of modern-day battery systems are presented with the focus being placed on lithium-ion batteries, and particularly on structure-property relationships.
- "Semiconductor devices": The structure and operating principles of diodes and field-effect transistors are explained. The focus is on the electrochemistry of semiconductor-metal and semiconductor- semiconductor junctions.
- "Photonic materials": The principles of modern optically active materials for the development of micro lasers, optical data storage and light guides are presented.
- In addition, particular optical quantum size effects in low-dimensional systems, particularly in quantum wires and quantum dots, are discussed.

<table>
<tr><td></td><td>Laboratory exercise Functional Principles of Selected Solid-State Materials
Practical syntheses are combined with the physical-chemical characterisation of microstructure and functional properties:

Synthesis of semiconductor nanoparticles: CdSe nanoparticles of varying size are synthesised in colloidal solution. The focus is on syntheses in an inert gas atmosphere, and the synthesis and purification of products.
Characterisation methods for semiconductor nanoparticles: The physical properties of colloidal quantum dots are characterised using the example of self-synthesised samples. Absorption and emission spectroscopies are used and related to size-dependent quantisation effects of quantum dots.
Synthesis and characterisation of metallic nanoparticles: Different metallic nanoparticles are synthesised in aqueous colloidal solution and then characterised. The phenomenon of localised surface plasmon resonances is taught with the help of spectroscopic methods. Size and shape-dependent extinction spectra of plasmonic particles are also addressed.
Synthesis and characterisation of elastomeric nanocomposites.
Microwave heating in the synthesis of porous materials: Synthesis of a metal-organic framework (MOF) structure of type ZIF-8 by microwave heating in Teflon autoclaves, isolation of the product.
Characterisation of a crystalline powder by means of powder X-ray diffraction (PXRD) and scanning electron microscopy (SEM): The products obtained from the synthesis of MOF ZIF-8 are analysed by PXRD on a Bruker D8 Advance diffractometer and a JEOL SEM (image acquisition and elemental analysis by energy-dispersive X-ray spectroscopy (EDXS)).

General content:

Interpretation and critical assessment of experimental results.
</td></tr>
<tr><td>3</td><td>Mode of teaching
◎ ◎ ◎ ◎ ◉ Lecture 1 Physical Chemistry of Solids and Nanosystems (3 semester hours)
◎ ◎ ◎ ◎ ◉ Exercise Physical Chemistry of Solids and Nanosystems (1 semester hour)
◎ ◎ ◎ ◎ ◉ Lecture 2 Functional Principles of Selected Solid-State Materials (2 semester hours)
◎ ◎ ◉ ◎ ◎ Laboratory exercise Functional Principles of Selected Solid-State Materials (2 semester hours)</td></tr>
<tr><td>4a</td><td>Participation requirements

Module assessment: None</td></tr>
<tr><td>4b</td><td>Recommended prior knowledge
Advanced knowledge of physical chemistry</td></tr>
<tr><td rowspan="3">5</td><td>Requirements for award of credit points</td></tr>
<tr><td>Coursework: Laboratory exercise Functional Principles of Selected Solid-State Materials</td></tr>
<tr><td>Assessment: Oral examination 30 minutes</td></tr>
</table>

6	**Literature** **Lecture 1/ Exercise Physical Chemistry of Solids and Nanosystems** S. Elliott, The Physics and Chemistry of Solids R. Gross, A. Marx, Festkörperphysik C. Kittel, Einführung in die Festkörperphysik J. Maier, Festkörper – Fehler und Funktion, Prinzipien der physikalischen Festkörperchemie In addition, current publications on the topics are used (no current books cover all topics). **Lecture 2 Functional Principles of Selected Solid-State Materials** W. Göpel, C. Ziegler, Einführung in die Materialwissenschaften: Physikalisch-Chemische Grundlagen und Anwendungen, Teubner, 1996 C.N.R. Rao, A. Müller, A.K. Cheetham, The Chemistry of Nanomaterials, Wiley-VCH, 2004 R. Memming, D. Vanmaekelbergh, Semiconductor Electrochemistry, Wiley-VCH, 2001 M.N. Rudden, J. Wilson, Elementare Festkörperphysik und Halbleiterelektronik, Spektrum Verlag, 1995 J. Jahns, Photonik, Oldenbourg Verlag, 2001 In addition, current publications on the topics are used (no current books cover all topics).
7	**Further information** **Lecturer(s):** Lecture 1: Feldhoff Exercise: Feldhoff Lecture 2: Bigall, Caro, Dorfs, Klüppel Laboratory exercise: Bigall, Caro, Dorfs, Feldhoff, Klüppel
8	**Organisational unit** Faculty of Natural Sciences, Institute of Physical Chemistry and Electrochemistry, Chemistry Teaching Unit; http://www.pci.uni-hannover.de
9	**Person responsible for module** Bigall, Feldhoff

◎ ◎ ◎ ◉ ◎ **Grundlagen der Materialanalytik / Basics of Materials Analysis**

Module title Basics of Materials Analysis		**Module code**
Degree programme MSc Chemistry		**Module type** Compulsory module
Credit points 6	**Module availability** Summer semester	**Language** German
Area of expertise None	**Recommended semester** 2nd semester	**Module duration** 1 semester
Student workload		
180 hours	75 contact hours	105 h independent study
Further use of module None		

1	**Learning objectives** **Aims:** Provide advanced skills and a deeper and broader understanding of materials analysis in theory and practice (for advanced master's students). **The module shall provide the students with the following specialised and key knowledge and skills:** **On successful completion of the module, students are able to** 1. understand and evaluate the main features of measurements employing the analytical techniques described in "Subject-specific content – Lecture Basics of Materials Analysis"; 2. independently decide which of the analytical techniques discussed are suitable in principle for addressing which analytical problem; 3. decide which of the analytical techniques discussed may be more suitable for investigating certain problems rather than others, and which of the analytical techniques discussed yield complementary and/or redundant information; 4. interpret results and data obtained using methods for analysing different kinds of solids (inorganic bulk materials, organic polymers, nanoparticles, composite and hybrid materials); 5. independently perform and interpret measurements described in "Subject-specific content – Laboratory exercise Basics of Materials Analysis"; 6. identify and evaluate measurement errors that may occur in practice when the analytical techniques discussed are used.
2	**Module content** **Subject-specific content:** **Lecture Basics of Materials Analysis** • Introducing materials analyses, various analytical methods and their applications are named and categorized, and the specific selection of the analytical methods that are discussed in this module is introduced.

- The basics of scanning force microscopy are explained, showing the use of this methodology for surface characterizations. Based on examples, newer developments are illustrated, such as the in-situ exploration of hydration layers on surfaces in solution.
- The basics of high-resolution and analytical electron microscopy are discussed with the help of examples of micro- and nanostructured solids, the focus being placed on energy dispersive X-ray spectroscopy (EDXS) and selected-area electron diffraction (SAED). The fundamental principles of transmission (TEM) and scanning (SEM) electron microscopies are discussed, i.e. the design principles, the origins of contrast, modes of imaging, and aberration.
- Procedures for the determination of the elemental compositions of solids and materials are introduced, especially with regards to spatially resolved analysis.
- The possibilities of using synchrotron and neutron radiation in materials analysis are introduced. The focus lies on the use of scattering techniques for the characterisation of non-crystalline and nanostructured specimens. Furthermore, there is an introduction to small angle X-ray scattering (SAXS), including an illustration of how it is used in the determination of sizes and shapes of dispersed nanoparticles as well as the analysis of the structure and porosity of amorphous gels.
- The analysis of dispersions is illustrated based on the examples of static and dynamic light scattering (SLS & DLS) as well as analytical ultracentrifugation (AUC). Starting with the basic theories, the data evaluation and the respective, accessible parameters (diffusion coefficient, particle size, molecular weight, etc.) are presented. The discussion of modern potentiometric titration methods for the analysis of the mechanisms of the formation of solids from solutions completes this chapter.
- The basic principles and possibilities of thermoanalytical techniques for the characterisation of materials are presented. The characterisation of elastomers and polymers for the purpose of identification, microstructure analysis and quantitative analysis serve as examples. The focus lies on thermogravimetric analysis (TGA), dynamic scanning calorimetry (DSC) and thermomechanical analysis (TMA). Furthermore, methods for the determination of molar masses and molar mass distributions of polymers, e.g. gel permeation chromatography (GPC), are presented.
- The special features of optical spectroscopies (Raman, IR, UV/Vis), which have to be considered during the characterisation of solid samples and surfaces, are introduced. Since solids can often not be analysed in transmission mode, for example, diffuse reflection and the Kubelka-Munk-Formalism have to be applied in UV/vis spectroscopy so as to differentiate between light absorption and undesired light scattering. The ATR device is discussed in relation to IR spectroscopy, inter alia.

Laboratory exercise Basics of Materials Analysis

- Experiments employing modern potentiometric methods for the analysis of the mechanisms of solid formation from aqueous solutions
- Scanning electron microscopy for the determination of the microstructure of synthetic materials
- Optical methods for the characterisation of solids (measurement of UV/vis spectra of powders and thin films of semiconductors and composites in diffuse reflection mode)
- Experiments employing thermoanalytical approaches like DSC and TGA (quantitative analysis of elastomers)
- Thermal stability of polymers (determination of glass-transmission temperature and melting points, and crystallisation behaviour)
- Experiments for the identification of additives in elastomers and of polymer matrices (thermoplastics, natural rubbers) employing FT-IR spectroscopic methods (transmission and ATR)

	• Experiments for the characterisation of molar masses and molar mass distributions of polymers using GPC. **General content:** • Nonbiased evaluation and interpretation of measurements (good scientific practice) • Critical assessment of measurement accuracy and measurement errors.
3	**Mode of teaching** ◎ ◎ ◎ ◎ ◉ Lecture Basics of Materials Analysis (2 semester hours) ◎ ◎ ◉ ◎ ◎ Laboratory exercise Basics of Materials Analysis (3 semester hours)
4a	**Participation requirements** **Module assessment:** None
4b	**Recommended prior knowledge** Advanced knowledge of inorganic, organic and physical chemistry, basic knowledge of instrumental analysis
5	**Requirements for award of credit points**
	Coursework: Laboratory exercise Basics of Materials Analysis
	Assessment: Written examination 120 minutes
6	**Literature** W. F. Hemminger, H. K. Cammenga: Methoden der thermischen Analyse, Springer Verlag, Berlin, Heidelberg, 1989, p. 57 Ullmanns Encyklopädie der technischen Chemie, Vol. 5, Analysen und Messverfahren, Verlag Chemie Weinheim D. W. Brazier, Applications of Thermal Analytical Procedures in the Study of Elastomers and Elastomer Systems, Rubber Chemistry and Technology, Vol. 53, p. 487 ff. H. Kuzmany: Festkörperspektroskopie, Springer Verlag, 1990 J.I. Goldstein, Scanning electron microscopy and X-ray microanalysis, 3rd Ed., Kluwer Acad./Plenum Publ., New York, 2003 L. Reimer, Scanning electron microscopy: Physics of image formation and microanalysis, 2nd Ed., Springer, Berlin (1998). In addition, current publications on the topics are used (no current books cover all topics).
7	**Further information** **Lecturer(s):** **Lecture:** Dorfs, Gebauer, Giese, Lacayo-Pineda **Laboratory exercise:** Bigall, Dorfs, Feldhoff, Gebauer, Giese, Lacayo-Pineda
8	**Organisational unit** Faculty of Natural Sciences, Institute of Inorganic Chemistry, Chemistry Teaching Unit; http://www.aci.uni-hannover.de
9	**Person responsible for module** Gebauer

◎ ◎ ◉ ◎ ◎ **Anorganisch-chemisches Forschungspraktikum in der materialorientierten Chemie / Laboratory Research Course in Inorganic Materials Chemistry**

<table>
<tr><td colspan="3">Module title Laboratory Research Course in Inorganic Materials Chemistry</td><td>Module code</td></tr>
<tr><td colspan="3">Degree programme MSc Chemistry</td><td>Module type
Compulsory module</td></tr>
<tr><td>Credit points 8</td><td colspan="2">Module availability Winter semester</td><td>Language German or English</td></tr>
<tr><td>Area of expertise None</td><td colspan="2">Recommended semester 3rd semester</td><td>Module duration
1 semester</td></tr>
<tr><td colspan="4">Student workload</td></tr>
<tr><td colspan="2">240 hours</td><td>150 contact hours</td><td>90 h independent study</td></tr>
<tr><td colspan="4">Further use of module
None</td></tr>
<tr><td>1</td><td colspan="3">Learning objectives

Aims:
Provide advanced skills and a deeper and broader understanding of inorganic materials chemistry in theory and practice (for advanced master’s students).

The module shall provide the students with the following specialised and key knowledge and skills:

On successful completion of the module, students are able to

1. apply the inorganic expertise acquired to understand, appropriately describe and assess basic processes on the atomic scale.
2. combine the theoretical knowledge acquired with experimental observations and practical skills acquired in the laboratory exercise.
3. stringently tackle current research topics.
4. apply methods of literature research.
5. independently use textbooks and reference literature to develop a greater understanding of subject-related/ inorganic and general topics.
6. independently perform literature searches.
7. work as instructed to apply basic experimental methods to inorganic problems and execute them in practice in compliance with current safety regulations.
8. put forward their own proposals for synthetic routes to novel materials.
9. organise the procurement of the requisite chemicals and equipment.
10. perform novel syntheses.
11. characterise the structural, chemical and physical properties of samples of unknown materials.
12. perform visual experimental observations and document them in accordance with the principles of research integrity.
13. analyse experimentally acquired data as instructed and present, critically evaluate and</td></tr>
</table>

	interpret the experimental results derived therefrom in accordance with the principles of research integrity.
2	**Module content** **Subject-specific content:** **Laboratory exercise Laboratory Research Course in Inorganic Materials Chemistry** The course content is taken from current research topics of the research groups in the "Materials Chemistry and Nanochemistry" specialisation. Students are set a problem by one of the lecturers and work with them to develop a strategy to solve it. Where necessary, any methods which are to be used but with which the student is unfamiliar are explained. Generally, syntheses are performed in close coordination with a doctoral student from the supervising lecturer's research group. To enhance their knowledge of current research topics, students also attend oral presentations in selected colloquia (GDCh colloquia, institute colloquia). **General content:** • General scientific working and presentation techniques: Students learn to quickly familiarise themselves with previously unknown topics and to independently gather and collate information on a well-defined subject, translate it into experimental work and present it in a suitable written form. On successful completion of the module, students are able to select and use suitable media for the presentation. • Organised and goal-oriented working practices: Students acquire the ability to independently organise the way they work and to meet deadlines, to develop an expedient structure for their work processes and adopt a goal-oriented approach to executing them. • Research integrity: On successful completion of the module, the student is familiar with the principles of research integrity.
3	**Mode of teaching** ◎ ◎ ◉ ◎ ◎ Laboratory exercise Laboratory Research Course in Inorganic Materials Chemistry (10 semester hours)
4a	**Participation requirements** **Module assessment and laboratory exercise:** Completed the "Inorganic Chemistry of Materials" module
4b	**Recommended prior knowledge** Advanced knowledge of materials chemistry
5	**Requirements for award of credit points**
	Coursework: Laboratory exercise Laboratory Research Course in Inorganic Materials Chemistry
	Assessment: Term paper

6	**Literature** Topic-related literature is provided partly by the supervisor, but also sourced by the students themselves.
7	**Further information** **Lecturer(s):** all lecturers in the "Materials Chemistry and Nanochemistry" specialisation of the Master of Chemistry degree programme
8	**Organisational unit** Faculty of Natural Sciences, Chemistry Teaching Unit
9	**Person responsible for module** Feldhoff

◎ ◎ ◉ ◎ ◎ Physikalisch-chemisches Forschungspraktikum in der materialorientierten Chemie / Laboratory Research Course in Physical Chemistry of Materials

<table>
<tr><td colspan="2">Module title Laboratory Research Course in Physical Chemistry of Materials</td><td>Module code</td></tr>
<tr><td colspan="2">Degree programme MSc Chemistry</td><td>Module type
Compulsory module</td></tr>
<tr><td>Credit points 8</td><td>Module availability Winter semester</td><td>Language German or English</td></tr>
<tr><td>Area of expertise None</td><td>Recommended semester 3rd semester</td><td>Module duration
1 semester</td></tr>
<tr><td colspan="3">Student workload</td></tr>
<tr><td>240 hours</td><td>150 contact hours</td><td>90 h independent study</td></tr>
<tr><td colspan="3">Further use of module
None</td></tr>
</table>

1	**Learning objectives** **Aims:** Provide advanced skills and a deeper and broader understanding of physical chemistry of materials in theory and practice (for advanced master's students). **The module shall provide the students with the following specialised and key knowledge and skills:** **On successful completion of the module, students are able to** 1. apply the physical chemistry expertise acquired to understand, appropriately describe and assess basic processes on the atomic scale. 2. combine the theoretical knowledge acquired with experimental observations and the practical skills acquired in the laboratory exercise. 3. stringently tackle current research topics. 4. use methods of literature research to obtain data. 5. independently use textbooks and reference literature to develop a greater understanding of subject-related and general physical chemistry topics. 6. independently perform literature searches. 7. work as instructed to apply basic experimental methods to physical-chemical problems and execute them in practice in compliance with current safety regulations. 8. propose their own synthetic routes to novel materials. 9. organise the procurement of the requisite chemicals and equipment. 10. perform novel syntheses. 11. characterise the structural, chemical and physical properties of unknown material samples. 12. perform visual experimental observations and document them in accordance with the principles of research integrity.. 13. analyse experimentally acquired data as instructed and present, critically assess and interpret the experimental results derived therefrom in accordance with the principles

	of research integrity.
2	**Module content** **Subject-specific content:** **Laboratory exercise Laboratory Research Course in Physical Chemistry of Materials** The course content is taken from current research topics of the research groups in the "Materials Chemistry and Nanochemistry" specialisation. Students are set a problem by one of the lecturers and work with them to develop a strategy to solve it. Where necessary, any methods which are to be used but with which the student is unfamiliar are explained. Syntheses are generally performed in close coordination with a doctoral student from the supervising lecturer's research group. To gain knowledge on current research topics, students also attend oral presentations in selected colloquia (GDCh colloquia, institute colloquia). **General content:** • General scientific working and presentation techniques: Students learn to quickly familiarise themselves with previously unknown topics and to independently gather and collate information on a well-defined subject, translate it into experimental work and present it in a suitable written form. On successful completion of the module, students are able to select and use suitable media for their presentation. • Organised and goal-oriented working practices: Students acquire the ability to independently organise the way they work and to meet deadlines, to develop an expedient structure for their work processes and adopt a goal-oriented approach to executing them. • Research integrity: On successful completion of the module, the student is familiar with the principles of research integrity.
3	**Mode of teaching** ◎ ◎ ◉ ◎ ◎ Laboratory exercise Laboratory Research Course in Physical Chemistry of Materials (10 semester hours)
4a	**Participation requirements** **Module assessment and Laboratory Exercise:** Completed the "Physical Chemistry of Materials" module
4b	**Recommended prior knowledge** Advanced knowledge of materials chemistry
5	**Requirements for award of credit points**
	Coursework: Laboratory exercise Laboratory Research Course in Physical Chemistry of Materials

	Assessment: Term paper
6	**Literature** Topic-related literature is provided partly by the supervisor, but also sourced by the students themselves.
7	**Further information** **Lecturer(s):** all lecturers in the “Materials Chemistry and Nanochemistry” specialisation of the Master of Chemistry degree programme
8	**Organisational unit** Faculty of Natural Sciences, Chemistry Teaching Unit
9	**Person responsible for module** Feldhoff

Module title Modern Aspects of Materials Chemistry		**Module code**
Degree programme MSc Chemistry		**Module type** Compulsory module
Credit points 6	**Module availability** Winter semester	**Language** German or English
Area of expertise None	**Recommended semester** 3rd semester	**Module duration** 1 semester
Student workload		
180 hours	60 contact hours	120 h independent study
Further use of module None		

1	**Learning objectives** **Aims:** Provide a more detailed and broader understanding of the demands placed on chemists working in the fields of materials chemistry and nanochemistry in the chemical industry and materials sciences. Furthermore, offer practical training in general approaches to developing an application for a research project focusing particularly on the technical, functional, legal, ethical and economic aspects (for advanced master's students). **The module shall provide the students with the following specialised and key knowledge and skills:** **On successful completion of the module, students are able to** 1. assess the demands placed on chemists with a background in materials chemistry and nanochemistry who are working in industrial chemistry or industrial materials science and identify possible job profiles for the future. 2. assess current research results as they are presented in scientific talks given by external experts. 3. recognise different presentation styles. 4. participate in scientific discussions. 5. describe the moral-ethical implications of materials chemistry and issues which are relevant to society as a whole. 6. adopt a systematic approach to developing a grant application. 7. develop an idea for a materials-oriented research project, critically assess the project idea and evaluate its relevance and its realisation prospects (in respect of scientific, legal, ethical and economic criteria). 8. compile a project plan with costs plan, milestones and risk mitigation.
2	**Module content** **Subject-specific content:** **Block lecture Industrial Materials Chemistry** Students learn about typical operational processes in industrial materials chemistry and

	materials science. The aim is to give them an impression of the demands placed on chemists with a background in materials chemistry and nanochemistry who are working in industrial chemistry or industrial materials science, to thus become acquainted with potential job profiles. Alternative job profiles (e.g. patent attorney, freelancer) may also be presented. The block lecture is preferably given by an expert from outside the higher education sector. Students independently tackle a problem from industrial materials chemistry in the form of a term paper. Seminar Current Findings in Materials Chemistry Students are introduced to current research results, as they are presented in scientific talks given by external experts, and learn to evaluate them. The students should become familiar with different presentation styles and acquire the skills needed to participate in scientific discussions. The scientific talks take the form of public scientific colloquia. Seminar Development of a Research Project The topics of the research projects to be developed are linked to the subjects investigated by the lecturers of the Master in Chemistry degree programme. General content: • Project management and innovation management: market analysis, cost-benefit analysis, ecological aspects, development of cost plans and calculation of a project. • Methods to elucidate the state-of-the-art (scientific literature search, patent search) as well as the legal, ecological and economic boundary conditions for the development of a project.
3	Mode of teaching ◎ ◎ ◎ ◎ ◉ Lecture Industrial Chemistry of Materials (1 semester hour, in a block), ◎ ◎ ◉ ◎ ◎ Seminar Current Findings in Materials Chemistry (1 semester hour) ◎ ◎ ◉ ◎ ◎ Seminar Development of a Research Proposal (2 semester hours)
4a	Participation requirements **Module assessment:** Completed the "Inorganic Chemistry of Materials" or "Physical Chemistry of Materials" module
4b	Recommended prior knowledge Advanced knowledge of inorganic, organic and physical chemistry
5	Requirements for award of credit points **Coursework:** Term paper for the Industrial Chemistry of Materials lectures, take part in 10 colloquia on Materials Chemistry and Nanochemistry **Assessment:** Project work
6	Literature Will be announced in the course
7	Further information **Lecturer(s):** All lecturers in the "Materials Chemistry and Nanochemistry" specialisation of the Master in Chemistry degree programme
8	Organisational unit Faculty of Natural Sciences, Chemistry Teaching Unit

9	**Person responsible for module** Feldhoff

Master of Science in Chemistry

Either

Compulsory Modules for the Medicinal and Natural Products Chemistry Specialisation

or

Required Elective Modules for the General Chemistry Study Line

◎ ◉ ◎ ◎ ◎ **Naturstoffchemie und biologisch aktive Substanzen / Chemistry of Natural Products and Biologically Active Substances**

<table>
<tr><td colspan="2">Module title Chemistry of Natural Products and Biologically Active Substances</td><td>Module code</td></tr>
<tr><td colspan="2">Degree programme MSc Chemistry</td><td>Module type
Compulsory module</td></tr>
<tr><td>Credit points 10</td><td>Module availability Summer semester</td><td>Language German</td></tr>
<tr><td>Area of expertise None</td><td>Recommended semester 2nd semester</td><td>Module duration
1 semester</td></tr>
<tr><td colspan="3">Student workload</td></tr>
<tr><td>300 hours</td><td>181 contact hours</td><td>119 h independent study</td></tr>
<tr><td colspan="3">Further use of module
None</td></tr>
</table>

1	**Learning objectives** **Aims:** Provide basic knowledge of natural products and medicinal chemistry in theory and practice, including knowledge about biosynthesis, biological activities and total syntheses. Additionally, the properties of biologically active compounds will be described and evaluated. **The module shall provide the students with the following specialised and key knowledge and skills:** **On successful completion of the module, students are able to** 1. describe basic concepts of natural products and apply these concepts. 2. evaluate syntheses and predict the outcome of chemical transformations. 3. solve chemical problems with these concepts. 4. analyse and evaluate basic problems of natural products. 5. establish interrelations between structure, reactivity and biological activity. 6. assess basic ADME parameters and pharmacokinetic properties of natural products. 7. independently solve complex laboratory tasks relating to natural product chemistry and perform isolation and analyses.
2	**Module content** **Subject-specific content:** **Lecture Synthesis of Natural Products** Discussion of selected natural product syntheses by including the most relevant natural product classes such as terpenes, alkaloids, polyketides, ß-lactams and prostaglandins. Syntheses of important classes of natural products. **Lecture Medicinal Chemistry I** Process of drug development, importance of physical properties, ADME parameters, basics of lead development.

	Exercise Chemistry of Natural Products and Biologically Active Substances Students independently solve exercises on the subtopics of natural products chemistry. Discussion of selected topics. **Laboratory exercise Synthesis of Natural Products** Students undertake laboratory work on different aspects of natural products and drugs, including their characterisation, isolation and medicinal aspects. These topics are closely linked to the topics of current research projects. **General content:** Use of modern tools and techniques for imparting knowledge. Link to biomedical problems. Improve analytical thinking.
3	**Mode of teaching** ◎ ◉ ◎ ◎ ◎ Lecture Synthesis of Natural Products (2 semester hours) ◎ ◉ ◎ ◎ ◎ Lecture Medicinal Chemistry I (1 semester hour) ◎ ◎ ◉ ◎ ◎ Exercise Chemistry of Natural Products and Biological Substances (1 semester hour) ◎ ◎ ◉ ◎ ◎ Laboratory exercise Chemistry of Natural Products and Biologically Active Substances (9 semester hours)
4a	**Participation requirements** **Module assessment:** None
4b	Recommended prior knowledge None
5	Requirements for award of credit points **Coursework:** Laboratory exercise Chemistry of Natural Products and Biologically Active Substances **Assessment:** Written examination 120 minutes
6	**Literature** K.C. Nicolaou, Classics in Total Synthesis I & II, Wiley VCH P.M. Dewick, Medicinal Natural Products, A Biosynthetic Approach, 3rd ed., John Wiley & Sons, 2008 Current papers from international journals.
7	**Further information** **Lecturer(s):** Lecture 1: Kalesse Lecture 2: Plettenburg Exercise: Kalesse, Plettenburg Laboratory exercise: Kalesse, Plettenburg
8	**Organisational unit** Faculty of Natural Sciences, Institute of Organic Chemistry, Chemistry Teaching Unit; http://www.oci.uni-hannover.de/

9	**Person responsible for module** Kalesse

◎ ◎ ◎ ◉ ◎ **Biosynthesen und Prozesstechnik / Biosynthesis and Process Technology**

Module title Biosynthesis and Process Technology			**Module code**
Degree programme MSc Chemistry			**Module type** Compulsory module
Credit points 10	**Module availability** Summer semester		**Language** German/English
Area of expertise None	**Recommended semester** 2nd semester		**Module duration** 1 semester
Student workload			
300 hours	140 contact hours		160 h independent study
Further use of module None			

1	**Learning objectives** **Aims** Provide advanced skills and a deeper and broader understanding of biosynthesis and process technology in theory and practice (for advanced master's students). **The module shall provide the students with the following specialised and key knowledge and skills:** **On successful completion of the module, students are able to** 1. analyse and classify the structure of complex natural products or secondary metabolites in a comprehensive context. 2. develop retro-biosyntheses for highly complex natural products. 3. describe individual biosynthesis stages using enzyme mechanisms. 4. formulate mixed biosyntheses of hybrid natural substances. 5. undertake a comparative evaluation of biosyntheses and chemical syntheses. 6. describe enzyme and growth kinetics mathematically. 7. derive the mass and heat balance equations for different reactor types based on balance and material equations. 8. mathematically describe the dynamics of bioreactors in batch, continuous and semi-continuous operation. 9. create models for complex bioprocesses with different levels of detail 10. deal with the problems of reactor control, understand simple control concepts and adjust regulators. 11. establish connections between the characteristic properties and the possible (bio)synthesis routes. 12. isolate natural and active substances with regard to their stereoselective and stereospecific behaviour. 13. independently carry out experiments carefully and without risk within a specified period of time, in compliance with occupational safety and laboratory regulations. 14. summarise, explain and clearly present the results in protocols, paying due

	regard to scientific criteria.
2	Module content Subject-specific content: Lecture Biogenesis of Natural Products The lecture teaches students about the universal biosynthetic pathways for the wide range of structurally diverse secondary metabolites (terpenes, prostanes, polyketides, non-ribosomal peptide natural products). • Introduction: primary versus secondary metabolism • Acetate biosynthetic pathway: general aspects, fatty acids and subsequent metabolites, acetylenic acids / acetylene fatty acids, methyl-branched fatty acids, prostaglandins and derivatives, chemical synthesis of prostaglandins, terpenes, mevalonate biosynthetic pathway, MEP biosynthetic pathway, terpene cyclases and their products • Polyketide natural products: biosynthesis of polyketide natural products (Type I-III PKS, an overview), methods for elucidating biosynthetic pathways • Non-ribosomal peptides (NRP), hybrids (PK-NRP), hormones and other amino acid derivatives: non-ribosomal biosynthesis, peptide hormones, ribosomal peptide natural products, lactam antibiotics (penicillins, cephalosporins, clavams), totally synthetic access to lactam antibiotics (basic synthesis strategies for lactam formation), chemical synthesis of penicillins, synthesis of 6-aminopenicillanic acid (6-APA), synthesis of the basic body of cephalosporin from penicillin, synthesis of thienamycin, synthesis of nocardicin Exercise Biogenesis of Natural Products Students independently tackle and then discuss exercises accompanying the lecture. The aim is to sharpen their awareness of the shared mechanistic character of different reactions in chemistry and in the cell. Laboratory exercise Biogenesis of Natural Products Students gain practical knowledge of the (bio)synthetic production of natural products using whole cells, biocatalysts, chemical catalysts and reagents. Furthermore, students carry out the structural characterisation and, where possible, the biological evaluation of the natural products. Another important aspect is the isolation and cleaning of the products, which are also based on modern methods of liquid chromatography, such as HPLC. The aim is to convey the basic concepts of synthetic biology, in particular the combination of biological synthesis systems with chemical synthesis. Students independently carry out the laboratory experiments carefully and without risk within a specified period of time, in compliance with occupational safety and laboratory regulations. They are able to summarise, explain and clearly present their results in protocols, paying due consideration to scientific criteria. Lecture Bioreaction Technology and Process Control The lecture is designed to teach students the universal concepts of modelling and analysis of

	bioprocesses as well as basic knowledge of process control. • Description of bioprocesses using balance and material equations • Modelling enzyme and growth kinetics of microorganisms • Comparison of models and alignment to real systems • Basic types of bioreactors • Turnover behaviour in batch, continuous and semi-continuous operation (fed batch) • Dynamics of bioreactors with non-linear reaction kinetics, stability of the stationary states • Problems of reactor control, elementary concepts of control technology and the mode of operation of simple controllers **Laboratory exercise Bioreaction Technology and Process Control** • Numerical simulation of chemical and biotechnical reactors • Numerical simulation of complex bioprocesses • Identification of kinetic parameters • Dynamic behaviour of the processes when starting up and after malfunctions • Behaviour of the basic types of controllers • Dynamic behaviour of the controlled process and stability of the steady state **General content:** • General concepts of mathematical modelling, stability analysis and control of dynamic systems.
3	**Mode of teaching** ◎ ◉ ◎ ◎ ◎ Lecture Biogenesis of Natural Products (2 semester hours) ◎ ◎ ◉ ◎ ◎ Exercise Biogenesis of Natural Products (1 semester hour) ◎ ◎ ◉ ◎ ◎ Laboratory exercise Biogenesis of Natural Products (3 semester hours) ◎ ◎ ◎ ◎ ◉ Lecture Bioreaction Technology and Process Control (2 semester hours) ◎ ◎ ◉ ◎ ◎ Laboratory exercise Bioreaction Technology and Process Control (2 semester hours)
4a	**Participation requirements** **Module assessment:** None
4b	**Recommended prior knowledge** None
5	Requirements for award of credit points **Coursework:** Laboratory exercise Biogenesis of Natural Products Laboratory exercise Bioreaction Technology and Process Control **Assessment:** Written examination 120 minutes or oral examination 30 minutes
6	Literature Lecture Biogenesis of Natural Products: Dewick, Medicinal Natural Products, 3rd Edition, John Wiley & Sons, 2008. Classics in total synthesis I and II, ISBN 3-527-29231-4; Autors: K. C. Nicolaou, Sörensen, Wiley VCH, ISBN 3-527-29231-4. Overviews and primary literature from international journals (Natural Products Reports, Journal of Natural Products, Angewandte Chemie, Chemical Reviews). Exercises Biogenesis of Natural Products Dewick, Medicinal Natural Products, Wiley, 1998 Overviews and primary literature from international journals (Natural Products Reports, Journal

	of Natural Products, Angewandte Chemie, Chemical Reviews). Lecture Bioreaction Technology and Process Control: Stephanopoulos et al., Metabolic Engineering, 1st Edition, Academic Press, 1998, ISBN 0-12-666260-6. Schügerl/Bellgardt, Bioreaction Engineering – Modelling and Control, 1st Edition, Springer, 2000, ISBN 3-540-6696-X. More literature will be announced in the lecture.
7	**Further information** **Lecturer(s):** Lecture 1: Kirschning Lecture 2: Solle Exercise: Kirschning Laboratory exercise 1: Kirschning Laboratory exercise 2: Solle
8	Organisational unit Faculty of Natural Sciences, Institute of Technical Chemistry, Institute of Organic Chemistry, Chemistry Teaching Unit; http://www.oci.uni-hannover.de/
9	Person responsible for module Kirschning, Solle

◎ ◎ ◎ ◉ ◎ **Naturstoff- und Bioanalytik /**
Analytics of Natural Products and Biomolecules

Module title Analytics of Natural Products and Biomolecules		**Module code**
Degree programme MSc Chemistry		**Module type** Compulsory module
Credit points 6	**Module availability** Summer semester	**Language** German, English
Area of expertise None	**Recommended semester** 2nd semester	**Module duration** 1 semester
Student workload		
180 hours	84 contact hours	96 h independent study
Further use of module None		

1	**Learning objectives** **Aims** Provide both theoretical and practical advanced skills in the analysis of natural products and biomolecules (for advanced master's students). **The module shall provide the students with the following specialised and key knowledge and skills:** **On successful completion of the module, students are able to** 1. Master the theoretical basis of 1D und 2D NMR experiments. 2. choose and apply the most suitable method to solve a given structural problem. 3. perform qualitative and quantitative analysis of the NMR spectra – verify the chemical structure. 4. set up cell cultures and measure the cell viability as a function of the membrane permeability to imaging chemicals. 5. use flow cytometry to characterise cell properties. 6. understand and apply the theoretical basis of several analytical methods and choose the correct method(s) to answer a given question. 7. conduct literature searches, acquire scientific knowledge of new areas and discuss them scientifically.
2	**Module content** **Subject-specific content:** **Lecture Analytics of Natural Products and Biomolecules** • Cellular test systems, e.g. animal cells • Cell proliferation and viability tests • Methods for cell differentiation and typing of genome, proteome and metabolome • Basics of immunochemistry; flow cytometry • DNA/protein-microarrays and microarray analysis (chemometrics / bioinformatics) • Theory and practice of 1D, 2D, … **ND** NMR spectroscopy

	• Methods for structural elucidation of natural products with a specific focus on COSY, TOCSY, HSQC, HMQC, HMBC, NOESY, ROESY, INADEQUATE, ADEQUATE • Theory of NMR spectra • Qualitative and quantitative analysis of NMR spectra. **Exercise Analytics of Natural Products and Biomolecules** Analyse and solve problem relating to each of the course topics. • Design and analysis of cellular testing. • Calculation exercises. • Demonstration of NMR measurements on the spectrometer. • Analysis of NMR spectra of natural products. **Laboratory exercise Analytics of Natural Products and Biomolecules** The students solve complex analytical problems on the spectrometer with a focus on natural products and their analogues, and peptides. In addition, they study cell systems (proliferation, differentiation, cell content analysis). They also conduct practical work using techniques such as NMR, laser flow-cytometry and DNA-microarray. The practical work is done in small groups and the members of each group work together to solve a given problem. **General content:**
3	**Mode of teaching** ◎ ◎ ◎ ◉ ◎ Lecture Analytics of Natural Products and Biomolecules (3 semester hours) ◉ ◎ ◎ ◎ ◎ Exercise Analytics of Natural Products and Biomolecules (1 semester hour) ◎ ◎ ◉ ◎ ◎ Laboratory exercise Analytics of Natural Products and Biomolecules (3 semester hours)
4a	**Participation requirements** **Module assessment:** None
4b	**Recommended prior knowledge** None
5	**Requirements for award of credit points**
	Coursework: Laboratory exercise Analytics of Natural Products and Biomolecules
	Assessment: Written examination 120 minutes or oral examination 30 minutes
6	**Literature** **Lecture/ Exercise Analytics of Natural Products and Biomolecules** Lottspeich, Zorbas, Bioanalytik Keeler, J., Understanding NMR spectroscopy G. Morris and J. Emsley, Multidimensional NMR Methods for the Solution State, Wiley & Sons, ISBN 978-0-470-77075-7 S. Richards and J. Hollerton, Essential Practical NMR for Organic Chemistry, Wiley & Sons, ISBN 978-0-470-71092-0 A. Randazzo, Guide to NMR Spectral Interpretation, Loghia Publishing, ISBN 978-8-895-12240-3 J. Cavanagh, N. Skelton, W. Fairbrother, M. Rance, A. Palmer III, M. Rance, Protein NMR,

	Spectroscopy – Principles and Practice, Academic Press, ISBN 978-0-121-64491-8 Original literature from international peer-reviewed journals
7	**Further information** **Lecturer(s):** Lecture: Müggenburg, Scheper, Stahl Exercise: Müggenburg Laboratory exercise: Müggenburg, Scheper, Stahl
8	**Organisational unit** Faculty of Natural Sciences, Institute of Organic Chemistry, Chemistry Teaching Unit; http://www.oci.uni-hannover.de/
9	**Person responsible for module** Stahl

◎ ◎ ◉ ◎ ◎ Organisch-chemisches Forschungspraktikum in der Wirk- und Naturstoffchemie / Laboratory Research Course in Organic Chemistry of Biologically Active Substances and Natural Products

<table>
<tr><td colspan="3">Module title Laboratory Research Course in Organic Chemistry of Biologically Active Substances and Natural Products</td><td>Module code</td></tr>
<tr><td colspan="3">Degree programme MSc Chemistry</td><td>Module type
Compulsory module</td></tr>
<tr><td>Credit points 8</td><td colspan="2">Module availability Winter semester</td><td>Language German or English</td></tr>
<tr><td>Area of expertise None</td><td colspan="2">Recommended semester 3rd semester</td><td>Module duration
1 semester</td></tr>
<tr><td colspan="4">Student workload</td></tr>
<tr><td colspan="2">240 hours</td><td>150 contact hours</td><td>90 h independent study</td></tr>
<tr><td colspan="4">Further use of module
None</td></tr>
</table>

1	**Learning objectives** **Aims** Provide advanced skills and a deeper and broader understanding of the organic chemistry of biologically active substances and natural products in theory and practice (for advanced master's students). **The module shall provide the students with the following specialised and key knowledge and skills:** **On successful completion of the module, students are able to** 1. apply the expertise on natural products chemistry they have acquired to understand, appropriately describe and assess basic processes on the atomic scale. 2. combine the theoretical knowledge they have acquired with experimental observations and the practical skills from the laboratory exercises. 3. stringently tackle current research topics. 4. use methods of literature research to obtain data. 5. independently use textbooks and reference literature to develop a greater understanding of topic-related and general organic-chemical contexts. 6. independently perform literature searches. 7. work as instructed to apply basic experimental methods to problems in organic and natural products chemistry and put them into practice in compliance with current safety regulations. 8. propose their own synthetic routes to novel natural products. 9. organise the procurement of the requisite chemicals and equipment. 10. characterise the structural, chemical and physical properties of unknown organic compounds. 11. analyse experimentally acquired data as instructed and present, critically assess and interpret the experimental results derived therefrom while respecting the principles of

	research integrity.
2	**Module content** **Subject-specific content:** **Laboratory Research Course in Organic Chemistry of Biologically Active Substances and Natural Products** The course content is taken from current research topics of the research groups in the "Medicinal and Natural Products Chemistry" specialisation. Students are set a problem by one of the lecturers and work with them to develop a strategy to solve it. Where necessary, any methods which are to be used but with which the student is unfamiliar are explained. Syntheses are generally performed in close coordination with a doctoral student from the lecturer's research group. **General content:** • General scientific working and presentation techniques: Students learn to quickly familiarise themselves with previously unknown topics and to independently gather and collate information on a well-defined subject, translate it into experimental work and present it in a suitable written form. On successful completion of the module, students are able to select and use suitable media for their presentation. • Organised and goal-oriented working practices: Students acquire the ability to independently organise the way they work and to meet deadlines, to develop an expedient structure for their work processes and adopt a goal-oriented approach to executing them. • Research integrity: On successful completion of the module, the student is familiar with the principles of research integrity.
3	**Mode of teaching** ◎ ◎ ◉ ◎ ◎ Laboratory exercise Laboratory Research Course in Organic Chemistry of Biologically Active Substances and Natural Products (10 semester hours)
4a	**Participation requirements** **Module assessment and laboratory exercise:** Completed the "Chemistry of Natural Products and Biologically Active Substances" module
4b	**Recommended prior knowledge** Advanced knowledge of medicinal and natural products chemistry
5	**Requirements for award of credit points** **Coursework:** Laboratory exercise Laboratory Research Course in Organic Chemistry of Biologically Active Substances and Natural Products **Assessment:** Term paper

6	**Literature** Topic-related literature is provided partly by the supervisor, but also sourced by the students themselves.
7	**Further information** **Lecturer(s):** all lecturers in the "Medicinal and Natural Products Chemistry" specialisation of the Master in Chemistry degree programme
8	**Organisational unit** Faculty of Natural Sciences, Chemistry Teaching Unit
9	**Person responsible for module** Kalesse

◎ ◎ ◉ ◎ ◎ Technisch-chemisches Forschungspraktikum in der Wirk- und Naturstoffchemie / Laboratory Research Course in Technical Chemistry of Biologically Active Substances and Natural Products

Module title Laboratory Research Course in Technical Chemistry of Biologically Active Substances and Natural Products			**Module code**
Degree programme MSc Chemistry			**Module type** Compulsory module
Credit points 8	**Module availability** Winter semester		**Language** German or English
Area of expertise None	**Recommended semester** 3rd semester		**Module duration** 1 semester
Student workload			
240 hours	150 contact hours		90 h independent study
Further use of module None			

1	**Learning objectives** **Aims** Provide advanced skills and a deeper and broader understanding of the technical chemistry of biologically active substances and natural products in theory and practice (for advanced master's students). **The module shall provide the students with the following specialised and key knowledge and skills:** **On successful completion of the module, students are able to** 1. apply the expertise they have acquired in organic chemistry and biotechnology to understand, appropriately describe and assess basic processes on the atomic scale. 2. combine the theoretical knowledge they have acquired with experimental observations and the practical skills from the laboratory exercises. 3. stringently tackle current research topics. 4. use methods of literature research to obtain data. 5. independently use textbooks and reference literature to develop a greater understanding of topic-related and general organic chemistry relationships. 6. independently perform literature searches. 7. work as instructed to apply basic experimental methods to problems of organic chemistry and put them into practice in compliance with current safety regulations. 8. propose their own synthetic routes to novel compounds. 9. organise the procurement of the requisite chemicals and equipment. 10. perform novel syntheses. 11. characterise the structural, chemical and physical properties of unknown compounds. 12. perform visual experimental observations and document them in accordance with the principles of research integrity. 13. analyse experimentally acquired data as instructed and present, critically assess and

	interpret the experimental results derived therefrom in accordance with the principles of research integrity.
2	**Module content** **Subject-specific content:** **Laboratory exercise Laboratory Research Course in Technical Chemistry of Biologically Active Substances and Natural Products** The course content is taken from current research topics of the research groups in the "Medicinal and Natural Products Chemistry" specialisation. Students are set a problem by one of the lecturers and work with them to develop a strategy to solve it. Where necessary, any methods which are to be used but with which the student is unfamiliar are explained. Syntheses are generally performed in close coordination with a doctoral student from the supervising lecturer's research group. To gain knowledge on current research topics, students also attend oral presentations in selected colloquia (GDCh colloquia, institute colloquia). **General content:** • General scientific working and presentation techniques: Students learn to quickly familiarise themselves with previously unknown topics and to independently gather and collate information on a well-defined subject, translate it into experimental work and present it in a suitable written form. On successful completion of the module, students are able to select and use suitable media for their presentation. • Organised and goal-oriented working practices: Students acquire the ability to independently organise the way they work and to meet deadlines, to develop an expedient structure for their work processes and adopt a goal-oriented approach to executing them. • Research integrity: On successful completion of the module, the student is familiar with the principles of research integrity.
3	**Mode of teaching** ◎ ◎ ◉ ◎ ◎ Laboratory exercise Laboratory Research Course in Technical Chemistry of Biologically Active Substances and Natural Products (10 semester hours)
4a	**Participation requirements** **Module assessment and laboratory exercise:** Completed the "Biosynthesis and Process Technology" module
4b	**Recommended prior knowledge** Advanced knowledge of medicinal and natural products chemistry
5	**Requirements for award of credit points** **Coursework:** Laboratory exercise Laboratory Research Course in Technical Chemistry of Biologically Active Substances and Natural Products

	Assessment: Term paper
6	**Literature** Topic-related literature is provided partly by the supervisor, but also sourced by the students themselves.
7	**Further information** **Lecturer(s):** all lecturers in the “Medicinal and Natural Products Chemistry” specialisation of the Master in Chemistry degree programme
8	**Organisational unit** Faculty of Natural Sciences, Chemistry Teaching Unit
9	**Person responsible for module** Kalesse

◎ ◎ ◎ ◉ ◎ **Aktuelle Aspekte der Natur- und Wirkstoffchemie / Modern Aspects of Medicinal and Natural Products Chemistry**

Module title Modern Aspects of Medicinal and Natural Products Chemistry			**Module code**
Degree programme MSc Chemistry			**Module type** Compulsory module
Credit points 6	**Module availability** Winter semester		**Language** German or English
Area of expertise None	**Recommended semester** 3rd semester		**Module duration** 1 semester
Student workload			
180 hours	42 contact hours		138 h independent study
Further use of module None			

1	**Learning objectives** **Aims:** Provide a more detailed and enhanced understanding of the industrial approach to the identification of therapeutically relevant targets and the synthesis of active substances, and offer practical training in general approaches to developing an application for a research project focusing particularly on the technical, functional, legal, ethical and economic aspects (for advanced master's students). **The module shall provide the students with the following specialised and key knowledge and skills:** **On successful completion of the module, students are able to** 1. develop a research project themselves from a scientific perspective. 2. elucidate not only the scientific aspects but also the actuality and relevance of a research topic and develop a project plan with costs plan, milestones and risk mitigation. 3. critically examine a project idea. 4. describe the moral-ethical implications of natural product and drug research and issues relating to this topic which are of relevance to society as a whole. 5. assess a project in terms of its relevance and feasibility, and also in terms of scientific, legal, ethical and economic criteria. 6. present a project idea and defend it to senior staff or reviewers in a seminar presentation. 7. identify the connections between the chemistry and the structures of biologically active compounds with the corresponding biological targets from an industrial point of view. 8. identify and apply the industrially relevant principles of drug design. 9. derive economic therapeutic approaches for medical research from molecular targets. 10. use selected examples to assess how drug development can take place.

2	**Module content** **Subject-specific content:** **Seminar Development of a Research Project:** • The topics of the research projects to be developed are taken from the range of topics investigated by the lecturers who teach the degree programme. Students can choose a topic and work closely with its originator to clarify the specifics, provide greater detail and carry out the work. • Students work in cooperation with the lecturers who teach the degree programme to study methods for assessing the patent situation (research), and the legal, ecological and economic boundary conditions for project development. • Cost plans and efficiency calculations are developed. • Alternative strategies for the project are worked out and evaluated. • The research proposal developed is presented and defended as part of a seminar presentation. **Block lectures "Industrial Medicinal Chemistry 1" & "Industrial Medicinal Chemistry 2":** • Industrial access to pharmacologically relevant compounds • Current biological targets with industrial importance • Current aspects of industrial drug research • Common high-throughput methods of drug chemistry • Regulatory aspects of industrial drug research • Independent investigation of a problem in the form of a short term paper (for both lecture 1 and lecture 2) **Seminar Modern Aspects of Medicinal and Natural Products Chemistry** The students should become familiar with current research results, as presented in lectures, particularly those given by visiting speakers (institute colloquia, GDCh colloquia, Leibniz / BMWZ symposium) and learn how to assess them. They should become familiar with different lecture styles and be able to participate in scientific discussions. The lectures are held as part of established scientific colloquia and are open to the public. **General content:** • The students learn to prepare a project in the form of a project proposal (individual research grants). In addition to the purely chemical aspects, the focus will also be on cost plans, milestones and alternative plans • Selected examples are used to provide students with the industrial view of and approach to topics that are otherwise only dealt with from an academic standpoint. • The lectures on Industrial Medicinal Chemistry (1&2) in particular deal with topics not only from a chemistry point of view. Students are introduced to the interdisciplinary approach to project work that is common in industry, and which includes process engineering, biological, pharmaceutical and medical expertise.
3	**Mode of teaching** ◎ ◎ ◉ ◎ ◎ Seminar Development of a Research Proposal & Seminar Modern Aspects of Medicinal and Natural Products Chemistry (together 1 semester hour) ◎ ◎ ◎ ◎ ◉ Block lecture Industrial Medicinal Chemistry 1 (1 semester hour) ◎ ◎ ◎ ◎ ◉ Block lecture Industrial Medicinal Chemistry 2 (1 semester hour)

4a	**Participation requirements** **Module assessment:** Completed the "Chemistry of Natural Products" or "Biosynthesis and Process Technology" module
4b	**Recommended prior knowledge** Advanced knowledge of organic chemistry
5	**Requirements for award of credit points**
	Coursework: Term paper to the lecture Industrial Medicinal Chemistry 1, Term paper to the lecture Industrial Medicinal Chemistry 2, take part in 5 colloquia on medicinal and natural products chemistry
	Assessment: Project work (research proposal)
6	**Literature** Will be announced in the course
7	**Further information** **Lecturer(s):** all lecturers in the "Medicinal and Natural Products Chemistry" specialisation of the Master in Chemistry degree programme; Dr. Rossen, Dr. Fleßner
8	**Organisational unit** Faculty of Natural Sciences, Institute of Organic Chemistry, Chemistry Teaching Unit; http://www.oci.uni-hannover.de
9	**Person responsible for module** Dräger

Master of Science in Chemistry

Required Elective Modules

◎ ◎ ◎ ◎ ◎ **Advanced Methods for Structure Analysis / Advanced Methods for Structure Analysis**

Module title Advanced Methods for Structure Analysise			**Module code**
Degree programme MSc Chemistry			**Module type** Required elective module
Credit points 4	**Module availability** Winter semester or summer semester		**Language** German/English
Area of expertise None	**Recommended semester** 1st, 2nd or, 3rd semester		**Module duration** 1 semester
Student workload			
120 hours		42 contact hours	78 h independent study
Further use of module M.Sc. Nanotechnology			

1	**Learning objectives** **Aims** Provide a deeper and broader understanding of the structural elucidation of complex, nanocrystalline and/or disordered materials (for advanced Master's students). **The module shall provide the students with the following specialised and key knowledge and skills:** **On successful completion of the module, students are able to** 1. assess the suitability of different structure elucidation methods for material analytical problems and recognise application potentials. 2. learn about X-ray powder diffraction as a method in the light of structure elucidation. 3. specifically, know and be able to explain three-dimensional electron diffraction as a method. 4. model and simulate, in principle, disordered materials. 5. learn the basic principles for handling the electron microscope with regard to electron diffraction. 6. get to know the basics of using specialised computer programmes for evaluating and determining structural analytical questions.
2	**Module content** **Subject-related module content:** **Lecture** • Refreshing crystallographic basics • Interference and diffraction at the crystal • Modelling and simulations • Typical methods for structure determination • Three-dimensional electron diffraction • Disorder in crystal structures

	General content: • Data analysis/data interpretation and modelling.
3	**Mode of teaching** ◎ ◎ ◉ ◎ ◎ Lecture Advanced Methods for Structure Analysis (3 semester hours)
4a	**Participation requirements** **Module assessment:** None
4b	**Recommended prior knowledge** Basic knowledge in TEM; basic knowledge in crystallography; advanced knowledge in solid state chemistry; basic knowledge in EDP
5	**Requirements for award of credit points**
	Coursework: None
	Assessment: Written examination 120 minutes or oral examination 30 minutes
6	**Literature** • J. Bohm, D. Klimm, M. Mühlberg: Einführung in die Kristallographie, ISBN-13: 978-3110460230 • U. Müller: Anorganische Strukturchemie, ISBN-13: 978-3834806260 • U. Müller: Symmetry Relationships Between Crystal Structures: Applications of Crystallographic Group Theory in Crystal Chemistry, ISBN-13: 978-0199669950 • X. Zou, S. Hovmoller, P. Oleynikov: Electron Crystallography: Electron Microscopy and Electron Diffraction, ISBN: 978-0199580200
7	**Further information** None **Lecturer(s):** Krysiak, Schaate, Siroky
8	**Organisational unit** Faculty of Natural Sciences, Institute of Inorganic Chemistry, Chemistry Teaching Unit, https://www.aci.uni-hannover.de/en/
9	**Person responsible for module** Krysiak

◎ ◎ ◉ ◎ ◎ Advanced Methods for Structure Analysis mit Laborübung / Advanced Methods for Structure Analysis with Laboratory Exercise

<table>
<tr><td colspan="3">Module title Advanced Methods for Structure Analysis with Laboratory Excercise</td><td>Module code</td></tr>
<tr><td colspan="3">Degree programme MSc Chemistry</td><td>Module type Required elective module</td></tr>
<tr><td>Credit points 8</td><td colspan="2">Module availability Winter semester or summer semester</td><td>Language German/English</td></tr>
<tr><td>Area of expertise None</td><td colspan="2">Recommended semester 1st, 2nd or, 3rd semester</td><td>Module duration 1 semester</td></tr>
<tr><td colspan="4">Student workload</td></tr>
<tr><td colspan="2">240 hours</td><td>98 contact hours</td><td>142 h independent study</td></tr>
<tr><td colspan="4">Further use of module
M.Sc. Nanotechnology</td></tr>
</table>

1	**Learning objectives** **Aims** Provide a deeper and broader understanding of the structural elucidation of complex, nanocrystalline and/or disordered materials in theory and practice (for advanced Master's students). **The module shall provide the students with the following specialised and key knowledge and skills:** **On successful completion of the module, students are able to** 7. assess the suitability of different structure elucidation methods for material analytical problems and recognise application potentials. 8. learn about X-ray powder diffraction as a method in the light of structure elucidation. 9. specifically, know and be able to explain three-dimensional electron diffraction as a method. 10. model and simulate, in principle, disordered materials. 11. learn the basic principles for handling the electron microscope with regard to electron diffraction. 12. get to know the basics of using specialised computer programmes for evaluating and determining structural analytical questions.
2	**Module content** **Subject-related module content:** **Lecture** • Refreshing crystallographic basics • Interference and diffraction at the crystal • Modelling and simulations • Typical methods for structure determination • Three-dimensional electron diffraction • Disorder in crystal structures

	Laboratory exercise • Preparation of PXRD and TEM samples • Measurement of powder X-ray diagrams • Indexing; possibly carrying out qualitative and quantitative phase analyses • Carrying out a simple crystal structure determination • Adjusting the transmission electron microscope • Testing of different measurement methods • Tilt series data reconstruction • Data analysis of electron diffraction data • Structure solution and refinement • Dynamical refinement of crystal structures **General content:** • Data analysis/data interpretation and modelling.
3	**Mode of teaching** ◎ ◎ ◉ ◎ ◎ Lecture Advanced Methods for Structure Analysis (3 semester hours) ◎ ◎ ◉ ◎ ◎ Laboratory exercise Advanced Methods for Structure Analysis (4 semester hour)
4a	**Participation requirements** **Module assessment:** None
4b	**Recommended prior knowledge** Basic knowledge in TEM; basic knowledge in crystallography; advanced knowledge in solid state chemistry; basic knowledge in EDP
5	**Requirements for award of credit points** **Coursework:** Laboratory exercise Advanced Methods for Structure Analysis **Assessment:** Written examination 120 minutes or oral examination 30 minutes
6	**Literature** • J. Bohm, D. Klimm, M. Mühlberg: Einführung in die Kristallographie, ISBN-13: 978-3110460230 • U. Müller: Anorganische Strukturchemie, ISBN-13: 978-3834806260 • U. Müller: Symmetry Relationships Between Crystal Structures: Applications of Crystallographic Group Theory in Crystal Chemistry, ISBN-13: 978-0199669950 • X. Zou, S. Hovmoller, P. Oleynikov: Electron Crystallography: Electron Microscopy and Electron Diffraction, ISBN: 978-0199580200
7	**Further information** None **Lecturer(s):** Krysiak, Schaate, Siroky
8	**Organisational unit** Faculty of Natural Sciences, Institute of Inorganic Chemistry, Chemistry Teaching Unit, https://www.aci.uni-hannover.de/en/

9	**Person responsible for module** Krysiak

◎ ◎ ◎ ◎ ◉ **Biokunststoffe / Bioplastics**

<table>
<tr><td colspan="3">Module title Bioplastics</td><td>Module code</td></tr>
<tr><td colspan="3">Degree programme MSc Chemistry</td><td>Module type Required elective module</td></tr>
<tr><td>Credit points 4</td><td colspan="2">Module availability Winter semester</td><td>Language German</td></tr>
<tr><td>Area of expertise None</td><td colspan="2">Recommended semester
1st-3rd semester</td><td>Module duration
1 semester</td></tr>
<tr><td colspan="4">Student workload</td></tr>
<tr><td colspan="2">120 hours</td><td>42 contact hours</td><td>78 h independent study</td></tr>
<tr><td colspan="4">Further use of module
None</td></tr>
</table>

1	**Learning objectives** **Aims** Holistic understanding of the origin, properties and degradation of bioplastics, which enables the students to evaluate opportunities and challenges of these polymers in an academic, industrial, socio-economic and ecologic context (for master's students). **The module shall provide the students with the following specialised and key knowledge and skills:** **On successful completion of the module, students are able to** 1. describe the manufacture of different bioplastics including their feedstock chain. 2. assess the suitability of different bioplastics for specific applications and recognise their potential and/or associated risks for certain applications. 3. identify feedstock sources for bioplastics, assess their sustainability and describe the parameters to determine their ecobalance. 4. describe current market shares and developments and put them into the socio-ecological context. 5. develop their own scientific ideas and research concepts in the field of bioplastics. 6. plan and write a short research proposal including work packages and risk analysis/management.
2	**Module content** **Subject-specific content:** **Lecture Bioplastics** • Basics: terms and definitions • Overview of biopolymers from nature (polypeptides, polysaccharides, polynucleotides): biosynthesis, structure and properties • Biopolymers from the food industry and from agricultural waste: structure, properties and applications • Preparation of monomers and polymers via microbiological/enzymatic fermentation with bacteria, fungi and with the help of microalgae: mechanism, isolation,

	purification and production • Features of the processability and (bio)degradation of bioplastics • Industrial processes, market share and stakeholders • Methodology and standards to evaluate the sustainability of biopolymers • Methodology to estimate the ecobalances of biopolymers Seminar Bioplastics • Principles to develop independent scientific research ideas • Literature search and market research • Principles to conceptualise research proposals • Exercise to prepare a research proposal • Write a research proposal (5-10 pages) as a term paper General content: • Critical reading of primary literature in English (journal articles). • Write a scientific text as a short research proposal.
3	**Mode of teaching** ◎ ◎ ◎ ◎ ◉ Lecture Bioplastics (2 semester hours) ◎ ◎ ◎ ◎ ◉ Seminar Bioplastics (1 semester hour)
4a	**Participation requirements** None
4b	**Recommended prior knowledge** Basic knowledge of polymer chemistry
5	**Requirements for award of credit points**
	Coursework: None
	Assessment: term paper
6	**Literature** G.Z. Papageorgiou (Ed.), Polymers from Renewable Resources, MDPI (2019) C. Kennes (Ed.) Bioconversion Processes, Bioconversion Processes, MDPI (2018) B. BayónIgnacio, R. Berti, A.M. Gagneten, G.R. Castro, Biopolymers from Wastes to High-Value Products in Biomedicine, In: Singhania R., Agarwal R., Kumar R., Sukumaran R. (Eds) Waste to Wealth. Energy, Environment, and Sustainability. Springer, Singapore (2018) O. Türk, Stoffliche Nutzung nachwachsender Rohstoffe: Grundlagen – Werkstoffe – Anwendungen, Springer Vieweg (2014) In addition, current publications on the topics are used (no current books cover all topics).
7	**Further information** **Lecturer(s):** Weinhart
8	**Organisational unit** Faculty of Natural Sciences, Institute of Physical Chemistry and Electrochemistry, Chemistry Teaching Unit; http://www.pci.uni-hannover.de/

9	**Person responsible for module** Weinhart

◎ ◎ ◎ ◎ ◉ **Biomaterialien und Biomineralisation/ Biomaterials and Biomineralisation**

<table>
<tr><td colspan="3">Module title Biomaterials and Biomineralisation</td><td>Module code</td></tr>
<tr><td colspan="3">Degree programme MSc Chemistry</td><td>Module type Required elective module</td></tr>
<tr><td>Credit points 4</td><td colspan="2">Module availability Winter semester or summer semester</td><td>Language German</td></tr>
<tr><td>Area of expertise None</td><td colspan="2">Recommended semester 1st, 2nd or 3rd semester</td><td>Module duration 1 semester</td></tr>
<tr><td colspan="4">Student workload</td></tr>
<tr><td colspan="2">120 hours</td><td>42 contact hours</td><td>78 h independent study</td></tr>
<tr><td colspan="4">Further use of module
MSc Biochemistry
MSc Life Science
MSc Biomedical Engineering
MSc Nanotechnology</td></tr>
<tr><td>1</td><td colspan="3">Learning objectives

Aims
Provide a deeper and broader understanding of biomaterials and biomineralisation processes (for advanced master's students).

The module shall provide the students with the following specialised and key knowledge and skills:

On successful completion of the module, students are able to

1. describe, explain and apply the concepts and content of the Biomaterials and Biomineralisation module.
2. analyse and discuss the specific problems of analytical studies on biomaterials and biomineralisation processes</td></tr>
<tr><td>2</td><td colspan="3">Module content

Subject-specific content:
Lecture Biomaterials and Biomineralisation
• The typical hierarchical structure of biominerals, their character as bioorganic-inorganic composite structures, the structures at the interfaces as well as general mechanisms of biomineralisation are discussed.
• Biominerals of selected substance classes (calcium carbonate, calcium phosphate, iron oxides, silicon dioxide) are presented in terms of their structure, properties and function.
• The use of biomineralisation principles for biomimetic synthesis is presented.
• Basic aspects of the use of biomaterials are explained.
• Polymers, inorganic ceramic materials and metals are presented as typical classes of inert or resorbable biomaterials. Special attention is paid to the interface between biomaterial and bioorganic molecules or biological structures (cells, tissue, body).
• Physical, chemical, biochemical and biological modifications of biomaterials are addressed.</td></tr>
</table>

	• Basic aspects of cell culture experiments as well as fundamental and ethical aspects of animal experiments are discussed. • The use of biomaterials for tissue and stem cell engineering as well as the health risks of solids and nanoparticles which come into contact with the body are discussed. • The specific problems of analytical investigations on biominerals and biomaterials (sample preparation, analysis of macromolecules, analysis of interfaces) are discussed. • Special analytical methods like microscopy in the µm range with photons (Raman, IR, UV, X-ray) and ions are presented. Special attention is paid to the analysis of tissue samples and the specific determination of mineral components and trace elements. **General content:**
3	**Mode of teaching** ◎ ◎ ◎ ◎ ◉ Lecture Biomaterials and Biomineralisation (3 semester hours)
4a	**Participation requirements** **Module assessment:** None
4b	**Recommended prior knowledge** Advanced knowledge of inorganic, organic, physical and/or technical chemistry, biochemistry, life sciences, nanotechnology, biomedical engineering.
5	**Requirements for award of credit points**
	Coursework: None
	Assessment: Written examination 120 minutes or oral examination 30 minutes
6	**Literature** **Lecture Biomaterials and Biomineralisation** M. Epple: Biomaterials and Biomineralisation, Teubner, 2003 S. Mann: Biomineralisation, Oxford 2001 B. Ratner u.a.: Biomaterials Science 2013
7	**Further information** **Lecturer(s):** Behrens, Ehlert, Gebauer, Weinhart
8	**Organisational unit** Faculty of Natural Sciences, Institute of Inorganic Chemistry, Chemistry Teaching Unit; http://www.aci.uni-hannover.de
9	**Person responsible for module** Behrens

◎ ◎ ◎ ◉ ◎ und Biomineralisation mit Laborübung /
Biomaterials and Biomineralisation with Laboratory Exercise

<table>
<tr><td colspan="2">Module title Biomaterials and Biomineralisation with Laboratory Exercise</td><td>Module code</td></tr>
<tr><td colspan="2">Degree programme MSc Chemistry</td><td>Module type Required elective module</td></tr>
<tr><td>Credit points 8</td><td>Module availability Winter semester</td><td>Language German</td></tr>
<tr><td>Area of expertise None</td><td>Recommended semester 3rd semester</td><td>Module duration 1 semester</td></tr>
<tr><td colspan="3">Student workload</td></tr>
<tr><td>240 hours</td><td>98 contact hours</td><td>142 h independent study</td></tr>
<tr><td colspan="3">Further use of module
MSc Biochemistry
MSc Life Science</td></tr>
</table>

1

Learning objectives

Aims
Provide a deeper and broader understanding of biomaterials and biomineralisation processes (for advanced master's students).

The module shall provide the students with the following specialised and key knowledge and skills:

On successful completion of the module, students are able to

1. describe, explain and apply the concepts and content of the Biomaterials and Biomineralisation module.
2. analyse and discuss the specific problems of analytical studies on biomaterials and biomineralisation processes
3. perform independent analytical investigations on specifically prepared specimens (major components, trace elements).
4. prepare biomaterials and carry out suitable test procedures.
5. evaluate and explain experimental results and combine them with theoretical principles.

2

Module content

Subject-specific content:
Lecture Biomaterials and Biomineralisation

- The typical hierarchical structure of biominerals, their character as bioorganic-inorganic composite structures, the structures at the interfaces as well as general mechanisms of biomineralisation are discussed.
- Biominerals of selected substance classes (calcium carbonate, calcium phosphate, iron oxides, silicon dioxide) are presented in terms of their structure, properties and function.
- The use of biomineralisation principles for biomimetic synthesis is presented.
- Basic aspects of the use of biomaterials are explained.
- Polymers, inorganic ceramic materials and metals are presented as typical classes of

	inert or resorbable biomaterials. Special attention is paid to the interface between biomaterial and bioorganic molecules or biological structures (cells, tissue, body). • Physical, chemical, biochemical and biological modifications of biomaterials are dealt with. • Basic aspects of cell culture experiments as well as fundamental and ethical aspects of animal experiments are discussed. • The use of biomaterials for tissue and stem cell engineering as well as the health risks of solids and nanoparticles which come into contact with the body are discussed. • The specific problems of analytical investigations on biominerals and biomaterials (sample preparation, analysis of macromolecules, analysis of interfaces) will be discussed. • Special analytical methods like microscopy in the µm range with photons (Raman, IR, UV, X-ray) and ions are presented. Special attention is paid to the analysis of tissue samples and the specific determination of mineral components and trace elements. **Laboratory exercise Biomaterials and Biomineralisation** On the one hand, the experiments serve to equip students with a basic knowledge of handling biological samples containing biominerals and their analytical characterisation. On the other hand, students produce biomaterials themselves and test different aspects of them. • Processing and characterisation of typical biominerals such as rice husks, eggshells, teeth or bones: Testing of different preparation methods (removal of organic components by enzymatic or chemical-oxidative degradation; removal of inorganic components by exploitation of selective solubilities); characterisation of the samples by different methods (thermoanalysis, microscopy, electron microscopy, IR spectroscopy, methods of elemental analysis). • Studies on the immobilisation of enzymes. Perform activity tests. • Synthesis and characterisation of composite materials • Methods of mechanical testing • Spatially resolved analysis of biological samples **General content:**
3	**Mode of teaching** ◎ ◎ ◎ ◎ ◉ Lecture Biomaterials and Biomineralisation (3 semester hours) ◎ ◎ ◉ ◎ ◎ Laboratory exercise Biomaterials and Biomineralisation (4 semester hours)
4a	**Participation requirements** **Module assessment:** None
4b	**Recommended prior knowledge** Advanced knowledge of inorganic, organic, physical and/or technical chemistry, biochemistry, life sciences, nanotechnology.
5	**Requirements for award of credit points** **Coursework:** Laboratory exercise Biomaterials and Biomineralisation **Assessment:** Written examination 120 minutes or oral examination 30 minutes

6	**Literature** **Lecture Biomaterials and Biomineralisation** M. Epple: Biomaterials and Biomineralisation, Teubner, 2003 S. Mann: Biomineralisation, Oxford 2001 B. Ratner u.a.: Biomaterials Science 2013 **Laboratory exercise Biomaterials and Biomineralisation** Handout for the Laboratory Exercise
7	**Further information** **Lecturer(s):** Lecture: Behrens, Ehlert, Gebauer, Weinhart Laboratory ecercise: Behrens, Ehlert, Gebauer, Weinhart
8	**Organisational unit** Faculty of Natural Sciences, Institute of Inorganic Chemistry, Chemistry Teaching Unit; http://www.aci.uni-hannover.de
9	**Person responsible for module** Behrens

◎ ◎ ◎ ◉ ◎ **Chemische Biologie / Chemical Biology**

Module title Chemical Biology		**Module code**
Degree programme MSc Chemistry		**Module type** Required elective module
Credit points 8	**Module availability** Winter semester	**Language** German
Area of expertise None	**Recommended semester** 3rd semester	**Module duration** 1 semester
Student workload		
240 hours	90 contact hours	150 h independent study
Further use of module None		

1	**Learning objectives** **Aims** Provide advanced skills and a deeper and broader understanding of chemical biology in theory and practice (for advanced master's students). **The module shall provide the students with the following specialised and key knowledge and skills:** **On successful completion of the module, students are able to** 1. design experiments to discover the mode of action of compounds. 2. undertake cell biology research with small-molecule probes (compounds with specific functions). 3. design small molecules and proteins with specific functions and/or for therapeutic purposes. 4. perform chemistry within cells.
2	**Module content** **Subject-specific content:** **Lecture/ Exercise/ Laboratory exercise Chemical Biology** • Bioorthogonal chemistry • Pulldown experiments for target identification • Correlation methods for target identification • Small molecules and their system-wide effects • Molecular imaging • Chemical, biochemical and genetic modifications of proteins **General content:** • Critical view of the significance and limitations of small molecules and their biological effects

3	**Mode of teaching** ◎ ◎ ◎ ◎ ◉ Lecture Chemical Biology (2 semester hours) ◎ ◎ ◎ ◎ ◉ Exercise Chemical Biology (1 semester hour) ◎ ◎ ◉ ◎ ◎ Laboratory exercise Chemical Biology (3 semester hours)
4a	**Participation requirements** **Module assessment:** None
4b	**Recommended prior knowledge** Advanced knowledge of chemistry; successful completion of the Medicinal Chemistry I lectures
5	**Requirements for award of credit points**
	Coursework: Laboratory exercise Chemical Biology
	Assessment: Written examination 120 minutes or oral examination 30 minutes
6	**Literature** [1] Chemical Biology, Learning through Case Studies. Waldmann, Herbert / Janning, Petra (Eds.), Wiley-VCH, ISBN: 978-3-527-32330-2 Selected reviews from scientific journals, e.g. S. Ziegler, V. Pries, C. Hedberg, H. Waldmann, Angew. Chem. 2013, 125, 2808 – 2859
7	**Further information** **Lecturer(s):** Brönstrup, Franke, Friederich, Heimann
8	**Organisational unit** Faculty of Natural Sciences, Institute of Organic Chemistry, Chemistry Teaching Unit; http://www.oci.uni-hannover.de
9	**Person responsible for module** Brönstrup

◉ ◎ ◎ ◎ ◎ **Computational Bio-Organic Chemistry**

<table>
<tr><td colspan="3">Module title Computational Bio-Organic Chemistry</td><td>Module code</td></tr>
<tr><td colspan="3">Degree programme MSc Chemistry</td><td>Module type Required elective module</td></tr>
<tr><td>Credit points 8</td><td colspan="2">Module availability Winter semester</td><td>Language English</td></tr>
<tr><td>Area of expertise None</td><td colspan="2">Recommended semester 3rd semester</td><td>Module duration 1 semester</td></tr>
<tr><td colspan="4">Student workload</td></tr>
<tr><td colspan="2">240 hours</td><td>105 contact hours</td><td>135 h independent study</td></tr>
<tr><td colspan="4">Further use of module
None</td></tr>
</table>

1	**Learning objectives** **Aims** Provide practical and theoretical skills in biomolecular computational chemistry (for advanced master's students). **The module shall provide the students with the following specialised and key knowledge and skills:** **On successful completion of the module, students are able to** 1. use force-fields to describe and calculate the internal energy of organic and biomolecules. 2. explain and apply methods of energy minimisation. 3. explain and apply methods for the optimisation of molecular structures. 4. explain Monte Carlo and molecular dynamics methods. 5. use databases for protein sequences and structures. 6. use ligand databases. 7. model protein-ligand interactions. 8. present results of the computation and critically analyse the results.
2	**Module content** **Subject-specific content:** **Lecture/ Exercise Computational Bio-Organic Chemistry** • Visualisation of the structure of organic molecules and proteins • Basics of modelling methods: force fields, algorithms of energy minimisation, algorithms for Monte Carlo and molecular dynamics calculations. • "Molecular modelling" programs • Protein-ligand "docking" methods • "Pharmacophore" mapping • Database search and results analysis. **General content:** • Mathematical search methods for energy minima on a multidimensional energy

	surface
3	**Mode of teaching** ◉ ◎ ◎ ◎ ◎ Lecture Computational Bio-Organic Chemistry (3 semester hours) ◉ ◎ ◎ ◎ ◎ Exercise Computational Bio-Organic Chemistry (4 semester hours)
4a	**Participation requirements** **Module assessment:** None
4b	**Recommended prior knowledge** Basic knowledge of computing, advanced knowledge of chemistry, good knowledge of mathematics (integrals, derivatives, matrices, vectors) and physical chemistry (thermodynamics etc.)
5	**Requirements for award of credit points**
	Coursework: Exercise Computational Bio-Organic Chemistry
	Assessment: Written examination 120 minutes or oral examination 30 minutes
6	**Literature** Molecular Modelling: Principles and Applications, Andrew R. Leach, Pearson Education, 2001
7	**Further information** **Lecturer(s):** Carlomagno
8	**Organisational unit** Faculty of Natural Sciences, Institute of Organic Chemistry, Chemistry Teaching Unit; http://www.oci.uni-hannover.de
9	**Person responsible for module** Carlomagno

◎ ◎ ◎ ◎ ◉ **Computational Inorganic Chemistry**

<table>
<tr><td colspan="2">Module title Computational Inorganic Chemistry</td><td>Module code</td></tr>
<tr><td colspan="2">Degree programme MSc Chemistry</td><td>Module type Required elective module</td></tr>
<tr><td>Credit points 4</td><td>Module availability Winter semester or summer semester</td><td>Language German</td></tr>
<tr><td>Area of expertise None</td><td>Recommended semester 1st, 2nd or 3rd semester</td><td>Module duration 1 semester</td></tr>
<tr><td colspan="3">Student workload</td></tr>
<tr><td>120 hours</td><td>42 contact hours</td><td>78 h independent study</td></tr>
<tr><td colspan="3">Further use of module
None</td></tr>
</table>

1	**Learning objectives** **Aims** Provide advanced skills and a deeper and broader understanding of inorganic computational chemistry in theory and practice (for advanced master's students). **The module shall provide the students with the following specialised and key knowledge and skills:** **On successful completion of the module, students are able to** 1. understand and apply the content of Computational Inorganic Chemistry. 2. apply the computational suites in other modules. 3. understand different approaches and models for different problems and methods. 4. evaluate results obtained from different modelling approaches.
2	**Module content** **Subject-specific content:** **Lecture/ Exercise Computational Chemistry** • Visualise structures of organic molecules and inorganic solid-state structures • Basics of modelling methods: force fields, minimising algorithms, Monte Carlo (MC) and molecular dynamics (MD) algorithms • Molecular modelling programs **General content:**
3	**Mode of teaching** ◎ ◎ ◎ ◎ ◉ Lecture Computational Inorganic Chemistry (1 semester hour) ◎ ◎ ◎ ◎ ◉ Practical exercise Computational Inorganic Chemistry (2 semester hours)

4a	**Participation requirements** **Module assessment:** None
4b	**Recommended prior knowledge** Basic knowledge of computing; advanced knowledge of chemistry
5	**Requirements for award of credit points** **Coursework:** Exercise Computational Inorganic Chemistry **Assessment:** Written examination 60 minutes
6	**Literature** Students will be provided with course-relevant literature.
7	**Further information** **Lecturer(s):** König, Schneider
8	**Organisational unit** Faculty of Natural Sciences, Institute of Inorganic Chemistry, Chemistry Teaching Unit; http://www.aci.uni-hannover.de
9	**Person responsible for module** König, Schneider

◎ ◎ ◎ ◎ ◎ Computational Spectroscopy

Module title Computational Spectroscopy			**Module code**
Degree programme MSc Chemistry			**Module type** Required elective module
Credit points 4	**Module availability** Winter semester or summer semester		**Language** German/English
Area of expertise None	**Recommended semester** 1st, 2nd or, 3rd semester		**Module duration** 1 semester
Student workload			
120 hours		56 contact hours	64 h independent study
Further use of module None			

1	**Learning objectives** **Aims** Provide a deeper and broader understanding of quantum-chemical calculations of spectroscopic properties of molecular systems as well as practical skills for the calculations of such molecular properties using quantum-chemical software packages. **The module shall provide the students with the following specialised and key knowledge and skills:** **On successful completion of the module, students are able to** 1. describe the approximation behind the quantum-chemical models for the calculation of optical spectra. 2. estimate the computational expense and the expected accuracy of quantum-chemical models. 3. design, carry out and analyze own quantum-chemical short projects.
2	**Module content** **Subject-related module content:** **Lecture** • strengthening of the underlying quantum mechanical principles • Born-Oppenheimer approximation • electronic-structure theory • density matrices • density functional theory • spectroscopic properties and response theory • implicit and explicit embedding approaches • fragmentation methods

	Laboratory exercise • application of quantum-chemical software packages • energy calculation for different points on the potential energy surface • quantum-chemical calculation of optical spectra • application of implicit and explicit embedding methods • avoid pitfalls in quantum-chemical calculations **General content:** • ωορκινγ ον χομπυτε χλυστερσ
3	**Mode of teaching** ◎ ◎ ◉ ◎ ◎ Lecture Computational Spectroscopy (2 semester hours) ◎ ◎ ◉ ◎ ◎ Laboratory exercise Computational Spectroscopy (1 semester hours)
4a	**Participation requirements** **Module assessment:** None
4b	**Recommended prior knowledge** Math for natural scientists (analysis, algebra, eigen value problems); basics of quantum mechanics (including quantum-mechanical description of atoms)
5	**Requirements for award of credit points** **Coursework:** Laboratory exercise Computational Spectroscopy **Assessment:** Oral assignment (20 minutes including discussions)
6	**Literature** • G.C. Schatz, M.A. Rantner, Quantum Mechanics in Chemistry • Parr, Yang, Density-Functional Theory of Atomes and Molecules • Szabo, Ostlund, Modern Quantum Chemistry • Jensen, Introduction to Computational Chemistry • Review articles and publications as named by the lecturer • Lecture notes
7	**Further information** **If you are interested, please send an email to** carolin.koenig@pci.uni-hannover.de for organisational details of this course. **Lecturer(s):** König
8	**Organisational unit** Faculty of Natural Sciences, Institute of Physical Chemistry and Electrochemistry, Chemistry Teaching Unit; http://www.pci.uni-hannover.de
9	**Person responsible for module** König

◎ ◎ ◎ ◉ ◎ Elektrische, magnetische und optische Eigenschaften von Molekülen und Festkörpern /
Electrical, Magnetic and Optical Properties of Molecules and Solids

<table>
<tr><td colspan="3">Module title Electrical, Magnetic and Optical Properties of Molecules and Solids</td><td>Module code</td></tr>
<tr><td colspan="3">Degree programme MSc Chemistry</td><td>Module type Required elective module</td></tr>
<tr><td>Credit points 8</td><td colspan="2">Module availability Winter semester</td><td>Language German</td></tr>
<tr><td>Area of expertise None</td><td colspan="2">Recommended semester 3rd semester</td><td>Module duration
1 semester</td></tr>
<tr><td colspan="4">Student workload</td></tr>
<tr><td colspan="2">240 hours</td><td>98 contact hours</td><td>142 h independent study</td></tr>
<tr><td colspan="4">Further use of module
None</td></tr>
</table>

1	**Learning objectives** **Aims** Provide advanced skills and a deeper and broader understanding of electrical, magnetic and optical properties of molecules and solids in theory and practice (for advanced master's students). **The module shall provide the students with the following specialised and key knowledge and skills:** **On successful completion of the module, students are able to** 1. explain the mathematical and physical principles of electrodynamics in media 2. describe properties by means of molecular data 3. calculate properties using quantum chemical programs such as GAUSSIAN
2	**Module content** **Subject-specific content:** **Lecture/ Exercise Electrical, Magnetic and Optical Properties of Molecules and Solids** • Introduction to vector analysis • Maxwell's equations • Wave equations in a vacuum and in media • Basics of wave optics • Polarisation and dipole densities • Langevin function • Polarisability tensor • Electronic excitations and perturbation theory • Electron correlation • Dielectric function • Magnetic susceptibilities

	• Optical anisotropy • Optical activity • Vector potential **Laboratory exercise Electrical, Magnetic and Optical Properties of Molecules and Solids** Optical, electrical and magnetic properties are calculated by using GAUSSIAN and ADF quantum chemical software. **General content:** Properties of liquid and solid media
3	**Mode of teaching** ◎ ◎ ◎ ◎ ◉ Lecture Electrical, Magnetic and Optical Properties of Molecules and Solids (2 semester hours) ◎ ◎ ◎ ◎ ◉ Exercise Electrical, Magnetic and Optical Properties of Molecules and Solids (1 semester hour) ◎ ◎ ◉ ◎ ◎ Laboratory exercise Electrical, Magnetic and Optical Properties of Molecules and Solids on the Computer (4 semester hours)
4a	**Participation requirements** **Module assessment:** None
4b	**Recommended prior knowledge** None
5	**Requirements for award of credit points**
	Coursework: Laboratory exercise Electrical, Magnetic and Optical Properties of Molecules and Solids on the Computer
	Assessment: Oral examination 30 minutes
6	**Literature** P. Atkins, R. Friedman, Molecular Quantum Mechanics, Oxford University Press, Oxford E. Hecht, A. Zajac, Optics, DA, New York C. Kittel, Introduction to Solid State Physics, John Wiley, New York
7	**Further information** **Lecturer(s):** Becker
8	**Organisational unit** Faculty of Natural Sciences, Institute of Physical Chemistry and Electrochemistry, Chemistry Teaching Unit; http://www.pci.uni-hannover.de/

9	**Person responsible for module** Becker

◎ ◎ ◎ ◎ ◎ Elektrochemie für Fortgeschrittene / Electrochemistry for Advanced Students

Module title Electrochemistry for Advanced Students		**Module code**
Degree programme MSc Chemistry		**Module type** Required elective module
Credit points 4	**Module availability** Winter semester or summer semester	**Language** German
Area of expertise None	**Recommended semester** 1st, 2nd or, 3rd semester	**Module duration** 1 semester
Student workload		
120 hours	42 contact hours	78 h independent study
Further use of module None		

1	**Learning objectives** **Aims** Provide a deeper and broader understanding of electrochemistry (for advanced students) with regard to applications in the fields of sustainable synthesis and battery research. **The module shall provide the students with the following specialised and key knowledge and skills:** **On successful completion of the module, students are able to** 13. explain chemical and physical foundations of electrochemistry in solutions and solids. 14. understand and explain electrochemical processes with respect to synthesis an energy storage. 15. be able to formulate electrochemical problems with respect to applications and to find suitable solutions.
2	**Module content** **Subject-related module content:** **Lecture** • electrodes • electrode kinetics • spectro-electrochemistry • single step reactions • multistep reactions • electrical double layers • electro capillarity • galvanic layer deposition • electrochemical nanotechnology • energy conversion and storage

	• battery types • solid state electrochemistry **Exercise** • problems are solve analytically and numerically **General content:** • electrified interfaces, energy conversion and storage
3	**Mode of teaching** ◎ ◎ ◎ ◎ ◎ Lecture Electrochemistry for Advanced Students (2 semester hours) ◎ ◎ ◎ ◎ ◎ Exercise Electrochemistry for Advanced Students (1 semester hour)
4a	**Participation requirements** **Module assessment:** None
4b	**Recommended prior knowledge** None
5	**Requirements for award of credit points**
	Coursework: None
	Assessment: Oral examination 30 minutes
6	**Literature** Electrochemistry, Carl H. Hamann Andrew Hamnett, Wolf Vielstich , Wiley-VCH; 2nd edition (2007) Batteries: Present and Future Energy Storage Challenges, Stefano Passerini (ed.), Wiley-VCH; 1st edition (2020) Interfacial Electrochemistry, Wolfgang Schmickler, Elizabeth Santos, Springer; 2nd edition (2010) Physical Electrochemistry: Fundamentals, Techniques and Applications Paperback, Noam Eliaz (Autor), Eliezer Gileadi, Wiley-VCH; 2nd edition (2018) Solid State Electrochemistry I and II: Fundamentals, Materials and their Applications, Vladislav V. Kharton, Wiley-VCH; 1st edition (2009)
7	**Further information** None **Lecturer(s):** Becker
8	**Organisational unit** Faculty of Natural Sciences, Institute of Physical Chemistry and Electrochemistry, Chemistry Teaching Unit, https://www.pci.uni-hannover.de/en/
9	**Person responsible for module** Becker

◎ ◎ ◎ ◎ ◎ **Elektronenmikroskopie /**
Electron Microscopy

Module title Electron Microscopy		**Module code**
Degree programme MSc Chemistry		**Module type** Required elective module
Credit points 4	**Module availability** Winter semester	**Language** German
Area of expertise None	**Recommended semester** 1st-3rd semester	**Module duration** 1 semester
Student workload		
120 hours	42 contact hours	78 h independent study
Further use of module None		

1	**Learning objectives** **Aims** Provide advanced skills and a deeper and broader understanding of electron microscopy in theory and practice (for advanced master's students). **The module shall provide the students with the following specialised and key knowledge and skills:** **On successful completion of the module, students are able to** 1. describe the principles of different electron microscopy methods for the microstructural and microchemical characterisation of solids and modern-day materials. 2. assess the suitability of different electron microscopy methods to tackle specific problems in the analysis of materials and identify potential applications of these methods. 3. combine and describe analyses in real space (imaging) and reciprocal space (electron diffraction). 4. describe local elemental analysis. 5. interpret different contrast methods in electron microscopy and interpret results of analyses. 6. evaluate experimentally acquired data, and suitably present, critically evaluate and interpret results derived therefrom.
2	**Module content** **Subject-specific content:** **Lecture Electron Microscopy** • Basics: de Broglie wavelength, Lorentz force, electron sources, electron lenses, aberrations • Scanning electron microscope (SEM): beam paths, stigmators, deflectors, interaction of the electron beam with matter, emission of secondary electrons, emission of backscattered electrons, emission of Auger electrons, emission of X-rays, electron

	detectors, in-lens detection of electrons • Focused ion beam (FIB): liquid-metal ion source, field ion microscope (FIM), helium ion microscopy • Transmission electron microscope (TEM): history, virology, wave optics approach to principle of the lens, 2-stage TEM, 3-stage TEM, beam paths for imaging and diffraction, resolving power, Fourier optics, diffraction absorption contrast • High-resolution transmission electron microscopy (HRTEM): phase contrast, phase-amplitude diagrams, $\lambda/4$ phase plate, phase contrast transfer function (PCTF), point resolution, contrast simulations (multislice and Bloch wave methods), delocalisation, focal series reconstruction, aberration correction (C_S and C_C) • Selected area electron diffraction (SAED): identifying zone axis, orientation relationships, kinematic approximation, analogies and differences between the diffraction of electrons and X-rays • Convergent beam electron diffraction (CBED): dynamical theory of diffraction, Kikuchi lines, symmetries, determining space groups • Scanning transmission electron microscopy (STEM): Z contrast, low-angle annular dark-field (LAADF), high-angle annular dark-field (HAADF), detection of light elements like H or Li • Electron energy-loss spectroscopy (EELS): electron energy-loss near-edge structure (ELNES), elemental analysis, analysis of the chemical bond • Energy-filtering transmission electron microscopy (EFTEM): elemental maps, maps of the chemical bond • Energy-dispersive X-ray spectroscopy (EDXS): X-ray spectra, elemental analysis, principles of X-ray detectors • Practical aspects: methods of sample preparation, media for image acquisition, investigation of samples that are sensitive to the high-energetic electron beam (Minimum Dose Exposure) Exercise Electron Microscopy • Principles of electron-optical imaging • Principles of electron diffraction • Principles of elemental analysis • Quantitative evaluation of electron diffraction patterns • Quantitative evaluation of phase contrast micrographs • Contrast simulations (multislice and Bloch wave methods) General content: • Evaluation of experimental data and suitable scientific presentation of results derived therefrom. Critical evaluation and interpretation.
3	Mode of teaching ◎ ◎ ◉ ◎ ◎ Lecture Electron Microscopy (2 semester hours) ◎ ◎ ◉ ◎ ◎ Exercise Electron Microscopy (1 semester hour)
4a	Participation requirements None
4b	Recommended prior knowledge Basic knowledge of computing; basic knowledge of quantum mechanics

5	**Requirements for award of credit points**
	Coursework: None
	Assessment: Oral examination 30 minutes
6	**Literature** R. Brydson, Aberration-corrected analytical transmission electron microscopy, Wiley (2011) J.I. Goldstein, Scanning electron microscopy and X-ray microanalysis, 3rd Ed., Kluwer Acad./Plenum Publ., New York (2003) L. Reimer, Scanning electron microscopy: physics of image formation and microanalysis, 2nd Ed., Springer, Berlin (1998) D. Shindo, T. Oikawa, Analytical electron microscopy for materials science, Springer (2002) D. Shindo, K. Hiraga, High-resolution electron microscopy for materials science, Springer (2002) N. Tanaka, Scanning transmission electron microscopy of nanomaterials, Imperial College Press (2015) In addition, current publications on the topics are used (no current books cover all topics).
7	**Further information** **Lecturer(s):** Feldhoff
8	**Organisational unit** Faculty of Natural Sciences, Institute of Physical Chemistry and Electrochemistry, Chemistry Teaching Unit; http://www.pci.uni-hannover.de/
9	**Person responsible for module** Feldhoff

◎ ◎ ◎ ◉ ◎ **Elementorganische Chemie / Organoelement Chemistry**

Module title Organoelement Chemistry		**Module code**
Degree programme MSc Chemistry		**Module type** Required elective module
Credit points 8	**Module availability** Winter semester	**Language** German
Area of expertise None	**Recommended semester** 3rd semester	**Module duration** 1 semester
Student workload		
240 hours	90 contact hours	150 h independent study
Further use of module None		

1	**Learning objectives** **Aims** Provide advanced skills and a deeper and broader understanding of organoelement chemistry in theory and practice (for advanced master's students). **The module shall provide the students with the following specialised and key knowledge and skills:** **On successful completion of the module, students are able to** 1. explain the diversity and the reactive similarities of organosilicon and organotin chemistry and use them in synthesis as key transformations. 2. comprehensively describe the diversity of organophosphorus chemistry and use it as a key reaction in synthesis. 3. comprehensively describe the diversity of organic sulphur chemistry and use it as a key reaction in synthesis. 4. comprehensively describe the diversity of organic halogen chemistry and use it as a key reaction in synthesis. 5. use the concepts of hypervalence and stereoelectronic effects to describe the mechanisms of organic reactions. 6. carry out elemental organic reactions and describe the products from a structure analytical perspective.
2	**Module content** **Subject-specific content:** **Lecture Organoelement Chemistry** • Introduction (general overview of oxidation levels and reactivity, hypervalence, non-organometallic properties) • Silicon and tin organic building blocks (allyl, vinyl, allenyl, acylsilanes / stannanes) and their chemistry (carbanion, carbocation and radical chemistry)

	• Organic phosphorus chemistry • Sulphur and selenium organic building blocks (thioethers, sulphoxides, sulphones, isothiocyanates, thiocarbonyl compounds, thiiranes and others) and their chemistry (carbanion, carbocation and radical chemistry) • Chemistry of halogens with a focus on fluorine and iodine organic chemistry (fluorination, oxidation levels, group transfer reactions, hypervalence, radicals); comparison to organometallic chemistry. • Selected syntheses using elemental organic reactions as key steps. **Exercise Organoelement Chemistry:** Students independently tackle and then discuss exercises accompanying the element organic chemistry lectures. The exercises deal with synthesis sequences and related analytical aspects (NMR, MS, IR spectra, EA). The exercises can be solved using the knowledge on syntheses imparted in the lecture and by interpreting the analytical data. **Laboratory exercise Organoelement Chemistry:** The practical laboratory work is based on research-related experiments and teaches students how to solve problems occurring in element organic chemistry. Students acquire this knowledge by carrying out multi-stage syntheses. **General content:** • Independent development of syntheses.
3	**Mode of teaching** ◎ ◎ ◎ ◎ ◉ Lecture Organoelement Chemistry (2 semester hours) ◎ ◎ ◎ ◎ ◉ Exercise Organoelement Chemistry (1 semester hour) ◎ ◎ ◉ ◎ ◎ Laboratory exercise Organoelement Chemistry (4 semester hours)
4a	**Participation requirements** **Module assessment:** None
4b	**Recommended prior knowledge** Basic knowledge of analytical chemistry; advanced knowledge of chemistry
5	**Requirements for award of credit points** **Coursework:** Laboratory exercise Organoelement Chemistry **Assessment:** Written examination 120 minutes or oral examination 30 minutes
6	**Literature** Review articles from Accounts Chemical Research, Angewandte Chemie, Chemical Reviews, Chemical Society Reviews, as well as current primary literature from international journals
7	**Further information** **Lecturer(s):** Kirschning, Dräger
8	**Organisational unit** Faculty of Natural Sciences, Institute of Organic Chemistry, Chemistry Teaching Unit; http://www.oci.uni-hannover.de

9	**Person responsible for module** Kirschning

◎ ◎ ◎ ◎ ◎ **Festkörperbildung: Mechanismen, Analytik, Anwendungen / Formation of solids: Mechanisms, analytics, applications**

<table>
<tr><td colspan="3">Module title Formation of solids: Mechanisms, analytics, applications</td><td>Module code</td></tr>
<tr><td colspan="3">Degree programme MSc Chemistry</td><td>Module type Required elective module</td></tr>
<tr><td>Credit points 4</td><td colspan="2">Module availability Winter semester or summer semester</td><td>Language German/English</td></tr>
<tr><td>Area of expertise None</td><td colspan="2">Recommended semester 1st, 2nd, 3rd semester</td><td>Module duration 1 semester</td></tr>
<tr><td colspan="4">Student workload</td></tr>
<tr><td colspan="2">120 hours</td><td>42 contact hours</td><td>78 h independent study</td></tr>
<tr><td colspan="4">Further use of module
MSc Nanotechnology</td></tr>
</table>

1	**Learning objectives** **Aims** The formation of solids from their dissolved chemical constituents is a fundamental step, in which first structure and morphology evolve. Thus, the understanding of the atomic/molecular mechanisms of the underlying processes is imperative, e.g., for designing target-oriented materials syntheses. The aim of the module is to convey an extended understanding of different theories of nucleation, growth and crystallization, their application, as well as of the methods of their experimental analysis. Here, the focus lies on aqueous systems. **The module shall provide the students with the following specialised and key knowledge and skills:** **On successful completion of the module, students are able to** 1. reproduce, explain and apply the concepts and technical contents of the module „Formation of solids: Mechanisms, analytics, applications". 2. interpret experimental observations from the perspective of different existing theories and to exploit their respective explanatory and predictive powers. 3. understand which factors –from the use of additives to the role of relevant physical chemical parameters– allow influencing the processes of the formation of solids. 4. capture the limitations of the different theories and to identify open questions. 5. develop own scientific ideas in the fields dealing with the exploration of the formation of solids.
2	**Module content** **Subject-specific module contents:** **Lecture** • Introduction to concepts and basics • Theoretical background of nucleation processes: Classical Nucleation Theory, 2-step Nucleation, Pre-Nucleation Cluster Pathway • Possibilities and factors for influencing nucleation processes within the scope of the discussed theories: Heterogeneous and additive-controlled nucleation

<table>
<tr><td></td><td>

- Special analytics for exploring the early stages of the formation of solids
- Overview of the state-of-the-art for selected model systems: Examples of nucleation mechanisms
- Theoretical background of crystal growth: Classical and non-classical crystallization, oriented attachment, additive-controlled crystallization, mesocrystals, classical and non-classical morphosynthesis
- Formation of glasses and gels
- Overview of the state-of-the-art for selected model systems: Examples of crystallization mechanisms
- Industrial applications: growing single crystals, mass crystallization, particle synthesis
- Methods for shaping solids: thin films and heterogenous constructs

Seminar

- Presentation and analysis of developments in the field of the formation of solids based on current and classical scientific papers and publications

General content

- Critical reading of English original literature (scientific papers)

</td></tr>
<tr><td>3</td><td>

Mode of teaching
◎ ◎ ◉ ◎ ◎ Lecture Formation of solids: Mechanisms, analytics, applications (2 semester hours)
◎ ◎ ◉ ◎ ◎ Seminar Formation of solids: Mechanisms, analytics, applications (1 semester hour)

</td></tr>
<tr><td>4a</td><td>

Participation requirements

Module assessment: None

</td></tr>
<tr><td>4b</td><td>

Recommendated prior knowledge
Advanced knowledge of inorganic, analytical and physical chemistry

</td></tr>
<tr><td rowspan="3">5</td><td>Requirements for award of credit points</td></tr>
<tr><td>Coursework: none</td></tr>
<tr><td>Assessment: Written examination 120 minutes or oral examination 30 minutes</td></tr>
<tr><td>6</td><td>

Literature
D. Kashchiev, Nucleation – Basic Theory with Applications, Butterworth-Heinemann, Oxford, 2000; ISBN 07506 4682 9
J. W. Mullin, Crystallization, Butterworth-Heinemann, Oxford, 2001; ISBN 9780750648332
H. Cölfen, M. Antonietti, Mesocrystals and Nonclassical Crystallization, Wiley, Chichester, 2008; ISBN 978-0-470-02981-7
A. E. S. Van Driessche, M. Kellermeier, L. G. Benning, D. Gebauer; Eds. New Perspectives on Mineral Nucleation and Growth, Springer, Cham, 2017; ISBN 978-3-319-45667-6
Further literature will be announced in the lecture.

</td></tr>
<tr><td>7</td><td>

Further information

Lecturer(s): Gebauer, Behrens

</td></tr>
</table>

8	**Organisational unit** Faculty of Natural Sciences, Institute of Inorganic Chemistry, Chemistry Teaching Unit; http://www.aci.uni-hannover.de
9	**Person responsible for module** Gebauer

◎ ◎ ◎ ◉ ◎ **Funktionale Koordinationsverbindungen der Übergangselemente / Functional Coordination Complexes of Transition Elements**

<table>
<tr><td colspan="2">Module title Functional Coordination Complexes of Transition Elements</td><td>Module code</td></tr>
<tr><td colspan="2">Degree programme MSc Chemistry</td><td>Module type Required elective module</td></tr>
<tr><td>Credit points 8</td><td>Module availability Winter semester</td><td>Language German</td></tr>
<tr><td>Area of expertise None</td><td>Recommended semester 3rd semester</td><td>Module duration
1 semester</td></tr>
<tr><td colspan="3">Student workload</td></tr>
<tr><td>240 hours</td><td>105 contact hours</td><td>135 h independent study</td></tr>
<tr><td colspan="3">Further use of module
None</td></tr>
</table>

1	**Learning objectives** **Aims** Provide in-depth knowledge on functional coordination complexes of transition elements in theory and practice (for advanced master's students) **The module shall provide the students with the following specialised and key knowledge and skills:** **On successful completion of the module, students are able to** 1. identify, name and synthesise coordination compounds (complexes) of Werner-type transition elements. 2. describe and explain the in-depth knowledge acquired on selected areas of coordination chemistry. 3. identify, assess and further develop special physical and chemical properties of the coordination compounds. 4. identify coordination compounds with properties that can be traced back to open electronic d-shells and classify them in a scientific context. 5. classify special analytical methods for the characterisation of the transition element compounds. 6. use the knowledge acquired on the variety of molecular, supramolecular and polymeric coordination compounds to recognise the manifold possible applications as innovative materials which result from their properties. 7. use special spectroscopic (Mössbauer, UV/Vis) and magnetic (SQUID) methods for the characterisation of transition element compounds. 8. independently transfer methods for the synthesis of molecular and polymeric coordination compounds discussed by way of current examples to other systems and thus produce new compounds. 9. understand and classify the structure-property relationships of complexes

2	**Module content** **Subject-specific content:** **Lecture Functional Coordination Complexes** The lecture covers Werner-type multinuclear and supramolecular complexes (e.g. rotaxanes, catenanes, molecular lattices, metallacycles and cages) as well as crystalline and amorphous coordination polymers of transition elements. Modern methods for the synthesis of supramolecular complexes (e.g. self-assembly, template synthesis) and coordination polymers (crystal engineering, reticular synthesis) are presented. The magnetic and optical properties are discussed in detail. Key topics are single molecule magnets, complexes with cooperative magnetic properties such as ferro- and antiferromagnetism and switchable bistable spin crossover complexes. The concept of molecular machines is introduced in relation to supramolecular coordination compounds. The special properties of porous polymers (organometallic framework compounds) are discussed. This requires an introduction to the field of complex crystalline compounds from a geometric and topological point of view (net-based structural chemistry). Furthermore, the completely new field of nanoscale coordination polymers is discussed in more detail. Typical methods for the characterisation of coordination compounds with open d-shell are discussed: Mössbauer spectroscopy, ESR spectroscopy, UV/Vis spectroscopy, methods for measuring magnetic properties (SQUID). **Laboratory exercise Functional Coordination Complexes** Students produce both molecular and polymeric coordination compounds. The examples come from the fields of switchable spin crossover complexes and porous crystalline coordination polymers. In addition to an initial standard characterisation, Mössbauer and UV/Vis spectra of the compounds are recorded and evaluated. Furthermore, the magnetic susceptibility as a function of temperature is measured on a SQUID. The crystal structure of a coordination polymer is determined and described after intensity measurements on an X-ray single crystal diffractometer. **General content:** • Special scientific teaching, working and presentation techniques: Students learn to familiarise themselves with special topics, acquire knowledge thereof, use this knowledge and present it in a suitable written form. • Students learn to derive rules systematically from the facts and to recognise their limits of validity. • Students learn to link theory and practice, to interpret, verify and extrapolate. • Students learn to identify and apply complex problem-solving methods using the Western way of abstraction in comparison to the holistic Eastern approach.
3	**Mode of teaching** ◎ ◎ ◎ ◎ ◉ Lecture Functional Coordination Complexes (2 semester hours) ◎ ◎ ◉ ◎ ◎ Laboratory exercise Functional Coordination Complexes (6 semester hours)
4a	**Participation requirements** **Module assessment:** None
4b	**Recommended prior knowledge** Advanced knowledge of inorganic, organic and physical chemistry

5	**Requirements for award of credit points**
	Coursework: Laboratory exercise Functional Coordination Complexes
	Assessment: Written examination 120 minutes or oral examination 30 minutes
6	**Literature** **Lecture Functional Coordination Complexes** L. Gade, Koordinationschemie, Wiley-VCH, 1998 C. Janiak in E. Riedel (Ed.), Moderne Anorganische Chemie, de Gruyter, 2007 J. R. Gispert, Coordination Chemistry, Wiley-VCH, 2008 J. Huheey, E. Keiter, R. Keiter, u.a. Anorganische Chemie: Prinzipien von Struktur und Reaktivität, 5th Edition. 2014, de Gruyter, Berlin; Recent Reviews and Original Literature. **Experimental exercises Functional Coordination Complexes** Descriptions of the experiments and literature for further reading will be provided for the respective experiments.
7	**Further information** **Lecturer(s):** Renz, N.N.
8	**Organisational unit** Faculty of Natural Sciences, Institute of Inorganic Chemistry, Chemistry Teaching Unit; http://www.aci.uni-hannover.de
9	**Person responsible for module** Renz

◎ ◎ ◎ ◎ ◉ Funktionale Nanostrukturen / Functional Nanostructures

Module title Functional Nanostructures				**Module code**
Degree programme MSc Chemistry				**Module type** Required elective module
Credit points 4	**Module availability** Winter semester			**Language** German/English
Area of expertise None	**Recommended semester** 1st, 2nd, 3rd semester			**Module duration** 1 semester
Student workload				
120 hours		42 contact hours		78 h independent study
Further use of module MSc Nanotechnology				

1	**Learning objectives** **Aims** Provide a more in-depth understanding of the synthesis and properties of novel functional nanostructures (for advanced master's students). **The module shall provide the students with the following specialised and key knowledge and skills:** **On successful completion of the module, students are able to** 6. explain and apply the concepts and content of the Functional Nanostructures module. 7. perform detailed literature research (inc. books and scientific papers) on a research-oriented topic. 8. become acquainted with scientific topics by means of modern scientific (mainly English) specialist literature. 9. identify problems and limits of functional nanostructures. 10. exemplify and critically discuss scientific concepts. 11. give well-structured scientific talks.
2	**Module content** **Subject-specific content:** • Synthesis and characterisation methods of nanostructures • Structure-property relationships of nanostructures • Electronic properties of selected functional nanostructures • Magnetic properties of selected functional nanostructures • Plasmonic properties of selected functional nanostructures • Properties of single nanostructures vs. ensemble properties • Interparticle interactions • Typical systems which are discussed: colloidal nanoparticles, assemblies of nanoparticles, carbon nanotubes, graphene, ball milling, electrospinning, nanowires, use of nanoparticles in biomedicine, solar cells, screen technologies etc. • Novel synthesis strategies for nanostructures • Physical principles of complex nanostructures

	General content: Seminar Functional Nanostructures • Teaches the basic principles for preparing and giving talks • Fosters critical discussion of scientific issues • Trains students to accept and give constructive feedback to their peers • Enhances their knowledge of scientific English Exercise Functional Nanostructures • Students learn how to familiarise themselves with new scientific topics • Enhances their knowledge of scientific English
3	Mode of teaching ◎ ◎ ◎ ◎ ◉ Seminar Functional Nanostructures (2 semester hours) ◎ ◎ ◎ ◎ ◉ Exercise Functional Nanostructures (1 semester hour)
4a	Participation requirements **Module assessment:** None
4b	Recommended prior knowledge Advanced knowledge of physical chemistry or nanotechnology, good command of English
5	Requirements for award of credit points
	Coursework: Exercise Functional Nanostructures
	Assessment: Seminar Functional Nanostructures, oral presentation of their work
6	Literature Individually assigned and literature research in current scientific journals on the particular topic.
7	Further information **Lecturer(s):** Bigall
8	Organisational unit Faculty of Natural Sciences, Institute of Physical Chemistry and Electrochemistry, Chemistry Teaching Unit; http://www.pci.uni-hannover.de
9	Person responsible for module Bigall

<table>
<tr><td colspan="3">Module title Glycoscience</td><td>Module code</td></tr>
<tr><td colspan="3">Degree programme MSc Chemistry</td><td>Module type Required elective module</td></tr>
<tr><td>Credit points 4</td><td colspan="2">Module availability Winter semester or summer semester</td><td>Language German</td></tr>
<tr><td>Area of expertise None</td><td colspan="2">Recommended semester 1st, 2nd or 3rd semester</td><td>Module duration 1 semester</td></tr>
<tr><td colspan="4">Student workload</td></tr>
<tr><td>120 hours</td><td colspan="2">48 contact hours</td><td>72 h independent study</td></tr>
<tr><td colspan="4">Further use of module
None</td></tr>
</table>

1	**Learning objectives** **Aims** Provide a deeper and broader understanding of the chemistry and biology of carbohydrates and their uses (for advanced master's students). **The module shall provide the students with the following specialised and key knowledge and skills:** **On successful completion of the module, students are able to** 1. recognise relationships between the structure, conformation, stereochemistry and properties of carbohydrates. 2. explain important methods for the synthesis of certain glycosides and oligosaccharides. 3. recognise other compounds such as the glycoproteins and glycolipids and describe their occurrence, structures and biosynthesis. 4. assess the areas of application of the named compounds on the basis of their structural mechanisms. 5. use the properties of the carbohydrates to explain the close relationship between the molecular structure and the biological functions. 6. understand the importance of carbohydrates for biological systems and their possible medical applications. 7. use key terms to correctly document topics in carbohydrate chemistry and give oral presentations.
2	**Module content** **Subject-specific content:** **Lecture/ Exercise Glycoscience** • Carbohydrates (structures, stereochemistry, conformations) • Protective group strategies in carbohydrate chemistry • Glycosylation methods • Synthesis of selected oligosaccharides • Enzymatic glycosylations

	• Glycoproteins and glycolipids • Sialic acids • Biological functions • Blood group concepts • Vaccination concepts based on glycobiology **General content:**
3	**Mode of teaching** ◎ ◎ ◎ ◎ ◉ Lecture Glycoscience (2 semester hours) ◎ ◎ ◎ ◎ ◉ Exercise Glycoscience (1 semester hour)
4a	**Participation requirements** **Module assessment:** None
4b	**Recommended prior knowledge** Advanced knowledge of organic chemistry
5	**Requirements for award of credit points**
	Coursework:
	Assessment: Written examination 60 minutes or oral examination 30 minutes
6	**Literature** Announced during the course
7	**Further information** **Lecturer(s):** Dräger
8	**Organisational unit** Faculty of Natural Sciences, Institute of Organic Chemistry, Chemistry Teaching Unit; http://www.oci.uni-hannover.de
9	**Person responsible for module** Dräger

◎ ◎ ◎ ◎ ◉ **Heterocyclen / Heterocycles**

<table>
<tr><td colspan="3">Module title Heterocycles</td><td>Module code</td></tr>
<tr><td colspan="3">Degree programme MSc Chemistry</td><td>Module type Required elective module</td></tr>
<tr><td>Credit points 4</td><td colspan="2">Module availability Winter semester or summer semester</td><td>Language German</td></tr>
<tr><td>Area of expertise None</td><td colspan="2">Recommended semester 1st, 2nd or 3rd semester</td><td>Module duration 1 semester</td></tr>
<tr><td colspan="4">Student workload</td></tr>
<tr><td colspan="2">120 hours</td><td>45 contact hours</td><td>75 h independent study</td></tr>
<tr><td colspan="4">Further use of module
None</td></tr>
<tr><td>1</td><td colspan="3">Learning objectives

Aims
Provide a deeper and broader understanding of heterocycles and their applications (for master's students).

The module shall provide the students with the following specialised and key knowledge and skills:

On successful completion of the module, students are able to

1. design synthesis routes to heterocycles and heterocyclic substructures of complex organic molecules.
2. modify heterocycles based on knowledge of their chemical reactivity.
3. evaluate heterocycles in respect of their basicity, their physical properties and pharmaceutical activity.
4. classify general access routes for heterocycles and postulate mechanisms for related syntheses.</td></tr>
<tr><td>2</td><td colspan="3">Module content

Subject-specific content:
Lecture/ Exercise Heterocycles
• Aromatic heterocycles:
    o Synthesis routes to major heterocyclic classes, general strategies in heterocyclic chemistry
    o Hetero aromaticity and basicity
    o Reactivity and functionalisation reactions
    o Use as building blocks for total syntheses
• Biochemical mode of action of selected heterocycles

General content:</td></tr>
</table>

3	**Mode of teaching** ◎ ◎ ◎ ◎ ◉ Lecture Heterocycles (2 semester hours) ◎ ◎ ◎ ◎ ◉ Exercise Heterocycles (1 semester hour)
4a	**Participation requirements** **Module assessment:** None
4b	**Recommended prior knowledge** Advanced knowledge of chemistry
5	**Requirements for award of credit points** **Coursework:** None **Assessment:** Written examination 60 minutes or oral examination 30 minutes
6	**Literature** [1] J. A. Joule and K. Mills "Heterocyclic Chemistry" Fifth Edition, Blackwell Publishing 2009
7	**Further information** **Lecturer(s):** Brönstrup, Jürjens
8	**Organisational unit** Faculty of Natural Sciences, Institute of Organic Chemistry, Chemistry Teaching Unit; http://www.oci.uni-hannover.de
9	**Person responsible for module** Brönstrup

◎ ◎ ◎ ◎ ◉ Intermolekulare Wechselwirkung / Intermolecular Interaction

<table>
<tr><td colspan="3">Module title Intermolecular Interaction</td><td>Module code</td></tr>
<tr><td colspan="3">Degree programme MSc Chemistry</td><td>Module type Required elective module</td></tr>
<tr><td>Credit points 4</td><td colspan="2">Module availability Winter semester or summer semester</td><td>Language German</td></tr>
<tr><td>Area of expertise None</td><td colspan="2">Recommended semester 1st, 2nd or 3rd semester</td><td>Module duration 1 semester</td></tr>
<tr><td colspan="4">Student workload</td></tr>
<tr><td>120 hours</td><td colspan="2">42 contact hours</td><td>78 h independent study</td></tr>
<tr><td colspan="4">Further use of module
None</td></tr>
<tr><td>1</td><td colspan="3">Learning objectives

Aims
Provide a deeper and broader understanding of the quantum statistical description of intermolecular interactions and its application (for advanced master's students).

The module shall provide the students with the following specialised and key knowledge and skills:

On successful completion of the module, students are able to
1. understand the different types of intermolecular interactions on the physical level.
2. apply statistical thermodynamics to solve the intermolecular interactions.
3. understand scattering and virial expansions.
4. quantify solvation in electrolytes.
5. describe the aspects of fluctuations.</td></tr>
<tr><td>2</td><td colspan="3">Module content

Subject-specific content:
Lecture/ Exercise Intermolecular Interaction:
• Basics of electrodynamics and quantum theory
• Types of intermolecular interactions
• Thermodynamic perturbation theory
• Virial expansion
• Collision processes
• Virial coefficients
• Joule-Thomson coefficient
• Electrolytes
• Poisson-Boltzmann equation
• Correlation functions
• Debye-Hückel theory</td></tr>
</table>

	• Fluctuations **General content:**
	Mode of teaching ◎ ◎ ◎ ◎ ◉ Lecture Intermolecular Interaction (2 semester hours) ◎ ◎ ◎ ◎ ◉ Exercise Intermolecular Interaction (1 semester hour)
4a	**Participation requirements** **Module assessment:** None
4b	**Recommended prior knowledge** None
5	**Requirements for award of credit points** **Coursework:** Exercise Intermolecular Interaction **Assessment:** Oral examination 30 minutes
6	**Literature** Intermolecular and surface forces, J. Israelachvili, Academic Press, London L.D. Landau, E.M. Lifschitz, Statistische Physik, Verlag Harry German, Zurich K. Lucas, Angewandte Statistische Thermodynamik, Springer Berlin
7	**Further information** **Lecturer(s):** Becker
8	**Organisational unit** Faculty of Natural Sciences, Institute of Physical Chemistry and Electrochemistry, Chemistry Teaching Unit; http://www.pci.uni-hannover.de/
9	**Person responsible for module** Becker

◎ ◎ ◎ ◎ ◉ **Klassiker in der Naturstoffsynthese gestern und heute /**
Classics of Natural Product Synthesis Past and Present

<table>
<tr><td colspan="3">Module title Classics in Synthesis of Natural Products in the Past and at Present</td><td>Module code</td></tr>
<tr><td colspan="3">Degree programme MSc Chemistry</td><td>Module type Required elective module</td></tr>
<tr><td>Credit points 4</td><td colspan="2">Module availability Winter semester or summer semester</td><td>Language German / English</td></tr>
<tr><td>Area of expertise None</td><td colspan="2">Recommended semester 1st, 2nd, 3rd semester</td><td>Module duration 1 semester</td></tr>
<tr><td colspan="4">Student workload</td></tr>
<tr><td colspan="2">120 hours</td><td>45 contact hours</td><td>75 h independent study</td></tr>
<tr><td colspan="4">Further use of module
None</td></tr>
</table>

1	**Learning objectives** **Aims** To provide a deeper understanding of the synthesis of natural products in the course of time and in view of the modern-day demands placed on this discipline. **The module shall provide the students with the following specialised and key knowledge and skills:** **On successful completion of the module, students are able to** 1. describe, explain and apply the concepts and technical content of the Classics of Natural Product Synthesis Past and Present module. 2. conduct comprehensive literature research (including books and international journals) on a research-related topic. 3. familiarise themselves with new specialist subject areas using modern scientific (including English) specialist literature. 4. identify problems and limitations of modern-day natural product synthesis. 5. explain and critically discuss scientific concepts of modern natural product synthesis. 6. give well-structured scientific talks on modern natural product syntheses.
2	**Module content** **Subject-specific content:** **Subject-specific content of the Classics of Natural Product Synthesis Past and Present lecture course:** • Synthetic chemistry and total synthesis • Scope and limitations of organic syntheses • Brief outline of organic synthesis • Practical aspects of total synthesis • Important target molecules • Natural products as synthetic target compounds • Strategies for synthesis

	• Retrosynthetic analyses • Classics in the synthesis of natural products **Subject-specific and general content of the Classics of Natural Product Synthesis Past and Present seminar** • Independently prepare scientific presentations based on information on current natural substance syntheses contained in international journals • Learn the basic principles of preparing and giving a presentation • Students are encouraged to critically examine and take part in professional discussions of scientific topics • Practise giving constructive feedback • Acquire advanced technical English skills **Subject-specific content of the Classics of Natural Product Synthesis Past and Present exercise:** • Extend and consolidate the repertoire of synthesis steps (name reactions) and their application in synthesis of natural products and modern organic chemistry
3	**Mode of teaching** ◎ ◎ ◎ ◎ ◉ Lecture Classics of Natural Product Synthesis in the Past (1 semester hour) ◎ ◎ ◎ ◎ ◉ Seminar Classics of Natural Product Synthesis at Present (1 semester hour) ◎ ◎ ◎ ◎ ◉ Exercise Classics of Natural Product Synthesis Past and Present (1 semester hour)
4a	**Participation requirements** **Module assessment:** None
4b	**Recommended prior knowledge** Advanced knowledge of organic chemistry; English language skills
5	**Requirements for award of credit points** **Coursework:** Seminar Classics of Natural Product Synthesis at Present, oral presentation of their work **Assessment:** Written examination 60 minutes or oral examination 30 minutes
6	**Literature** K.C. Nicolaou, Classics in Total Synthesis I & II, Wiley-VCH; Gewert, J. A. u. a. Organic Synthesis Workbook, Wiley-VCH; C. Bittner u. a. Organic Synthesis Workbook II, Wiley-VCH as well as primary literature from international journals
7	**Further information** **Lecturer(s):** Cordes
8	**Organisational unit** Faculty of Natural Sciences, Institute of Organic Chemistry, Chemistry Teaching Unit; http://www.oci.uni-hannover.de
9	**Person responsible for module** Cordes

◎ ◎ ◎ ◉ ◎ **Kolloide und Nanoteilchen / Colloids and Nanoparticles**

<table>
<tr><td colspan="3">Module title Colloids and Nanoparticles</td><td>Module code</td></tr>
<tr><td colspan="3">Degree programme MSc Chemistry</td><td>Module type Required elective module</td></tr>
<tr><td>Credit points 4</td><td colspan="2">Module availability Winter semester</td><td>Language German/English</td></tr>
<tr><td>Area of expertise None</td><td colspan="2">Recommended semester 3rd semester</td><td>Module duration 1 semester</td></tr>
<tr><td colspan="4">Student workload</td></tr>
<tr><td>120 hours</td><td colspan="2">60 contact hours</td><td>60 h independent study</td></tr>
<tr><td colspan="4">Further use of module
None</td></tr>
</table>

1	**Learning objectives** **Aims** Provide advanced skills and a deeper and broader understanding of the physical and chemical principles of colloids, nanoparticles and their characterisation in theory and practice (for advanced master's students). **The module shall provide the students with the following specialised and key knowledge and skills:** **On successful completion of the module, students are able to** 1. recognise basic principles of colloid chemistry. 2. use techniques for the structuration of nanoparticles as the basis of their actions. 3. apply criteria they have learned to evaluate whether colloidal solutions are stable. 4. decide which chemical or physical methods should be applied when constructing a nanostructured unit (e.g. in nano- or microelectronics). 5. explain the special properties of specific colloidal solutions which have been discussed by way of example. 6. provide a detailed explanation of and apply some common methods for the characterisation of colloids and nanoparticles.
2	**Module content** **Subject-specific content:** **Lecture Colloids and Nanoparticles** The stabilisation of colloidal solutions is discussed; the DLVO theory for the stability and coagulation of particles is used to explain the effects of the most important static and electrostatic interactions. An important part is the stabilisation of surface active agents and the formation of micellar colloids. The synthesis, stabilisation and application potential of macro- and microemulsions is also discussed. The assembly of colloidal particles to 3D structures is explained using the example of latex particles for building inverse artificial opals. The use of such inverse opals as photonic crystals is briefly introduced. Terms such as electrochemical double layer and zeta potential are discussed. Starting from the basic methods for the preparation of nanoparticles in gas, liquid and solid

<table>
<tr><td></td><td>phases, techniques for the stabilisation and deposition of nanoparticles are dealt with.
Nanoparticles from the liquid phase can be attached to pre-treated surfaces of planar and porous solids by means of electrostatic interactions (different zeta potentials). By taking advantage of hydrophilic/hydrophobic interactions, surfaces of bulk materials can be decorated with nanoparticles by means of the Langmuir-Blodgett technique, for example. Chemical (covalent) bonding can also be employed for such decoration. A special route for nanoparticle assembly is the synthesis and concentration in micellar fluids as well as their in situ synthesis and stabilisation in porous solids.
For the manipulation and analysis of atomic surface structures, various scanning techniques are of great importance such as scanning tunnelling microscopy and atomic force microscopy. Deposition from gas phase (CVD, PVD) as well as laser and plasma based sputter techniques can be employed by taking advantage of the differences in surface energies of 1D and 2D nanostructures as surface layers according to the Volmer-Weber law. Anisotropic etching as well as positive and negative lithography techniques allow various structurations of layers of nanoparticles.

Laboratory exercise Colloids and Nanoparticles
The size distribution of nanoparticles in various colloids / suspensions of nanoparticles is determined by means of "Nanoparticle Tracking Analysis". In this context the theory of the diffusion of nanoparticles in solutions is also discussed (fluctuations, statistical thermodynamics treatment).
Cyclic voltammetry is used to investigate typical adsorption and desorption processes at electrodes. An introduction to voltammetry as an electrochemical standard characterisation method to describe electrode processes is given.
ZnO nanoparticles are synthesised in solution, and the growth of these particles (Ostwald ripening) is studied by means of UV/Vis spectroscopy. In this context students learn about approaches for describing crystal growth and the theory of light absorption by semiconductor nanoparticles.
Laser-Doppler anemometry is used to determine the zeta potential of colloidal nano- and microparticles made of silica. The particles are synthesised by means of Stöber synthesis and characterised according to their pH-dependent zeta potentials.
General content:
Critical analysis of current specialist literature to acquire a more in-depth understanding of the course content.
Critical evaluation of experimental results.</td></tr>
<tr><td>3</td><td>Mode of teaching
◎ ◎ ◎ ◎ ◉ Lecture Colloids and Nanoparticles (2 semester hours)
◎ ◎ ◉ ◎ ◎ Laboratory exercise Colloids and Nanoparticles (2 semester hours)</td></tr>
<tr><td>4a</td><td>Participation requirements

Module assessment: None</td></tr>
<tr><td>4b</td><td>Recommended prior knowledge
Advanced knowledge of physical chemistry</td></tr>
<tr><td rowspan="2">5</td><td>Requirements for award of credit points</td></tr>
<tr><td>Coursework: Laboratory exercise Colloids and Nanoparticles</td></tr>
</table>

	Assessment: Written examination 60 minutes or oral examination 30 minutes
6	**Literature** **Lecture Colloids and Nanoparticles** H.-D. Dörfler, Grenzflächen- und Kolloidchemie, VCH Verlag, 1994 C.N.R. Rao, A. Müller, A.K. Cheetham, The Chemistry of Nanomaterials, Wiley-VCH, 2004. R. J. Hunter, Foundations of Colloid Science, Oxford University Press, 2004 G. Brezinsky, H. Mügel, Grenzflächen und Kolloide, Spektrum Verlag, 1993, Bergmann-Schäfer, Vielteilchensysteme, Vol. 5, Walter de Gruyter, 1992. In addition, current publications on the topics are used (no current books cover all topics). **Laboratory exercise Colloids and Nanoparticles** The description of the experiments and literature for further reading will be provided for the respective experiments.
7	**Further information** **Lecturer(s):** Lecture: Bigall, Dorfs, Lauth Laboratory exercise: Bigall, Dorfs, Lauth
8	**Organisational unit** Faculty of Natural Sciences, Institute of Physical Chemistry and Electrochemistry, Chemistry Teaching Unit; http://www.pci.uni-hannover.de
9	**Person responsible for module** Bigall

◎ ◎ ◎ ◎ ◎ Medizinische Chemie II / Medicinal Chemistry II

<table>
<tr><td colspan="2">Module title Medicinal Chemistry II</td><td>Module code</td></tr>
<tr><td colspan="2">Degree programme MSc Chemistry</td><td>Module type Required elective module</td></tr>
<tr><td>Credit points 8</td><td>Module availability Winter semester</td><td>Language German</td></tr>
<tr><td>Area of expertise None</td><td>Recommended semester 3rd semester</td><td>Module duration
1 semester</td></tr>
<tr><td colspan="3">Student workload</td></tr>
<tr><td>240 hours</td><td>90 contact hours</td><td>150 h independent study</td></tr>
<tr><td colspan="3">Further use of module
None</td></tr>
</table>

1	**Learning objectives** **Aims** Provide advanced skills and a deeper and broader understanding of medicinal chemistry in theory and practice (for advanced master's students). **The module shall provide the students with the following specialised and key knowledge and skills:** **On successful completion of the module, students are able to** 1. understand the interplay between structural elements of organic molecules and physiological properties 2. evaluate the metabolic stability of organic molecules 3. evaluate methods of lead structure optimisation 4. develop and improve concepts for the optimisation of potential lead compound properties
2	**Module content** **Subject-specific content:** **Lecture/ Exercise/ Laboratory exercise Medicinal Chemistry II** • Modern methods of medicinal chemistry • Concepts of lead structure identification • Characteristics of target classes • Optimisation parameters, especially in relation to ADME (absorption, distribution, metabolisation, excretion) • Optimisation strategies • Case studies **General content:**

3	**Mode of teaching** ◎ ◎ ◎ ◎ ◉ Lecture Medicinal Chemistry II (2 semester hours) ◎ ◎ ◎ ◎ ◉ Exercise Medicinal Chemistry II (1 semester hour) ◎ ◎ ◉ ◎ ◎ Laboratory exercise Medicinal Chemistry II (3 semester hours)
4a	**Participation requirements** **Module assessment:** None
4b	**Recommended prior knowledge** Basic knowledge of computing; advanced knowledge of chemistry; have attended the Medicinal Chemistry I lectures
5	**Requirements for award of credit points**
	Coursework: Laboratory exercise Medicinal Chemistry II
	Assessment: Written examination 120 minutes or oral examination 30 minutes
6	**Literature** [1] G. Klebe, Wirkstoffdesign, 2nd edition, Spektrum Verlag, ISBN 978-3-8274-2046-6 [2] E. Stevens, Medicinal chemistry: the modern drug discovery process, Pearson, ISBN 978-0321892706 [3] R.B. Silverman, M.W. Holladay, The Organic Chemistry of Drug Design and Drug Action, 3rd edition, Academic Press, ISBN 978-0123820303 In addition, current publications on the topics are used (no current books cover all topics).
7	**Further information** **Lecturer(s):** Plettenburg, Jürjens
8	**Organisational unit** Faculty of Natural Sciences, Institute of Organic Chemistry, Chemistry Teaching Unit; http://www.oci.uni-hannover.de
9	**Person responsible for module** Plettenburg

◎ ◎ ◎ ◉ ◎ Metallorganische Chemie I / Organometallic Chemistry I

<table>
<tr><td colspan="2">Module title Organometallic Chemistry I</td><td>Module code</td></tr>
<tr><td colspan="2">Degree programme MSc Chemistry</td><td>Module type Required elective module</td></tr>
<tr><td>Credit points 8</td><td>Module availability Winter semester</td><td>Language German</td></tr>
<tr><td>Area of expertise None</td><td>Recommended semester 1st or 3rd semester</td><td>Module duration 1 semester</td></tr>
<tr><td colspan="3">Student workload</td></tr>
<tr><td>240 hours</td><td>98 contact hours</td><td>142 h independent study</td></tr>
<tr><td colspan="3">Further use of module
None</td></tr>
</table>

1	**Learning objectives** **Aims** Provide fundamental skills and an in-depth and broad understanding of organometallic chemistry in theory and practice (for advanced master's students). **The module shall provide the students with the following specialised and key knowledge and skills:** Knowledge of and the ability to apply the organometallic chemistry of main group and transition metals. **On successful completion of the module, students are able to** 1. describe the historical development of organometallic chemistry. 2. assess the possible dangers associated with organometallic compounds. 3. apply special working techniques of organometallic chemistry. 4. make use of the spectroscopic specialties of organometallic compounds. 5. prepare highly active metals and perform reactions with them. 6. describe the preparation of main group organometallic compounds. 7. describe the preparation of organometallic compounds of transition metals. 8. describe important metal-catalysed reactions. 9. perform syntheses and purification operations under exclusion of air. 10. describe important organometallic industrial processes. 11. solve special problems of organometallic syntheses.
2	**Module content** **Subject-specific content:** **Lecture Organometallic Chemistry I** • Structural principle of main group and transition metal organic compounds • Stereochemical and stereoelectronic aspects

	• Special working techniques of organometallic chemistry • Analysis of organometallic compounds • Preparation of the most important organometallic classes of compounds • Examples of important organometallic reactions (introduction) • Decomplexation of organic ligands • Reactions of organometallic compounds: nucleophilic and electrophilic attack, cyclisation • Principles of catalytic reactions • Special aspects **Exercise Organometallic Chemistry I** Students tackle exercises to gain a more in-depth knowledge of the material covered in the Organometallic Chemistry lectures. **Laboratory exercise Organometallic Chemistry** Laboratory course on fundamental aspects and selected applications of organometallic chemistry. **General content:**
3	**Mode of teaching** ◎ ◎ ◎ ◎ ● Lecture Organometallic Chemistry I (2 semester hours) ◎ ◎ ◎ ◎ ● Exercise Organometallic Chemistry I (1 semester hour) ◎ ◎ ● ◎ ◎ Laboratory exercise Organometallic Chemistry I (4 semester hours)
4a	**Participation requirements** **Module assessment:** None
4b	**Recommended prior knowledge** Advanced knowledge of organic and inorganic chemistry
5	**Requirements for award of credit points** **Coursework:** Laboratory exercise Organometallic Chemistry I **Assessment:** Written examination 120 minutes
6	**Literature** J. Hartwig, Organotransition Metal Chemistry, University Science Books, Sausalito, California 2010. C. Elschenbroich, Organometallchemie, 6th ed., Teubner, Stuttgart 2008. D. Astruc, Organometallic Chemistry and Catalysis, Springer, Berlin 2007.
7	**Further information** **Lecturer(s):** Butenschön
8	**Organisational unit** Faculty of Natural Sciences, Institute of Organic Chemistry, Chemistry Teaching Unit; http://www.oci.uni-hannover.de

9	**Person responsible for module** Butenschön

◎ ◎ ◎ ◎ ◉ **Metallorganische Chemie II / Organometallic Chemistry II**

Module title Organometallic Chemistry II			**Module code**
Degree programme MSc Chemistry			**Module type** Required elective module
Credit points 4	**Module availability** Summer semester		**Language** German
Area of expertise None	**Recommended semester** 2nd or 4th semester		**Module duration** 1 semester
Student workload			
120 hours	42 contact hours		78 h independent study
Further use of module None			

1	**Learning objectives** **Aims** Provide advanced skills and an in-depth and broad understanding of organometallic chemistry in theory and practice building on the organometallic chemistry I module (for advanced master's students). **The module shall provide the students with the following specialised and key knowledge and skills:** Advanced knowledge of and the ability to apply the organometallic chemistry of transition metals. **On successful completion of the module, students are able to** 1. describe the importance of metallacycles as intermediates in stoichiometric and catalytic organometallic reactions. 2. contextualise and apply specialised knowledge of [2+2+2] cyclisation chemistry. 3. contextualise and apply specialised knowledge of the chemistry of carbene complexes. 4. contextualise and apply specialised knowledge of transition metal catalysed reactions, including current developments.
2	**Module content** **Subject-specific content:** **Lecture Organometallic Chemistry** • Metallacycles in stoichiometric and catalytic reactions • [2+2+2] cyclisation • Reactions of carbene complexes • Catalytic reactions with transition metal complexes **Exercise Organometallic Chemistry II**

	The exercises deal with the content of the Organometallic Chemistry 2 lectures (synthesis, structure, reactivity, catalysis) in more detail. **General content:**
3	**Mode of teaching** ◎ ◎ ◎ ◎ ◉ Lecture Organometallic Chemistry II (2 semester hours) ◎ ◎ ◎ ◎ ◉ Exercise Organometallic Chemistry II (1 semester hour)
4a	**Participation requirements** **Module assessment:** None
4b	**Recommended prior knowledge** Knowledge of the content of the Organometallic Chemistry I module
5	**Requirements for award of credit points**
	Coursework: Exercise Organometallic Chemistry II
	Assessment: Written examination 60 minutes
6	**Literature** J. Hartwig, Organotransition Metal Chemistry, University Science Books, Sausalito, California 2010. C. Elschenbroich, Organometallchemie, 6th ed., Teubner, Stuttgart 2008. D. Astruc, Organometallic Chemistry and Catalysis, Springer, Berlin 2007.
7	**Further information** **Lecturer(s):** Butenschön
8	**Organisational unit** Faculty of Natural Sciences, Institute of Organic Chemistry, Chemistry Teaching Unit; http://www.oci.uni-hannover.de
9	**Person responsible for module** Butenschön

◎ ◎ ◎ ◎ ◉ Molekülspektroskopie / Molecular Spectroscopy

<table>
<tr><td colspan="3">Module title Molecular Spectroscopy</td><td>Module code</td></tr>
<tr><td colspan="3">Degree programme MSc Chemistry</td><td>Module type Required elective module</td></tr>
<tr><td>Credit points 4</td><td colspan="2">Module availability Winter semester or summer semester</td><td>Language German</td></tr>
<tr><td>Area of expertise None</td><td colspan="2">Recommended semester 1st, 2nd or 3rd semester</td><td>Module duration 1 semester</td></tr>
<tr><td colspan="4">Student workload</td></tr>
<tr><td>120 hours</td><td colspan="2">42 contact hours</td><td>78 h independent study</td></tr>
<tr><td colspan="4">Further use of module
None</td></tr>
<tr><td>1</td><td colspan="3">Learning objectives

Aims
Provide a deeper and broader understanding of high-resolution molecular spectroscopy and its applications (for advanced master's students).

The module shall provide the students with the following specialised and key knowledge and skills:

On successful completion of the module, students are able to

1. explain electric dipole transitions and their uses in molecular spectroscopy.
2. apply the techniques and application fields of quantum theory to the most important basic types of molecular spectra using di-atomic and poly-atomic molecules by way of example.
3. utilise numerical methods in the determination of initially stationary (time-independent) problems.
4. describe the general and specific selection rules of spectroscopic transitions and explain electronic states.
5. describe the experimental techniques used in spectroscopy.
6. present molecular spectroscopy topics in writing and verbally.
7. understand the interaction between molecules and electromagnetic radiation so as to be able to qualitatively classify and quantitatively describe line shapes (intensity, width).
8. describe and explain electronic effects with respect to transmission, diffraction and emission.
9. explain the use of the FT compared to the CW technique to enhance the sensitivity and improve the signal/noise ratio.
10. apply mathematical methods to physico-chemical tasks in molecular spectroscopy.
11. apply approximations to solve the Schrödinger equation.
12. derive the properties of molecules from energetic descriptions and electronic structures.</td></tr>
</table>

2	**Module content** **Subject-specific content:** **Lecture Molecular Spectroscopy** • Foundations, techniques, and applications (origin, principles) of quantum mechanics • Basic types of molecular spectra (rotational, vibrational excitation) • General and specific selection rules of spectroscopic transitions • Electronic states and related observations • Line shape (intensity, width) • Experimental techniques (CW, FT, transmission, diffraction, emission) • Characteristics of spectroscopy (coherence and laser spectroscopy) • Special aspects (high-resolution spectroscopy, density-matrix formalism etc.) **Exercise Molecular Spectroscopy** Students solve exercises to gain a more detailed understanding of the molecular spectroscopy topics covered in the lectures. Molecular spectroscopy relies on a deep understanding of the underpinning quantum mechanics, in order to understand and quantitatively describe the phenomena observed. The exercises therefore demonstrate • the principles of quantum mechanics (momentum and spatial co-ordinates, uncertainty) • the application of quantum mechanics (Schrödinger's wave mechanics) • the utilisation of numerical methods (Heisenberg's matrix mechanics) in the determination of initially stationary (time-independent) problems • the illustration of mathematical approximations and determination of their limits (Born-Oppenheimer approximation, perturbation theory) • spectral positions and shape of molecular dipole transitions • interaction of molecules with electromagnetic radiation: intensity of spectral lines, linewidth, spin statistics, selection rules, centrifugal distortion, anharmonicity, instationary (time-dependent) response to perturbations **General content:** • Application of physical and mathematical methods and techniques
3	**Mode of teaching** ◎ ◎ ◎ ◎ ● Lecture Molecular Spectroscopy (2 semester hours) ◎ ◎ ◎ ◎ ● Exercise Molecular Spectroscopy (1 semester hour)
4a	**Participation requirements** **Module assessment:** None
4b	**Recommended prior knowledge** Advanced knowledge of physical chemistry
5	**Requirements for award of credit points**
	Coursework: None
	Assessment: Written examination 60 minutes or oral examination 30 minutes

6	**Literature** P. F. Bernath, Spectra of Atoms and Molecules, 2nd ed., Oxford University Press, NY, 2005. J. I. Steinfeld, Molecules and Radiation, Dover, Mineola, 2005. J. M. Hollas, High Resolution Spectroscopy, 2nd ed., John Wiley & Sons, Chichester, 1998. General textbooks on physical chemistry.
7	**Further information** **Lecturer(s):** Grabow, Becker
8	**Organisational unit** Faculty of Natural Sciences, Institute of Physical Chemistry and Electrochemistry, Chemistry Teaching Unit; http://www.pci.uni-hannover.de
9	**Person responsible for module** Grabow

◎ ◎ ◎ ◉ ◎ **Molekülspektroskopie mit Laborübung / Molecular Spectroscopy with Laboratory Exercise**

Module title Molecular Spectroscopy with Laboratory Exercise			**Module code**
Degree programme MSc Chemistry			**Module type** Required elective module
Credit points 8	**Module availability** Winter semester or summer semester		**Language** German
Area of expertise None	**Recommended semester** 3rd semester		**Module duration** 1 semester
Student workload			
240 hours	98 contact hours		142 h independent study
Further use of module None			

1	**Learning objectives** **Aims:** Provide advanced skills and a deeper and broader understanding of high-resolution molecular spectroscopy in theory and practice (for advanced master's students). **The module shall provide the students with the following specialised and key knowledge and skills:** **On successful completion of the module, students are able to** 1. explain electric dipole transitions and their application in molecular spectroscopy. 2. apply the techniques and application fields of quantum theory to the basic types of molecular spectra using di-atomic and poly-atomic molecules by way of example. 3. utilise numerical methods in the determination of initially stationary (time-independent) problems. 4. describe the general and specific selection rules of spectroscopic transitions and explain electronic states. 5. describe the experimental techniques used in spectroscopy. 6. present molecular spectroscopy topics in writing and verbally. 7. understand the interaction between molecules and electromagnetic radiation so as to be able to qualitatively classify and quantitatively describe line shapes (intensity, width). 8. describe and explain electronic effects with respect to transmission, diffraction and emission. 9. explain the use of the FT compared to the CW technique to enhance the sensitivity and improve the signal/noise ratio. 10. apply mathematical methods to physico-chemical tasks in molecular spectroscopy. 11. apply approximations to solve the Schrödinger equation. 12. derive the properties of molecules from energetic descriptions and electronic structures. 13. understand and utilise the principles of the design and signal processing in spectroscopic instruments. 14. assess and solve the specific problems in high-resolution spectroscopy. 15. utilise their knowledge on the applications of spectroscopic techniques to practical

	chemical problems. 16. apply quantum mechanical calculation methods to solve tasks in molecular physics and describe them in a suitable written and oral form. 17. perform high-resolution spectroscopic experiments. 18. use spectroscopic methods to deal with a problem from molecular physics. 19. perform and analyse a complete literature search. 20. interpret measurements both qualitatively and quantitatively in order to critically evaluate the results. 21. participate in problem-oriented discussions with other students and scientists working in the field.
2	**Module content** **Subject-specific content:** **Lecture Molecular Spectroscopy** • Foundations, techniques, and applications (origin, principles) of quantum mechanics • Basic types of molecular spectra (rotational, vibrational excitation) • General and specific selection rules of spectroscopic transitions • Electronic states and related observations • Line shape (intensity, width) • Experimental techniques (CW, FT, transmission, diffraction, emission) • Characteristics of spectroscopy (coherence and laser spectroscopy) • Special aspects (high-resolution spectroscopy, density-matrix formalism etc.) **Exercise Molecular Spectroscopy** Students solve exercises to gain a more detailed understanding of the molecular spectroscopy topics covered in the lectures. Molecular spectroscopy relies on a deep understanding of the underpinning quantum mechanics, in order to understand and quantitatively describe the phenomena observed. The exercises therefore demonstrate • the principles of quantum mechanics (momentum and spatial co-ordinates, uncertainty) • the application of quantum mechanics (Schrödinger's wave mechanics) • the utilisation of numerical methods (Heisenberg's matrix mechanics) in the determination of initially stationary (time-independent) problems • the illustration of mathematical approximations and determination of their limits (Born-Oppenheimer approximation, perturbation theory) • spectral positions and shape of molecular dipole transitions • interaction of molecules with electromagnetic radiation: o intensity of spectral lines o line width o spin statistics o selection rules o centrifugal distortion o anharmonicity o instationary (time-dependent) response to perturbations **Laboratory exercise Molecular Spectroscopy** Foundations and selected applications of molecular spectroscopy. The most important theoretical content from the lectures and the exercises is put into practice and investigated in more detail in the laboratory by means of selected hands-on spectroscopic experiments.

	General content: • Applications of physical methods and techniques in chemistry. • Familiarisation with safety regulations and safety measures when using (invisible) coherent (laser) radiation, RF and high-voltage techniques. • Understand and operate digital and analog systems for data acquisition, measurement and control techniques, instrument automation.
3	**Mode of teaching** ◎ ◎ ◎ ◎ ◉ Lecture Molecular Spectroscopy (2 semester hours) ◎ ◎ ◎ ◎ ◉ Exercise Molecular Spectroscopy (1 semester hour) ◎ ◎ ◉ ◎ ◎ Laboratory exercise Molecular Spectroscopy (4 semester hours)
4a	**Participation requirements** **Module assessment:** None
4b	**Recommended prior knowledge** Advanced knowledge of physical chemistry
5	**Requirements for award of credit points** **Coursework:** Laboratory exercise Molecular Spectroscopy **Assessment:** Written examination 120 minutes or oral examination 30 minutes
6	**Literature** P. F. Bernath, Spectra of Atoms and Molecules, 2nd ed., Oxford University Press, NY, 2005. J. I. Steinfeld, Molecules and Radiation, Dover, Mineola, 2005. J. M. Hollas, High Resolution Spectroscopy, 2nd ed., John Wiley & Sons, Chichester, 1998. General textbooks on physical chemistry.
7	**Further information** **Lecturer(s):** Grabow, Becker
8	**Organisational unit** Faculty of Natural Sciences, Institute of Physical Chemistry and Electrochemistry, Chemistry Teaching Unit; http://www.pci.uni-hannover.de
9	**Person responsible for module** Grabow

◎ ◎ ◎ ◎ ◉ **Naturstoffsynthese für Fortgeschrittene / Synthesis of Natural Products for Advanced Students**

<table>
<tr><td colspan="3">Module title Synthesis of Natural Products for Advanced Students</td><td>Module code</td></tr>
<tr><td colspan="3">Degree programme MSc Chemistry</td><td>Module type Required elective module</td></tr>
<tr><td>Credit points 4</td><td colspan="2">Module availability Winter semester or summer semester</td><td>Language German</td></tr>
<tr><td>Area of expertise None</td><td colspan="2">Recommended semester 1st, 2nd or 3rd semester</td><td>Module duration 1 semester</td></tr>
<tr><td colspan="4">Student workload</td></tr>
<tr><td>120 hours</td><td colspan="2">42 contact hours</td><td>78 h independent study</td></tr>
<tr><td colspan="4">Further use of module
None</td></tr>
<tr><td>1</td><td colspan="3">Learning objectives

Aims
Provide a deeper and broader understanding of the synthesis of complex natural products (for advanced master’s students).

The module shall provide the students with the following specialised and key knowledge and skills:

On successful completion of the module, students are able to

1. use the knowledge of organic synthesis they have acquired to plan syntheses, understand syntheses and describe and assess syntheses.
2. work stringently while solving problems of current synthetic tasks.
3. use methods of literature research to obtain data.
4. independently use textbooks and reference literature to develop a greater understanding of synthetic interactions.
5. independently perform literature searches.
6. use their knowledge of syntheses to understand, assess and describe total syntheses.
7. gain an insight into reaction sequences in total syntheses.
8. independently use text books and reference literature for designing syntheses and assessing their practicability.
9. put forward their own proposals for the synthesis of complex natural products.</td></tr>
<tr><td>2</td><td colspan="3">Module content

Subject-specific content:
Lecture Synthesis of Natural Products for Advanced Students
The lecture covers the syntheses of complex natural products. All important classes such as polyketides, terpenes and alkaloids are covered. The lecture focuses on the specific strategies and concepts of the individual classes. New synthetic strategies such as photo-organo-catalysis are covered and put into context. The lecture is based on current total syntheses.

Exercise Synthesis of Natural Products for Advanced Students</td></tr>
</table>

	Independent problem-solving of current synthetic problems. More in-depth discussion of selected topics from the literature. **General content:** • General scientific working and presentation techniques: Students learn to quickly familiarise themselves with previously unknown topics and to independently gather and collate information on a well-defined subject, translate it into experimental work and present it in a suitable written form. On successful completion of the module, students are able to select and utilise suitable media for their presentation.
3	**Mode of teaching** ◎ ◎ ◎ ◎ ◉ Lecture Synthesis of Natural Products for Advanced Students (2 semester hours) ◎ ◎ ◎ ◎ ◉ Exercise Synthesis of Natural Products for Advanced Students (1 semester hour)
4a	**Participation requirements** **Module assessment:** None
4b	**Recommended prior knowledge** None
5	**Requirements for award of credit points**
	Coursework: None
	Assessment: Written examination 60 minutes or oral examination 30 minutes
6	**Literature** **Lecture/ exercises Synthesis of Natural Products for Advanced Students** Classics in Total Synthesis I-III, Wiley-VCH, K.C. Nicolaou Organic Synthesis: The Disconnection Approach, 2008, Stuart Warren, Paul Wyatt Enantioselective Chemical Synthesis: Methods, Logic, and Practice, Elias J. Corey, Laszlo Kurti
7	**Further information** **Lecturer(s):** Kalesse
8	**Organisational unit** Faculty of Natural Sciences, Institute of Organic Chemistry, Chemistry Teaching Unit; http://www.oci.uni-hannover.de
9	**Person responsible for module** Kalesse

◉ ◎ ◎ ◎ ◎ **NMR for Biopolymers**

<table>
<tr><td colspan="3">Module title NMR for Biopolymers</td><td>Module code</td></tr>
<tr><td colspan="3">Degree programme MSc Chemistry</td><td>Module type Required elective module</td></tr>
<tr><td>Credit points 8</td><td colspan="2">Module availability Winter semester</td><td>Language English</td></tr>
<tr><td>Area of expertise None</td><td colspan="2">Recommended semester 3rd semester</td><td>Module duration
1 semester</td></tr>
<tr><td colspan="4">Student workload</td></tr>
<tr><td>240 hours</td><td colspan="2">90 contact hours</td><td>150 h independent study</td></tr>
<tr><td colspan="4">Further use of module
None</td></tr>
</table>

1	**Learning objectives** **Aims:** Provide both theoretical and advanced practical skills in NMR spectroscopy and its application to biomolecules (for advanced master's students). **The module shall provide the students with the following specialised and key knowledge and skills:** **On successful completion of the module, students are able to** 1. explain multidimensional NMR experiments for biomolecules. 2. explain mechanisms of magnetisation transfers between nuclei. 3. interpret 3D spectra. 4. assign protein resonances (^{1}H, ^{13}C, ^{15}N). 5. measure structural parameters from NMR spectra. 6. explain the theory of relaxation. 7. explain the theoretical basis of NOEs, scalar and dipolar couplings. 8. calculate protein structures from NMR data. 9. detect and characterise interactions between proteins and small ligands, other proteins or nucleic acids by means of NMR.
2	**Module content** **Subject-specific content:** **Lecture/ Exercise NMR for Biopolymers** • 3D experiments • Pulse programs • Protein resonance assignment • Measurement of NOEs • Measurement of scalar and dipolar couplings • Qualitative and quantitative analysis of spectra

	• Relaxation • Structure calculation • Characterisation of intermolecular interactions • Application of NMR spectroscopy to drug design. **General content:** • Protein and nucleic acid structure • Structural biology • Intermolecular interactions
3	**Mode of teaching** ◉ ◎ ◎ ◎ ◎ Lecture NMR for Biopolymers (3 semester hours) ◉ ◎ ◎ ◎ ◎ Exercise NMR for Biopolymers (4 semester hours)
4a	**Participation requirements** **Module assessment:** None
4b	**Recommended prior knowledge** Basic knowledge of computing, advanced knowledge of chemistry, basic knowledge of NMR spectroscopy (including 2D experiments), applications of NMR spectroscopy in organic chemistry
5	**Requirements for award of credit points** **Coursework:** Exercise NMR for Biopolymers **Assessment:** Written examination 120 minutes or oral examination 30 minutes
6	**Literature** Protein NMR spectroscopy – Principles and Practice. Cavanagh, Fairbrother, Palmer, Rance, Skelton, Academic Press (Second Edition, 2007)
7	**Further information** **Lecturer(s):** Carlomagno
8	**Organisational unit** Faculty of Natural Sciences, Institute of Organic Chemistry, Chemistry Teaching Unit; http://www.oci.uni-hannover.de
9	**Person responsible for module** Carlomagno

◎ ◎ ◎ ◎ ◎ **Oberflächenchemie / Surface Chemistry**

<table>
<tr><td colspan="3">Module title Surface Chemistry</td><td>Module code</td></tr>
<tr><td colspan="3">Degree programme MSc Chemistry</td><td>Module type Required elective module</td></tr>
<tr><td>Credit points 4</td><td colspan="2">Module availability Winter semester or summer semester</td><td>Language English or German</td></tr>
<tr><td>Area of expertise None</td><td colspan="2">Recommended semester 1st, 2nd or 3rd semester</td><td>Module duration 1 semester</td></tr>
<tr><td colspan="4">Student workload</td></tr>
<tr><td colspan="2">120 hours</td><td>42 contact hours</td><td>78 h independent study</td></tr>
<tr><td colspan="4">Further use of module
None</td></tr>
<tr><td>1</td><td colspan="3">Learning objectives

Aims
Provide a deeper and broader understanding of surface chemistry and its applications (for advanced master's students).

The module shall provide the students with the following specialised and key knowledge and skills:

On successful completion of the module, students are able to
1. understand the physical-chemical properties of surfaces and establish relationships between the properties of surfaces and their functionality in heterogeneous catalysis
2. understand the basic principles of surface analysis and select the appropriate technique from a pool of surface analysis techniques.</td></tr>
<tr><td>2</td><td colspan="3">Module content

Subject-specific content:
Lecture/Exercise Surface Chemistry
Surfaces have electronic and structural properties that are different from the bulk properties of materials. These specific properties enable surfaces to adsorb atoms/molecules and to catalyse reactions. Numerous methods exist for the structural and chemical characterisation of surfaces; the most important ones are introduced in this course:
• photo-electron and Auger electron spectroscopy
• surface diffraction with electrons
• scanning tunnelling and atomic force microscopy
• vibrational spectroscopy
• ion scattering
• methods based on synchrotron radiation.
Surfaces play an important role in heterogeneous catalysis, i.e. in industrial catalysis and environmental catalysis, in electrochemistry including energy storage and energy conversion,</td></tr>
</table>

	and in nanotechnology. **General content:**
3	**Mode of teaching** ◎ ◎ ◉ ◎ ◎ Lecture Surface Chemistry (2 semester hours) ◎ ◎ ◉ ◎ ◎ Exercise Surface Chemistry (1 semester hour)
4a	**Participation requirements** **Module assessment:** None
4b	**Recommended prior knowledge** Advanced knowledge of physical chemistry
5	**Requirements for award of credit points**
	Coursework: None
	Assessment: Written examination 60 minutes or oral examination 30 minutes
6	**Literature** K. Christmann, Introduction to surface physical chemistry, Steinkopff/Springer. I. Chorkendorff, J. W. Niemantsverdriet, Concepts of modern catalysis and kinetics, Wiley-VCH. G. Ertl, J. Küppers, Low energy electrons and surface chemistry, Wiley-VCH.
7	**Further information** **Lecturer(s):** Imbihl
8	**Organisational unit** Faculty of Natural Sciences, Institute of Physical Chemistry and Electrochemistry, Chemistry Teaching Unit; http://www.pci.uni-hannover.de
9	**Person responsible for module** Imbihl

◎ ◎ ◎ ◉ ◎ Organische Massenspektrometrie / Organic Mass Spectrometry

Module title Organic Mass Spectrometry			**Module code**
Degree programme MSc Chemistry			**Module type** Required elective module
Credit points 4	**Module availability** Winter semester or summer semester		**Language** German
Area of expertise None	**Recommended semester** 1st, 2nd or 3rd semester		**Module duration** 1 semester
Student workload			
120 hours	48 contact hours		72 h independent study
Further use of module None			

1	**Learning objectives** **Aims:** Provide advanced skills and a deeper and broader understanding of mass spectrometry to elucidate the structure of various classes of natural products in theory and practice (for advanced master's students). **The module shall provide the students with the following specialised and key knowledge and skills:** **On successful completion of the module, students are able to** 1. gain information on the molecular structure of organic compounds using mass spectrometry which incorporates a suitable ionisation method. 2. select a suitable mass spectrometer for the molecule under investigation. 3. solve analytical problems with mass spectrometry and plan & perform measurements with the instruments. 4. predict which mass spectrometry experiments produce the best results for individual compound classes. 5. explain different mass spectrometry techniques, discuss them and apply them to solve problems. 6. perform literature studies on mass spectrometry topics and use the knowledge to solve their own research tasks. 7. place mass spectrometry problems into a scientific context. 8. use current scientific publications to work out the applications of mass spectrometry, structure the information, draw conclusions and present the results in a short scientific talk.
2	**Module content** **Subject-specific content:** • modern methods in mass spectrometry • modern ionisation methods

	• physical and technical knowledge of MS-instruments • coupling of MS with chromatographic units • MS/MS analysis • MS analysis of biomolecules **General content:** • General scientific literature research and presentation: The students learn to select a specialised topic from literature, to undertake an extensive study of this topic and to present the topic in a scientific talk.
3	**Mode of teaching** ◎ ◎ ◎ ◎ ◉ Lecture Organic Mass Spectrometry (1 semester hour) ◎ ◎ ◎ ◎ ◉ Seminar Organic Mass Spectrometry (2 semester hours) ◎ ◎ ◉ ◎ ◎ Laboratory exercise Organic Mass Spectrometry (1 semester hour)
4a	**Participation requirements** None
4b	**Recommended prior knowledge** Basic knowledge of mass spectrometry
5	**Requirements for award of credit points** **Coursework:** Seminar Organic Mass Spectrometry, oral presentation of their work; Laboratory exercise Organic Mass Spectrometry **Assessment:** Written examination 60 minutes or oral examination 30 minutes
6	**Literature** E. de Hoffmann, V. Stroobant, Mass Spectrometry – Principles and Applications, 2nd Edition, Wiley-VCH, ISBN 0-471-48566-7; J.R. Chapman, Practical Organic Mass Spectrometry – A Guide for Chemical and Biochemical Analysis, 2nd Edition, Wiley-VCH, ISBN 0-471-95831-X; current primary literature from international journals.
7	**Further information** **Lecturer(s):** Dräger, Kirschning
8	**Organisational unit** Faculty of Natural Sciences, Chemistry Teaching Unit
9	**Person responsible for module** Dräger

◎ ◎ ◎ ◎ ◉ Organische Syntheseplanung / Synthesis Planning in Organic Chemistry

Module title Synthesis Planning in Organic Chemistry			**Module code**
Degree programme MSc Chemistry			**Module type** Required elective module
Credit points 4	**Module availability** Winter semester or summer semester		**Language** German
Area of expertise None	**Recommended semester** 1st, 2nd or 3rd semester		**Module duration** 1 semester
Student workload			
120 hours	45 contact hours		75 h independent study
Further use of module None			

1	**Learning objectives** **Aims** Provide a deeper and broader understanding of synthesis planning in organic chemistry and its applications (for advanced master's students). **The module shall provide the students with the following specialised and key knowledge and skills:** **On successful completion of the module, students are able to** 1. perform a retrosynthetic analysis on molecules in order to deduce and identify crucial functional group distances as well as neighbouring group and transannular effects. 2. describe and explain the knowledge they have acquired on the chemistry of protective groups and the transformation of functional groups. 3. postulate their own retrosynthetic plans of molecules. 4. analyse and evaluate a synthesis of an unknown molecule on their own.
2	**Module content** **Subject-specific content:** **Lecture/ Exercise Synthesis planning in organic chemistry** • Basics of retrosynthesis (retrosynthetic cut, synthons, defunctionalisation and functional group transformation) • Analysis of functional group distances including neighbouring group effects and transannular reactions • Chemoselectivity and chemistry of protective groups • Chemistry of carbenium ions, carbanions and radicals • Kinetics and chemical control of cyclisation reactions • Construction of polycyclic compounds **General content:**

	• Basic understanding of synthesis planning in organic chemistry.
3	**Mode of teaching** ◎ ◎ ◎ ◎ ◉ Lecture Synthesis planning in organic chemistry (2 semester hours) ◎ ◎ ◎ ◎ ◉ Exercise Synthesis planning in organic chemistry (1 semester hour)
4a	**Participation requirements** **Module assessment:** None
4b	**Recommended prior knowledge** Basic knowledge of computing; advanced knowledge of chemistry
5	**Requirements for award of credit points**
	Coursework: Successfully complete the exercises
	Assessment: Written examination 60 minutes or oral examination 30 minutes
6	**Literature** [1] R. W. Hoffmann, Elements of Synthesis Planning, Springer Verlag, ISBN 978-3-540-79219-2 [2] S. Warren, P. Wyatt, Organic Synthesis –The Disconnection Approach, 2nd edition, Wiley, ISBN 978-0-470-71236-8 As well as current publications.
7	**Further information** **Lecturer(s):** Jürjens, Plettenburg
8	**Organisational unit** Faculty of Natural Sciences, Institute of Organic Chemistry, Chemistry Teaching Unit; http://www.oci.uni-hannover.de
9	**Person responsible for module** Plettenburg

◎ ◎ ◎ ◉ ◎ Polymere Materialien / Polymeric Materials

<table>
<tr><td colspan="3">Module title Polymeric Materials</td><td>Module code</td></tr>
<tr><td colspan="3">Degree programme MSc Chemistry</td><td>Module type Required elective module</td></tr>
<tr><td>Credit points 8</td><td colspan="2">Module availability Winter semester</td><td>Language German</td></tr>
<tr><td>Area of expertise None</td><td colspan="2">Recommended semester 3rd semester</td><td>Module duration
1 semester</td></tr>
<tr><td colspan="4">Student workload</td></tr>
<tr><td>240 hours</td><td colspan="2">90 contact hours</td><td>150 h independent study</td></tr>
<tr><td colspan="4">Further use of module
None</td></tr>
</table>

1	**Learning objectives** **Aims** Provide advanced skills and a deeper and broader understanding of polymeric materials in theory and practice (for advanced master's students). **The module shall provide the students with the following specialised and key knowledge and skills:** **On successful completion of the module, students are able to** 1. explain the physical-chemical properties of selected organic polymers in terms of their constitution, conformation and configuration, and apply this knowledge to predict properties from the structure-property relationships of polymers and polymer composites in the solid state (glass-transition, crystallisation and melting) and also the mechanical properties (visco-elasticity, rubber elasticity etc.). 2. describe and explain the deeper understanding of physical chemistry and the physics of polymers they have acquired. 3. understand fundamental synthesis methods and techniques used in step-growth and chain growth reactions with regard to the desired properties of polymer materials and apply them in practice. 4. discuss and explain polymerisation techniques such as polymerisation in the heterogeneous (emulsion and suspension polymerisation) and the homogeneous phase (solution polymerisation and mass polymerisation) in conjunction with appropriate polyreactions. 5. explain the functional principles and the preparation of polymeric nanocomposites. 6. perform chemical, physical and rheological characterisations of organic polymers and polymer composites. 7. explain special aspects of polymer analyses in comparison to the analyses of low molecular substances especially of polymers as solid materials and in solution. 8. analyse molar masses, molar mass distributions and monomer compositions, length of blocks, substitutions as well as degree of branching and crosslinking.

	9. discuss methods such as size exclusion chromatography, osmometry, viscosimetry, equilibrium swelling in relation to the performance and the desired information. 10. select and practically apply methods for the characterisation of thermal properties and chain mobility especially of the uncrosslinked rubbers and elastomers in comparison to thermoplastic materials like DSC, NMR-relaxation time, swelling or mechanical measurements like stress-strain properties.
2	**Module content** **Subject-specific content:** **Lecture Synthesis of Polymers and Polymeric Composites** • Physical-chemical properties of selected organic polymers in terms of their constitution, conformation and configuration • Prediction of properties from the structure-property relationships of polymers and polymer composites in the solid state (glass-transition, crystallisation and melting) and also the mechanical properties (visco-elasticity, rubber elasticity etc.). • Fundamental synthesis methods and techniques used in step-growth and chain growth reactions • Polymerisation techniques : polymerisation in the heterogeneous (emulsion and suspension polymerisation) and the homogeneous phase (solution polymerisation and mass polymerisation) • Functional principles and preparation of polymeric nanocomposites. **Lecture Polymer Analysis** • Polymer identification using thermal properties • Composition of polymeric materials according to their main components • Analyses of molar masses, molar mass distributions, monomer compositions, block length, substitutions, degree of branching and crosslinking • Analytical methods: size exclusion chromatography, osmometry, viscosimetry, equilibrium swelling, DSC, TGA, NMR-relaxation, stress-strain properties **Laboratory exercise Polymeric Materials** The following experiments are scheduled: • Synthesis of selected polymers (for example polystyrene, polyacrylates) using emulsion and solution polymerisation • Preparation of a rubber mixture and an elastomer using sulphur vulcanisation • Determination of molar mass by characterisation of the mean molar mass weight (Mw) and the mean molar mass number (Mn) by means of size exclusion permeation chromatography (SEC). • Characterisation of the thermal properties of polymers using differential scanning calorimetry (DSC). Determination of the melting points and glass transition temperatures of different polymers in particular. Additionally, the effect of the thermal history on melting points and melting enthalpies is measured. The measurements are used to estimate the size of crystallites in the polymer samples investigated. • Characterisation of the chain mobility of polymers/elastomers by means of relaxation time NMR. • Determination of the polymer composition by means of pyrolysis-GC-MS or IR-spectroscopy

	• Morphological characterisation of blends or nanocomposites using TEM **General content:** • Development of purposeful strategies and work processes
3	**Mode of teaching** ◎ ◎ ◎ ◎ ◉ Lecture Synthesis of Polymers and Polymeric Composites (2 semester hours) ◎ ◎ ◎ ◎ ◉ Lecture Polymer Analysis (2 semester hours) ◎ ◎ ◉ ◎ ◎ Laboratory exercise Polymeric Materials (2 semester hours)
4a	**Participation requirements** **Module assessment:** None
4b	**Recommended prior knowledge** Advanced knowledge of inorganic ,organic, physical and technical chemistry
5	**Requirements for award of credit points**
	Coursework: Laboratory exercise Polymeric Materials
	Assessment: Written examination 120 minutes or oral examination 30 minutes
6	**Literature** W. Keim, Kunststoffe, Synthese, Herstellungsverfahren, Apparaturen, Wiley-VCH Verlag, 2006 B. Tieke, Makromolekulare Chemie – Eine Einführung, Wiley-VCH Verlag, 2005 J. M. G. Cowie, Chemie und Physik der Synthetischen Polymere, Vieweg Verlag, 1991 M. D. Lechner, K. Gehrke, H. Nordmeier, Makromolekulare Chemie, Birkhäuser Verlag, 2003 D. Braun, H. Cherdon, H. Ritter, Praktikum der makromolekularen Stoffe, Wiley-VCH Verlag, 1999 H.-G. Elias, Makromoleküle – Physikalische Strukturen und Eigenschaften (Vols. 1 to 4), Wiley-VCH Verlag, 2001 H.-J. Endres, A. Siebert-Raths, Technische Biopolymere, Carl Hanser Verlag, 2009 H.-G. Elias, Makromoleküle – Volume 1 Grundlagen, Hüthig & Wepf Verlag, 1990 In addition, current publications on the topics are used (no current books cover all topics). **Lecture Polymer Analysis** W. F. Hemminger, H. K. Cammenga: Methoden der thermischen Analyse, Springer Verlag, Berlin, Heidelberg, 1989 Ullmanns Encyklopädie der technischen Chemie, Vol. 5, Analysen und Messverfahren, Verlag Chemie Weinheim, Ostromow: Analyse von Kautschuk und Elastomeren, Springer Verlag (1981) M. Hesse, H. Meier, B. Zeeh: Spektroskopische Methoden in der organischen Chemie, Thieme Verlag, Stuttgart New York, 1995 H. Naumer, W. Heller: Untersuchungsmethoden in der Chemie, Thieme Verlag, Stuttgart, 1996, p. 204 ff H. Günzler, H. Böck: IR-Spektroskopie, VCH-Verlag 1983 In addition, current publications on the topics are used (no current books cover all topics).

7	**Further information** **Lecturer(s):** Giese
8	**Organisational unit** Faculty of Natural Sciences, Institute of Inorganic Chemistry, Chemistry Teaching Unit; http://www.aci.uni-hannover.de, German Institute of Rubber Technology
9	**Person responsible for module** Giese

◎ ◎ ◎ ◎ ◎ **Praktische Probleme der Kernresonanzspektroskopie / Practical Problems of Nuclear Magnetic Resonance Spectroscopy**

<table>
<tr><td colspan="3">Module title Practical Problems of Nuclear Magnetic Resonance Spectroscopy</td><td>Module code</td></tr>
<tr><td colspan="3">Degree programme MSc Chemistry</td><td>Module type Required elective module</td></tr>
<tr><td>Credit points 4</td><td colspan="2">Module availability Winter semester and summer semester</td><td>Language German</td></tr>
<tr><td>Area of expertise None</td><td colspan="2">Recommended semester
2nd or 3rd semester</td><td>Module duration
1 semester</td></tr>
<tr><td colspan="4">Student workload</td></tr>
<tr><td colspan="2">120 hours</td><td>48 contact hours</td><td>72 h independent study</td></tr>
<tr><td colspan="4">Further use of module
None</td></tr>
</table>

1	**Learning objectives** **Aims** In-depth knowledge of different analytical methods with a focus on nuclear magnetic resonance and spectral analysis. **The module shall provide the students with the following specialised and key knowledge and skills:** **On successful completion of the module, students are able to** 1. evaluate theoretically different analytical methods and use them on the basis of their individual strengths. 2. find a suitable method to identify the structure of organic molecules. 3. analyse NMR spectra and identify the structures of complex organic molecules. 4. use theoretical knowledge of different analytical techniques to critically discuss results obtained and defend them in front of others. 5. perform literature research on an analytical problem. The results are presented in front of the course and discussed together.
2	**Module content** **Subject-specific content:** **Lecture Practical Problems of Nuclear Magnetic Resonance Spectroscopy** • Short introduction to the theoretical background of one dimensional and two dimensional NMR. • Discussion of the strengths and weaknesses of NMR compared to other analytical methods like IR or UV-spectroscopy, mass spectrometry and X-ray. • Methods to elucidate the structure of organic molecules which are based on J-couplings, such as COSY, TOCSY, HSQC, HMQC and HMBC. • Methods to elucidate the structure of organic molecules which are based on dipolar couplings, like NOESY and ROESY. • Methods to elucidate the structure of organic molecules which are rarely used by

	synthetic chemists, such as INADEQUATE or ADEQUATE. • Classical and quantum mechanical explanation of NMR spectra. **Exercise Practical Problems of Nuclear Magnetic Resonance Spectroscopy** • Independently tackle problems related to specific topics • Evaluate spectra of different organic molecules **Seminar Practical Problems of Nuclear Magnetic Resonance Spectroscopy** • Students give a short lecture on a topical theme from NMR spectroscopy and discuss it afterwards with the audience. Examples: heteronuclear NMR (phosphorus, boron, fluorine), heteronuclear couplings for structure elucidation, exchange processes in NMR, in-cell NMR, NMR in food screening. **General content:** Literature research, preparation of a short presentation, presentation in front of the course, discussion with the audience. As NMR lies at an interface between chemistry, biology and physics, topics from these fields can also be addressed.
3	**Mode of teaching** ◎ ◎ ◉ ◎ ◎ Lecture Practical Problems of Nuclear Magnetic Resonance Spectroscopy (1 semester hour) ◎ ◎ ◉ ◎ ◎ Seminar Practical Problems of Nuclear Magnetic Resonance Spectroscopy (1 semester hour) ◎ ◎ ◉ ◎ ◎ Exercise Practical Problems of Nuclear Magnetic Resonance Spectroscopy (2 semester hours)
4a	**Participation requirements** **Module assessment:** None
4b	**Recommended prior knowledge** None
5	**Requirements for award of credit points** None
	Coursework: Seminar Practical Problems of Nuclear Magnetic Resonance Spectroscopy, oral presentation of their work; Exercise Practical Problems of Nuclear Magnetic Resonance Spectroscopy
	Assessment: Written examination 60 minutes or oral examination 30 minutes
6	**Literature** Friebolin, Basic one- and two-dimensional NMR Spectroscopy S. Richards and J. Hollerton, Essential Practical NMR for Organic Chemistry, Wiley & Sons, ISBN 978-0-470-71092-0 Current primary literature.
7	**Further information** **Lecturer(s):** Müggenburg
8	**Organisational unit** Faculty of Natural Sciences, Chemistry Teaching Unit

9	**Person responsible for module** Müggenburg

◎ ◎ ◎ ◎ ◉ **Quantenchemie / Quantum Chemistry**

<table>
<tr><td colspan="2">Module title Quantum Chemistry</td><td>Module code</td></tr>
<tr><td colspan="2">Degree programme MSc Chemistry</td><td>Module type Required elective module</td></tr>
<tr><td>Credit points 4</td><td>Module availability Winter semester or summer semester</td><td>Language German</td></tr>
<tr><td>Area of expertise None</td><td>Recommended semester 1st, 2nd or 3rd semester</td><td>Module duration 1 semester</td></tr>
<tr><td colspan="3">Student workload</td></tr>
<tr><td>120 hours</td><td>42 contact hours</td><td>78 h independent study</td></tr>
<tr><td colspan="3">Further use of module
None</td></tr>
</table>

1	**Learning objectives** **Aims** Provide a deeper and broader understanding of quantum chemistry (for advanced master's students). **The module shall provide the students with the following specialised and key knowledge and skills:** **On successful completion of the module, students are able to** 1. model quantum mechanical energy expressions and derive the corresponding equations of motion. 2. understand existing energy expressions on the basis of their physical background. 3. form an energy expression, vary it under constraints and derive equations of motion. 4. understand the relationship between Hartree-Fock and Kohn-Sham theory. 5. understand classical Newton dynamics and its application to nuclear motion. 6. apply a first-principles molecular dynamics code which combines density functional theory and molecular dynamics.
2	**Module content** **Subject-specific content:** **Lecture Quantum Chemistry** Functional variation, orbital theory, Hartree-Fock equations, Kohn-Sham equations, density functionals, motion on potential energy surfaces, classical molecular dynamics, first-principles molecular dynamics, periodic boundary conditions, plane waves, application to surfaces and solids, for example. **Exercise Quantum Chemistry** File directory tree under Linux, elementary Linux commands, preparation of input files for an established first-principles molecular dynamics code, evaluation of the data.

	General content: • Mathematical methods (functional variation).
3	**Mode of teaching** ◎ ◎ ◎ ◎ ◉ Lecture Quantum Chemistry (2 semester hours) ◎ ◎ ◎ ◎ ◉ Exercise Quantum Chemistry (1 semester hour)
4a	**Participation requirements** **Module assessment:** None
4b	**Recommended prior knowledge** Basic knowledge of mathematics and physical chemistry
5	**Requirements for award of credit points**
	Coursework: Exercise Quantum Chemistry
	Assessment: Written examination 60 minutes or oral examination 30 minutes
6	**Literature** **Lecture Quantum Chemistry** Levine, Quantum Chemistry Parr u. Yang, Density Functional Theory for Atoms and Molecules Szabo u. Ostlund, Modern Quantum Chemistry Haile, Molecular Dynamics Simulation: Elementary Methods
7	**Further information** **Lecturer(s):** Frank
8	**Organisational unit** Faculty of Natural Sciences, Institute of Physical Chemistry and Electrochemistry, Chemistry Teaching Unit; https://www.pci.uni-hannover.de/
9	**Person responsible for module** Frank

◎ ◎ ◎ ◉ ◎ **Quantenchemie mit Laborübung /**
Quantum Chemistry with Laboratory Exercise

Module title Quantum Chemistry with Laboratory Exercise			**Module code**
Degree programme MSc Chemistry			**Module type** Required elective module
Credit points 8	**Module availability** Winter semester		**Language** German
Area of expertise None	**Recommended semester** 3rd semester		**Module duration** 1 semester
Student workload			
240 hours	98 contact hours		142 h independent study
Further use of module None			

1	**Learning objectives** **Aims** Provide advanced skills and a deeper and broader understanding of quantum chemistry in theory and practice (for advanced master's students). **The module shall provide the students with the following specialised and key knowledge and skills:** **On successful completion of the module, students are able to** 1. deal with differential equations and describe quantum theory with such equations. 2. form energy expressions using quantum mechanical approximation methods and derive equations of motion. 3. convert quantum mechanical concepts into a working code and apply it. 4. form quantum chemical energy expressions and perform a functional variation. 5. establish the relationship between Hartree-Fock and Kohn-Sham theory. 6. understand classical Newton dynamics and its application to nuclear motion. 7. transform quantum chemical approximations into a program. 8. write a molecular dynamics code. 9. apply a first-principles molecular dynamics code which combines density functional theory and molecular dynamics.
2	**Module content** **Subject-specific content:** **Lecture Quantum Chemistry** Functional variation, orbital theory, Hartree-Fock equations, Kohn-Sham equations, density functionals, motion on potential energy surfaces, classical molecular dynamics, first-principles molecular dynamics, periodic boundary conditions, plane waves, application to surfaces and solids, for example. **Laboratory exercise Computational Quantum Chemistry**

	File directory tree under Linux, elementary Linux commands, program structure with Fortran, elementary Fortran commands, programming formulae using Fortran, write two simple programs (Hartree-Fock program and molecular dynamics program). Prepare inputs for an established first-principles molecular dynamics code, evaluate the data. **General content:** • Mathematical methods (functional variation). • Ability to translate a set of equations into a program.
3	**Mode of teaching** ◎ ◎ ◎ ◎ ◉ Lecture Quantum Chemistry (2 semester hours) ◎ ◎ ◎ ◎ ◉ Exercise Quantum Chemistry (1 semester hour) ◎ ◎ ◉ ◎ ◎ Laboratory exercise Computational Quantum Chemistry (4 semester hours)
4a	**Participation requirements** **Module assessment:** None
4b	**Recommended prior knowledge** Basic knowledge of mathematics and physical chemistry
5	**Requirements for award of credit points** **Coursework:** Laboratory exercise Computational Quantum Chemistry **Assessment:** Written examination 120 minutes or oral examination 30 minutes
6	**Literature** **Lecture Quantum Chemistry** Levine, Quantum Chemistry Parr u. Yang, Density Functional Theory for Atoms and Molecules Szabo u. Ostlund, Modern Quantum Chemistry Haile, Molecular Dynamics Simulation: Elementary Methods **Laboratory exercise Computational Quantum Chemistry** Descriptions of the experiments will be provided for the respective experiments.
7	**Further information** **Lecturer(s):** Frank
8	**Organisational unit** Faculty of Natural Sciences, Institute of Physical Chemistry and Electrochemistry, Chemistry Teaching Unit; https://www.pci.uni-hannover.de/
9	**Person responsible for module** Frank

◎ ◎ ◎ ◉ ◎ **Radiochemie und Radioanalytik I / Radiochemistry and Radioanalytical Chemistry I**

<table>
<tr><td colspan="3">Module title Radiochemistry and Radioanalytical Chemistry I</td><td>Module code</td></tr>
<tr><td colspan="3">Degree programme MSc Chemistry</td><td>Module type Required elective module</td></tr>
<tr><td>Credit points 4</td><td colspan="2">Module availability Summer semester</td><td>Language German</td></tr>
<tr><td>Area of expertise None</td><td colspan="2">Recommended semester 2nd semester</td><td>Module duration 1 semester</td></tr>
<tr><td colspan="4">Student workload</td></tr>
<tr><td colspan="2">120 hours</td><td>40 contact hours</td><td>80 h independent study</td></tr>
<tr><td colspan="4">Further use of module
None</td></tr>
</table>

1	**Learning objectives** **Aims** Provide in-depth knowledge of ionising radiation, radioactivity, radiochemistry and radioanalytical chemistry in theory and practice (for advanced master's students). The module places special emphasis on the environmental aspects of the subject matter and the effect of ionising radiation on humans. **The module shall provide the students with the following specialised and key knowledge and skills:** **On successful completion of the module, students are able to** 1. describe and explain basic concepts of nuclear physics, radiochemistry and radioecology 2. characterise and detect ionising radiation. 3. understand the chart of nuclides and describe applications of isotopy in chemistry 4. explain basic concepts of radiation protection 5. describe the mode of operation of the most important radioanalytical and mass spectrometric methods in the analysis of radionuclides 6. follow and critically consider emotional contributions in the public discussion on nuclear issues 7. evaluate and assess analytical measurement results.
2	**Module content** **Subject-specific content:** **Lecture Fundamentals of Radioactivity and Radiation Protection** • Terminology and energies of nuclei, cross section, Schrödinger equation, Heisenberg uncertainty relation • Overview of radioactive decay types, introduction to the chart of nuclides, nuclear properties • Natural radioactivity: cosmogenic, primordial, radiogenic radionuclides, including the three decay series and equilibria; anthropogenic radioactivity • Determination of natural radioactivity

	• Binding energy: droplet model • Alpha decay • Beta decay • Shell model of the atomic nucleus • Gamma decay • Neutrons: detection and applications • Neutron-induced nuclear fission; reactors • Medical use of radionuclides **Laboratory exercise Radioanalytical Instrumentation and Metrology** • Phenomenology of radioactive decay • Interaction of radiation with matter, distance square law • Radiation measurement methods for alpha, beta, and gamma radiation • Measurement of short-lived daughters of the uranium decay series • Neutron activation • Dosimetry of radiation exposures • Measurement of natural radioactivity **General content:** • Evaluation of experimentally collected data and appropriate scientific presentation of experimental results.
3	**Mode of teaching** ◎ ◎ ◎ ◎ ◉ Lecture Fundamentals of Radioactivity and Radiation Protection (2 semester hours) ◎ ◎ ◉ ◎ ◎ Laboratory exercise Radioanalytical Instrumentation and Metrology (2 semester hours)
4a	**Participation requirements** None
4b	**Recommended prior knowledge** Interest in analytical and inorganic chemistry as well as physics
5	**Requirements for award of credit points** **Coursework:** Laboratory exercise Radioanalytical Instrumentation and Metrology **Assessment:** Oral examination 30 minutes
6	**Literature** J. Lehto, X. Hou, Chemistry and Analysis of Radionuclides, Wiley-VCH, 2011 J.-V. Kratz, K.H. Lieser, Nuclear and Radiochemistry, Vol. 1 & 2, Wiley-VCH, 2013 In addition, current publications on the topics are used (no current books cover all topics).
7	**Further information** **Lecturer(s):** Walther, Steinhauser

8	**Organisational unit** Faculty of Mathematics and Physics, Institute of Radioecology and Radiation Protection; http://www.irs.uni-hannover.de/
9	**Person responsible for module** Walther

◎ ◎ ◎ ◉ ◎ **Radiochemie und Radioanalytik II (mit Möglichkeit zum Fachkundeerwerb) / Radiochemistry and Radioanalytical Chemistry II (with Possibility to Gain *Expert Knowledge* of Radiation Protection)**

Module title Radiochemistry and Radioanalytical Chemistry II (with Possibility to Gain *Expert Knowledge* of Radiation Protection)			**Module code**
Degree programme MSc Chemistry			**Module type** Required elective module
Credit points 8	**Module availability** Winter semester		**Language** German/English
Area of expertise None	**Recommended semester** 3rd semester		**Module duration** 1 semester
Student workload			
240 hours		90 contact hours	150 h independent study
Further use of module None			

1	**Learning objectives** **Aims** Provide in-depth and broader knowledge on radiochemistry and radioanalytical chemistry in theory and practice (for advanced master's students). In this module, *Expert Knowledge* (Fachkunde) in radiation protection can be acquired, which is a prerequisite to be appointed as a radiation protection officer. All facilities/laboratories that handle radioactive substances above the exemption limit or operate X-ray systems are required to have a radiation protection officer. The module also focuses on the environmental aspects of the subject matter. The effect of ionising radiation on humans is also dealt with. **The module shall provide the students with the following specialised and key knowledge and skills:** **On successful completion of the module, students are able to** 1. analyse radionuclides 2. understand and apply radioanalytical measurement techniques 3. master the measuring principles of alpha, beta and gamma spectrometry 4. carry out radiochemical separations 5. describe chemical properties of natural and artificial radionuclides 6. critically observe the public discussion of the subject matter 7. evaluate and assess analytical measurement results
2	**Module content** **Subject-specific content:** **Lecture Radiation Protection and Radioecology** • Gain a deeper understanding of the basic concepts of nuclear physics, ionising radiation, radiochemistry and radioecology • Dosimetry

	• Natural radionuclides and their dose contributions • Exposure pathways • Biological radiation effects / history and radium therapy / dose – risk correlations • Epidemiological studies (LSS, Preston, Radon Wismut Cohort, KIKK) • Radiation protection ordinance (StrSchV) §47 releases from nuclear facilities • Non-ionising radiation • Radiation protection in aviation and space travel • Radiation protection law/tasks and duties of the radiation protection officer • Practice exercises for the *Expert Knowledge* examination **Lecture Chemistry and Physical Methods for the Analysis of Radionuclides** • Chemical aspects of nuclear reactions • Nuclear fission and production of radionuclides • Chemistry of selected natural and anthropogenic radionuclides • Radiometric measurement techniques (alpha, beta, gamma) • Neutron activation analysis • Chemical aspects in the analysis of radionuclides **Laboratory exercise Radioanalytical Chemistry (formerly Radiochemical Laboratory)** • Gamma spectrometry • Beta spectrometry (tritium analysis) • Radiochemical separation • Alpha spectrometry • Swipe test **General content:** • Applicability of specific (trace) analytical techniques and methods. Evaluation of experimentally collected data and appropriate scientific presentation of experimental results with a focus on the statistical relevance of the results. Critical evaluation and interpretation.
3	**Mode of teaching** ◎ ◎ ◎ ◎ ◉ Lecture Radiation Protection and Radioecology (2 semester hours) ◎ ◎ ◉ ◎ ◎ Lecture Chemistry and Physical Methods for the Analysis of Radionuclides (2 semester hours) ◎ ◎ ◉ ◎ ◎ Laboratory exercise Radioanalytical Chemistry (4 semester hours)
4a	**Participation requirements** **Module assessment and laboratory exercise:** Completed Radiochemistry and Radioanalytical Chemistry I module
4b	**Recommended prior knowledge** Interest in analytical and inorganic chemistry as well as physics
5	**Requirements for award of credit points**
	Coursework: Laboratory exercise Radioanalytical Chemistry
	Assessment: Oral examination 30 minutes

6	**Literature** J. Lehto, X. Hou, Chemistry and Analysis of Radionuclides, Wiley-VCH, 2011 J.-V. Kratz, K.H. Lieser, Nuclear and Radiochemistry, Vol. 1 & 2, Wiley-VCH, 2013 In addition, current publications on the topics are used (no current books cover all topics).
7	**Further information** **Lecturer(s):** Walther, Steinhauser
8	**Organisational unit** Faculty of Mathematics and Physics, Institute of Radioecology and Radiation Protection; http://www.irs.uni-hannover.de/
9	**Person responsible for module** Walther

◎ ◎ ◎ ◉ ◎ Reaktionsmechanismen /
Reaction Mechanisms

<table>
<tr><td colspan="2">Module title Reaction Mechanisms</td><td>Module code</td></tr>
<tr><td colspan="2">Degree programme MSc Chemistry</td><td>Module type Required elective module</td></tr>
<tr><td>Credit points 8</td><td>Module availability Winter semester or summer semester</td><td>Language German</td></tr>
<tr><td>Area of expertise None</td><td>Recommended semester 1st-3rd semester</td><td>Module duration 1 semester</td></tr>
<tr><td colspan="3">Student workload</td></tr>
<tr><td>240 hours</td><td>105 contact hours</td><td>135 h independent study</td></tr>
<tr><td colspan="3">Further use of module
None</td></tr>
</table>

1	**Learning objectives** **Aims** Students will gain further knowledge on the reaction mechanisms of syntheses of different natural product classes. Additionally, the concept of stereoelectronics will serve to provide them with a better understanding of reaction mechanisms (for advanced master's students). **The module shall provide the students with the following specialised and key knowledge and skills:** **On successful completion of the module, students are able to** 1. identify reaction mechanisms and use them for predicting transformations. 2. use the knowledge they have acquired to identify, describe and explain selected aspects of organic chemistry. 3. use reaction mechanisms in the context of stereocontrol. 4. use reactive intermediates and intermediate stages to predict chemical reactivity. 5. identify the reactivity of transition metal-mediated reactions (Pd, Fe, Ru, Rh, Cu, Ni, Au) and predict which products will result from these transformations. 6. apply the knowledge they have acquired to unknown substances and assess transformations correctly. 7. apply their knowledge of reactivities to the synthesis of complex natural products.
2	**Module content** **Subject-specific content:** **Lecture Reaction Mechanisms** Students are able to understand reaction mechanisms such as pericyclic ring closing reactions, additions, reactions involving transition metals, carben complexes. Students are able to use this knowledge to control stereochemistry. They will use the Baldwin rules to make predictions

	about ring closing reactions. Additionally, students will become familiar with orbital control and will be able to describe the interaction of different orbitals. Exercise Reaction Mechanisms The exercise offers students the opportunity to interact in scientific discussions of complex scientific topics. They will use their knowledge and the material covered in the lectures to start the process of independent problem-solving. Laboratory exercise Reaction Mechanisms Student s will learn how to predict the reactivity of selected natural products classes on the basis of their structures and by doing so learn about modern aspects of applied natural products and drug research. Students will be able to describe mechanisms of transition metal-mediated reactions such as cycloadditions and photochemical activated transformations. Students are able to perform the experiments carefully, safely and without risk within a specified time frame and in compliance with the occupational safety and laboratory regulations. They will gain a better understanding of how to handle air sensitive and flammable substances. General content: • Special techniques for presenting scientific results. • Learn how to arrive at systematic conclusions from the results obtained. • Learn how to combine theory and the results obtained and to interpret, verify and extrapolate them. • Students will learn to identify problem-solving strategies.
3	Mode of teaching ◎ ◎ ◎ ◎ ◉ Lecture Reaction Mechanisms (2 semester hours) ◎ ◎ ◎ ◎ ◉ Exercise Reaction Mechanisms (1 semester hour) ◎ ◎ ◉ ◎ ◎ Laboratory exercise Reaction Mechanisms (4 semester hours)
4a	Participation requirements **Module assessment:** None
4b	Recommended prior knowledge Advanced knowledge of inorganic, organic and physical chemistry
5	Requirements for award of credit points **Coursework:** Laboratory exercise Reaction Mechanisms **Assessment:** Written examination 120 minutes or oral examination 30 minutes
6	Literature Lecture und theoretical exercise Reaction Mechanisms [1] Clayden Greeves, Warren, Wothers, Organic Chemistry, Oxford University Press, ISBN 0198503466 [2] I. Fleming, Frontier Orbitals and Organic Chemical Reactions, John Wiley & Sons, ISBN 0471 018198; R.W. Hoffmann, Elemente der Syntheseplanung, Elsevier, ISBN-13: 978-3-8274-1725-1 Current papers from the literature. Laboratory exercise Reaction Mechanisms Descriptions of the experiments and literature for further reading will be provided for the respective experiments.

7	**Further information** **Lecturer(s):** Kalesse
8	**Organisational unit** Faculty of Natural Sciences, Institute of Organic Chemistry , Chemistry Teaching Unit; http://www.oci.uni-hannover.de
9	**Person responsible for module** Kalesse

◎ ◎ ◎ ◎ ◉ Reaktionsmechanismen für Fortgeschrittene /
Reaction Mechanisms for Advanced Students

<table>
<tr><td colspan="3">Module title Reaction Mechanisms for Advanced Students</td><td>Module code</td></tr>
<tr><td colspan="3">Degree programme MSc Chemistry</td><td>Module type Required elective module</td></tr>
<tr><td>Credit points 4</td><td colspan="2">Module availability Winter semester</td><td>Language German</td></tr>
<tr><td>Area of expertise None</td><td colspan="2">Recommended semester 3rd semester</td><td>Module duration 1 semester</td></tr>
<tr><td colspan="4">Student workload</td></tr>
<tr><td>120 hours</td><td colspan="2">42 contact hours</td><td>78 h independent study</td></tr>
<tr><td colspan="4">Further use of module</td></tr>
<tr><td>1</td><td colspan="3">Learning objectives

Aims
Provide a deeper and broader understanding of reaction mechanisms in organic chemistry (for advanced master’s students).

The module shall provide the students with the following specialised and key knowledge and skills:

On successful completion of the module, students are able to

1. use reaction mechanisms for assessing reactions and to understand and describe reactions.
2. use a stringent concept for proposing reaction mechanisms.
3. use methods of literature research to obtain data.
4. independently use textbooks and reference literature to develop a greater understanding of current reaction mechanisms.
5. independently perform literature searches.
6. use the knowledge they have acquired to understand reaction mechanisms, and to assess and describe them.
7. gain an understanding of combinations of established and new mechanisms in new transformations.
8. independently use text books and reference literature to develop proposals for unknown reaction mechanisms and evaluate their practicability.
9. develop independent proposals to unravel unknown reaction mechanisms.</td></tr>
<tr><td>2</td><td colspan="3">Module content

Subject-specific content:
Reaction Mechanisms for Advanced Students
The lectures will cover reaction mechanisms which are not covered in the basic course. These are for instance different applications of photochemistry, rearrangements, and modern metal</td></tr>
</table>

	organic chemistry. All important reaction mechanisms will be covered and used to develop concepts for stereoselectivity. **Exercise Reaction Mechanisms for Advanced Students** Students independently tackle exercises on selected topics. More in-depth discussion of selected topics from the literature. **General content:** • General scientific working and presentation techniques: Students learn to quickly familiarise themselves with previously unknown topics and to independently gather and collate information on a well-defined subject, translate it into experimental work, and present it in a suitable written form. On successful completion of the module, students are able to select and use suitable media for the presentation.
3	**Mode of teaching** ◎ ◎ ◎ ◎ ◉ Lecture Reaction Mechanisms for Advanced Students (2 semester hours) ◎ ◎ ◎ ◎ ◉ Exercise Reaction Mechanisms for Advanced Students (1 semester hour)
4a	**Participation requirements** **Module assessment:** None
4b	**Recommended prior knowledge** None
5	**Requirements for award of credit points** **Coursework:** None **Assessment:** Written examination 60 minutes or oral examination 30 minutes
6	**Literature** **Lecture / Exercise Reaction Mechanisms for Advanced Students** Reaktionsmechanismen, R. Brückner, Springer Organisch-Chemischer Denksport, R. Brückner, Vieweg Molecular Orbitals and Organic Chemical Reactions, I. Fleming, Wiley
7	**Further information** **Lecturer(s):** Kalesse
8	**Organisational unit** Faculty of Natural Sciences, Institute of Organic Chemistry, Chemistry Teaching Unit; http://www.oci.uni-hannover.de
9	**Person responsible for module** Kalesse

◉ ◎ ◎ ◎ ◎ **Self-Organisation in Chemistry**

<table>
<tr><td colspan="3">Module title Self-Organisation in Chemistry</td><td>Module code</td></tr>
<tr><td colspan="3">Degree programme MSc Chemistry</td><td>Module type Required elective module</td></tr>
<tr><td>Credit points 4</td><td colspan="2">Module availability Winter semester or summer semester</td><td>Language English/German</td></tr>
<tr><td>Area of expertise None</td><td colspan="2">Recommended semester 1st, 2nd or 3rd semester</td><td>Module duration 1 semester</td></tr>
<tr><td colspan="4">Student workload</td></tr>
<tr><td>120 hours</td><td colspan="2">42 contact hours</td><td>78 h independent study</td></tr>
<tr><td colspan="4">Further use of module
None</td></tr>
<tr><td>1</td><td colspan="3">Learning objectives

Aims
Provide a broader understanding of self-organisation in chemistry and biochemistry (advanced master's students).

The module shall provide the students with the following specialised and key knowledge and skills:

On successful completion of the module, students are able to

1. understand the basic mechanisms and the mathematical descriptions underlying the various forms of self-organisation in chemistry and biochemistry.</td></tr>
<tr><td>2</td><td colspan="3">Module content

Lecture/Exercise Self-Organisation in Chemistry
In chemical systems far from thermodynamic equilibrium, self-organisation may occur leading to structures ordered in space and/or time. Well-known examples are kinetic oscillations, chemical wave patterns and chaotic behaviour. After presenting the phenomenology, the basic mathematical tools which are required to understand such phenomena, i.e. stability theory and bifurcation analysis, are introduced. Bistable, excitable and oscillatory systems, Turing patterns (=stationary concentration patterns), the role of fluctuations, deterministic chaos and various routes from ordered behaviour to chaos are discussed.</td></tr>
<tr><td>3</td><td colspan="3">Mode of teaching
◉ ◎ ◎ ◎ ◎ Lecture Self-Organisation in Chemistry (2 semester hours)
◉ ◎ ◎ ◎ ◎ Exercise Self-Organisation in Chemistry (1 semester hour)</td></tr>
</table>

4a	**Participation requirements** **Module assessment:** None
4b	**Recommended prior knowledge** Advanced knowledge of physical chemistry
5	**Requirements for award of credit points**
	Coursework: None
	Assessment: Written examination 60 minutes or oral examination 30 minutes
6	**Literature** [1] A. S. Mikhailov, Foundations of Synergetics I, Springer, Berlin, 1994. [2] F. W. Schneider, A. F. Münster, Nichtlineare Dynamik in der Chemie, Spektrum Akademischer Verlag, Heidelberg 1996.
7	**Further information** **Lecturer(s):** Imbihl
8	**Organisational unit** Faculty of Natural Sciences, Institute of Physical Chemistry and Electrochemistry, Chemistry Teaching Unit; http://www.pci.uni-hannover.de
9	**Person responsible for module** Imbihl

◎ ◎ ◎ ◎ ◎ **Smart Materials: Funktion durch Stimulus-Materie Interaktionen / Smart Materials: Function through Matter-Stimulus Interactions**

<table>
<tr><td colspan="3">Module title Smart Materials: Function by Matter-Stimulus Interactions</td><td>Module code</td></tr>
<tr><td colspan="3">Degree programme MSc Chemistry</td><td>Module type Required elective module</td></tr>
<tr><td colspan="2">Credit points 4</td><td>Module availability Winter semester</td><td>Language German</td></tr>
<tr><td colspan="2">Area of expertise None</td><td>Recommended semester
1st to 3rd semester</td><td>Module duration
1 semester</td></tr>
<tr><td colspan="4">Student workload</td></tr>
<tr><td colspan="2">120 hours</td><td>42 contact hours</td><td>78 h independent study</td></tr>
<tr><td colspan="4">Further use of module
MSc Nanotechnology</td></tr>
<tr><td>1</td><td colspan="3">Learning objectives

Aims
The products of materials chemistry form the basis for a large number of technologies which either are already used on an everyday basis or may become important in the future. The key for these applications is how a material reacts to an external trigger (physical or chemical) by unleashing a certain functionality. The goal of the module is to provide advanced skills and a broader understanding of the connection between the reaction of materials to external stimuli and their resulting utilisation in important technologies (for advanced master's students).

The module shall provide the students with the following specialised and key knowledge and skills:

On successful completion of the module, students are able to

1. describe, explain and apply the concepts and content of the Smart Materials module.
2. comprehend why understanding the functional principles behind chemical materials is indispensable for the optimisation of the properties of those materials and their utilisation in the desired technology.
3. acquire an understanding of which secondary processes occur after the materials have been exposed to certain stimuli, and how to control them.</td></tr>
<tr><td>2</td><td colspan="3">Module content

Subject-specific content:
Lecture Smart Materials
• We analyse: which (complex) technologies are used in selected product examples; how these technologies are related to the unique functionality of designated chemical materials; how to alter and optimise the functionality. A distinction is made according to the stimulus which leads to the desired functionality.
• Light as a trigger: e.g. photodetectors; solar cells; photo-electrochemistry; transparent conducting electrodes; photonic materials; molecular switches.
• Electricity as a trigger: e.g. light emitting diodes (LEDs), electromobility – battery technology, electrodes and electrochemistry; super- and pseudocapacitors; materials</td></tr>
</table>

	for micro- and nanoelectronics. • Magnetic fields as a trigger: e.g. ferromagnets, ferrimagnets, antiferromagnets, spin valves, magnetic sensors. • Chemical triggers: e.g. self-organisation phenomena, surfactants, detergents; self-cleaning surfaces; chemical sensors; lambda-probe – solid-state electrolytes. • Heat as a trigger: e.g. thermoelectric materials; ferroelectric materials. • Force as a trigger: e.g. triboelectric generators, shape-memory systems. • Diseases as a trigger: e.g. nanomedicine; theranostics; drug delivery. **Seminar Smart Materials** Presentation and analysis of developments in the field of 'Smart Materials' on the basis of recent publications or new products/ technologies. **General content:** Information about the utilisation of the materials discussed in technologies and products (e.g. automobiles, smartphones, computers, medicine, etc.).
3	**Mode of teaching** ◎ ◎ ◉ ◎ ◎ Lecture Smart Materials (2 semester hours) ◎ ◎ ◉ ◎ ◎ Seminar Smart Materials (1 semester hour)
4a	**Participation requirements** **Module assessment:** None
4b	**Recommended prior knowledge** Advanced knowledge of chemistry.
5	**Requirements for award of credit points**
	Coursework: None
	Assessment: Written examination 120 minutes or oral examination 30 minutes
6	**Literature** S. O. Kasap, Optoelectronic and Photonics: Principles and Practices, Prentice Hall, 2001. J. D. Joannopoulos, S. G. Johnson, J. N. Winn, R. D. Meade and Editors, Photonic Crystals: Molding the Flow of Light (Second Edition), Princeton University Press, 2008. B. Viswanathan and M. A. Scibioh, Photoelectrochemistry: Principles and Practices, Narosa Publishing House, 2014. P. H. Rieger, Electrochemistry, Springer Netherlands, 1993. Y. G. Wang, Y. F. Song and Y. Y. Xia, Chemical Society Reviews, 2016, 45, 5925-5950. F.-G. Banica, Chemical Sensors and Biosensors: Fundamentals and Applications, Wiley, 2012. R. Crawford, E. Ivanova and Editors, Superhydrophobic Surfaces, Elsevier, 2015. G. Y. Chen, I. Roy, C. H. Yang and P. N. Prasad, Chemical Reviews, 2016, 116, 2826-2885. A. Filimon and Editor, Smart Materials: Integrated Design, Engineering Approaches, and Potential Applications, Apple Academic Press Inc., 2019. In addition, current publications on the topics are used (no current books cover all topics).

7	**Further information** **Lecturer(s):** Polarz, Krysiak
8	**Organisational unit** Faculty of Natural Sciences, Institute of Inorganic Chemistry, Chemistry Teaching Unit; https://www.aci.uni-hannover.de
9	**Person responsible for module** Polarz

◎ ◎ ◉ ◎ ◎ Smart Materials: Funktion durch Stimulus-Materie Interaktionen mit Laborübung / Smart Materials: Function through Matter-Stimulus Interactions with Laboratory Exercise

Module title Smart Materials: Function by Matter-Stimulus Interactions with Laboratory Exercise		**Module code**
Degree programme MSc Chemistry		**Module type** Required elective module
Credit points 8	**Module availability** Winter semester	**Language** German
Area of expertise None	**Recommended semester** 3rd semester	**Module duration** 1 semester
Student workload		
240 hours	98 contact hours	142 h independent study
Further use of module MSc Nanotechnology		

1

Learning objectives

Aims
The products of materials chemistry form the basis for a large number of technologies which either are already used on an everyday basis or may become important in the future. The key for these applications is how a material reacts to an external trigger (physical or chemical) by unleashing a certain functionality. The goal of the module is to provide advanced skills and a broader understanding of the connection between the reaction of materials to external stimuli and their resulting utilisation in important technologies (for advanced master's students).

The module shall provide the students with the following specialised and key knowledge and skills:

On successful completion of the module, students are able to

4. describe, explain and apply the concepts and the content of the Smart Materials module.
5. comprehend why understanding the functional principles behind chemical materials is indispensable for the optimisation of the properties of those materials and their utilisation in the desired technology.
6. acquire an understanding of which secondary processes occur after the materials have been exposed to certain stimuli, and how to control them.
7. prepare complex functional materials and investigate their properties.
8. apply analytical techniques suitable for nanomaterial characterisation.
9. interpret and explain experimental results and relate them to the theoretical background.

2

Module content

Subject-specific content:
Lecture Smart Materials

- We analyse: which (complex) technologies are used in selected product examples; how these technologies are related to the unique functionality of designated chemical materials; how to alter and optimise the functionality. A distinction is made according

	to the stimulus which leads to the desired functionality. • Light as a trigger: e.g. photodetectors; solar cells; photo-electrochemistry; transparent conducting electrodes; photonic materials; molecular switches. • Electricity as a trigger: e.g. light emitting diodes (LEDs), electromobility – battery technology, electrodes and electrochemistry; super- and pseudocapacitors; materials for micro- and nanoelectronics. • Magnetic fields as a trigger: e.g. ferromagnets, ferrimagnets, antiferromagnets, spin valves, magnetic sensors. • Chemical triggers: e.g. self-organisation phenomena, surfactants, detergents; self-cleaning surfaces; chemical sensors; lambda-probe – solid-state electrolytes. • Heat as a trigger: e.g. thermoelectric materials; ferroelectric materials. • Force as a trigger: e.g. triboelectric generators, shape-memory systems. • Diseases as a trigger: e.g. nanomedicine; theranostics; drug-delivery. **Seminar Smart Materials** Presentation and analysis of developments in the field of 'Smart Materials' on the basis of recent publications or new products/ technologies. **Laboratory exercise Smart Materials** Research-oriented, practical work on the synthesis of functional materials, the analytical characterisation of composition and nanostructure, and the exploration of perspectives for their application. **General content:** Information about the utilisation of the materials discussed in technologies and products (e.g. automobiles, smartphones, computers, medicine, etc.).
3	**Mode of teaching** ◎ ◎ ◉ ◎ ◎ Lecture Smart Materials (2 semester hours) ◎ ◎ ◉ ◎ ◎ Seminar Smart Materials (1 semester hour) ◎ ◎ ◉ ◎ ◎ Laboratory exercise Smart Materials (4 semester hours)
4a	**Participation requirements** **Module assessment:** None
4b	**Recommended prior knowledge** Advanced knowledge of chemistry.
5	**Requirements for award of credit points**
	Coursework: Laboratory exercise Smart Materials
	Assessment: Written examination 120 minutes or oral examination 30 minutes
6	**Literature** S. O. Kasap, Optoelectronic and Photonics: Principles and Practices, Prentice Hall, 2001. J. D. Joannopoulos, S. G. Johnson, J. N. Winn, R. D. Meade and Editors, Photonic Crystals: Molding the Flow of Light (Second Edition), Princeton University Press, 2008. B. Viswanathan and M. A. Scibioh, Photoelectrochemistry: Principles and Practices, Narosa Publishing House, 2014. P. H. Rieger, Electrochemistry, Springer Netherlands, 1993.

	Y. G. Wang, Y. F. Song and Y. Y. Xia, Chemical Society Reviews, 2016, 45, 5925-5950. F.-G. Banica, Chemical Sensors and Biosensors: Fundamentals and Applications, Wiley, 2012. R. Crawford, E. Ivanova and Editors, Superhydrophobic Surfaces, Elsevier, 2015. G. Y. Chen, I. Roy, C. H. Yang and P. N. Prasad, Chemical Reviews, 2016, 116, 2826-2885. A. Filimon and Editor, Smart Materials: Integrated Design, Engineering Approaches, and Potential Applications, Apple Academic Press Inc., 2019. In addition, current publications on the topics are used (no current books cover all topics).
7	**Further information** **Lecturer(s):** Polarz, Krysiak
8	**Organisational unit** Faculty of Natural Sciences, Institute of Inorganic Chemistry, Chemistry Teaching Unit; https://www.aci.uni-hannover.de
9	**Person responsible for module** Polarz

◎ ◎ ◎ ◎ ◉ **Spezielle Radioanalytik für Weltraumanwendungen / Special Radioanalytics for Space Applications**

<table>
<tr><td colspan="3">Module title Special Radioanalytics for Space Applications</td><td>Module code</td></tr>
<tr><td colspan="3">Degree programme MSc Chemistry</td><td>Module type
Required elective module</td></tr>
<tr><td>Credit points 4</td><td colspan="2">Module availability
Summer semester</td><td>Language
German</td></tr>
<tr><td>Area of expertise None</td><td colspan="2">Recommended semester 2nd semester</td><td>Module duration
1 semester</td></tr>
<tr><td colspan="4">Student workload</td></tr>
<tr><td colspan="2">120 hours</td><td>45 contact hours</td><td>75 h independent study</td></tr>
<tr><td colspan="4">Further use of module
None</td></tr>
</table>

<table>
<tr><td>1</td><td>Learning objectives

Aims
To provide a deeper and broader understanding of the radioanalysis of extraterrestrial materials through in-situ measurements during space missions

The module shall provide the students with the following specialised and key knowledge and skills:

On successful completion of the module, students are able to

1. explain the special methods used in radioanalytics.
2. describe the physical and chemical principles of the methods presented
3. determine the method which is suitable for a given field of application.
4. evaluate, analyse and interpret data obtained by measurement.
5. apply the methods discussed to other systems and fields of application using current examples</td></tr>
<tr><td>2</td><td>Module content

Subject-specific content:
Lecture Special Radioanalytics for Space Applications
In this lecture different radioanalytical methods and procedures are discussed, especially their functional principles. The physical and chemical principles are examined in detail. A main focus will be on the sensitivity of the different methods and their detection limits. Typical characterisation methods will be discussed: Mössbauer spectroscopy, ESR spectroscopy, UV/Vis spectroscopy, other optical methods, X-ray fluorescence and X-ray spectroscopy, neutron spectrometry, gamma spectrometry, etc.

Seminar Special Radioanalytics for Space Applications

General content:</td></tr>
</table>

	• Special scientific teaching, working and presentation techniques: Students learn to familiarise themselves with special topics, acquire knowledge thereof, use this knowledge and present it in a suitable written form • Students learn to derive rules systematically from the facts and to recognise their limits of validity. • Students learn to link theory and practice, to interpret, verify and extrapolate.
3	**Mode of teaching** ◎ ◎ ◎ ◎ ◉ Lecture Special Radioanalytics for Space Applications (1 semester hour) ◎ ◎ ◎ ◎ ◉ Seminar Special Radioanalytics for Space Applications (3 semester hours)
4a	**Participation requirements** **Module assessment:** None
4b	**Recommended prior knowledge** Knowledge of inorganic and physical chemistry, atomic physics
5	**Requirements for award of credit points** **Coursework:** Seminar Special Radioanalytics for Space Applications **Assessment:** Written examination 120 minutes or oral examination 30 minutes
6	**Literature** **Lecture Special Radioanalytics for Space Applications** Carle M. Pieters and Peter A.J. Englert, Remote Geochemical Analysis: Elemental and Mineralogical Composition, Cambridge University Press, 1993. ISBN 0-521-40281-6. W.G. Rees, Physical Properties of Remote Sensing, Cambridge University Press, 2012. P. Gütlich, E. Bill, A.X. Trautwein, Mössbauer Spectroscopy and Transition Metal Chemistry, Springer Verlag Berlin Heidelberg 2011. ISBN: 978-3-540-88428-6. Lucy-Ann McFadden, Paul R. Weissmann, Torrence V. Johnson (eds.), Encyclopedia of the Solar System, Sec. Ed.; Elsevier Academic Press 2007; ISBN-13: 978-0-12-088589-3. **Seminar Special Radioanalytics for Space Applications** Descriptions of the experiments and literature for further reading will be provided for the respective experiments. Optional field trip is offered.
7	**Further information** **Lecturer(s):** Renz
8	**Organisational unit** Faculty of Natural Sciences, Institute of Inorganic Chemistry, Chemistry Teaching Unit; http://www.aci.uni-hannover.de
9	**Person responsible for module** Renz

◎ ◎ ◎ ◎ ◉ Wirkstoffmechanismen und -darstellung / Mechanisms and Chemical Synthesis of Active Substances

<table>
<tr><td colspan="3">Module title Mechanisms and Chemical Synthesis of Active Substances</td><td>Module code</td></tr>
<tr><td colspan="3">Degree programme MSc Chemistry</td><td>Module type Required elective module</td></tr>
<tr><td>Credit points 8</td><td colspan="2">Module availability Winter semester</td><td>Language German</td></tr>
<tr><td>Area of expertise None</td><td colspan="2">Recommended semester 3rd semester</td><td>Module duration 1 semester</td></tr>
<tr><td colspan="4">Student workload</td></tr>
<tr><td colspan="2">240 hours</td><td>84 contact hours</td><td>156 h independent study</td></tr>
<tr><td colspan="4">Further use of module</td></tr>
</table>

1	**Learning objectives** **Aims** Provide a deeper and broader understanding of medicinal and natural products chemistry and its applications (for advanced master's students). **The module shall provide the students with the following specialised and key knowledge and skills:** **On successful completion of the module, students are able to** 1. use the knowledge they have acquired to understand basic processes, to describe and assess them. 2. stringently tackle current research topics. 3. use methods of literature research to obtain data. 4. independently use textbooks and reference literature to develop a greater understanding of organic chemistry and put it into an interdisciplinary context. 5. independently perform literature searches. 6. characterise unknown compounds with respect to their biomedical and biotechnological properties. 7. develop an understanding of the coupling of different compartments in bioprocesses and with respect to reaction kinetics and transport.
2	**Module content** **Subject-specific content:** **Lecture Mechanisms of Active Substances and Pharmaceutical Properties** The lecture covers the generation of pharmacologically relevant compounds. It addresses important targets as well as important classes of natural products and biological targets. Besides current topics of drug research, it also addresses modern aspects of inorganic chemistry. Students use case studies to interact with medicinal methods and topics. Additionally, current topics of biological chemistry such as chemical genomics and metabolomics are discussed. The use of high-throughput techniques completes the understanding of medicinal chemistry.

	Exercise Mechanisms of Active Substances and Pharmaceutical Properties Students independently tackle exercises on selected topics. More in-depth discussion of selected topics. **Lecture Bioprocess Control** • Reaction kinetics of biotechnological processes (coupling transport and reaction kinetics) • Transport phenomena in biotechnological processes • Special reactor techniques/types • Metabolic flux analysis • Process examples • Downstream processing • Plant biotechnology • Marine biotechnology • Tissue engineering • Cell culture • Industrial biotransformation **Seminar Bioprocess Control** Work in small groups to produce their own talks on current topics in biotechnology. **General content:** 1. General scientific working and presentation techniques: Students learn to quickly familiarise themselves with previously unknown topics and to independently gather and collate information on a well-defined subject, translate it into experimental work and present it in a suitable written form. On successful completion of the module, students are able to select and use suitable media for the presentation. 2. Organised and goal-oriented working practices: Students acquire the ability to independently organise the way they work and to meet deadlines, to develop an expedient structure for their work processes and adopt a goal-oriented approach to executing them.
3	**Mode of teaching** ◎ ◎ ◎ ◎ ◉ Lecture Mechanisms of Active Substances and Pharmaceutical Properties (2 semester hours) ◎ ◎ ◎ ◎ ◉ Exercise Mechanisms of Active Substances and Pharmaceutical Properties (1 semester hour) ◎ ◎ ◎ ◎ ◉ Lecture Bioprocess Control (2 semester hours) ◎ ◎ ◎ ◎ ◉ Seminar Bioprocess Control (1 semester hour)
4a	**Participation requirements** **Module assessment:** None
4b	**Recommended prior knowledge** None
5	**Requirements for award of credit points**

	Coursework: None
	Assessment: Written examination 120 minutes or oral examination 30 minutes
6	**Literature** **Lecture/ Exercise Mechanisms of Active Substances and Pharmaceutical Properties** H. Dugas, Bioorganic Chemistry, Springer, 1999 H.-J. Böhm, G. Klebe, H. Kubinyi, Wirkstoffdesign, Spektrum Verlag, 1996 E. Mutschler, Arzneimittelwirkungen, Wissenschaftliche Verlagsgesellschaft, Stuttgart, 1991 W. Forth, D. Henschler, W. Rummel, K. Starke (Hrsg.), Pharmakologie und Toxikologie, Spektrum Verlag, 1998 P.M. Dewick, Medicinal Natural Products, 3. Ausgabe, John Wiley & Sons, 2008 **Lecture Bioprocess Control** J. Bailey, D. Ollis, Biochemical Engineering Fundamentals, McGraw Hill, ISBN 0-07-003212-2 H. Chmiel, Bioprozesstechnik, Spektrum Verlag, ISBN 978-3-8274-2476-1 P.M. Doran, Bioprocess Engineering Principles, Academic Press, ISBN 978-0-12-220851-5 Liese, K. Seelbach, C. Wandray, Industrial Biotransformations, Wiley-VCH ISBN 3-527-30094-5 K. Buchholz, V. Kasche, Biokatalysatoren und Enzymtechnologie, VCH, ISBN 3-527-28238-6 H. Land, D. Clark: Biochemical Engineering, Marcel Dekker, Inc. ISBN 0-8247-0099-6 H.-J. Rehm: Industrielle Mikrobiologe, Springer-Verlag, ISBN 3-540-09642-2 Eine aktuelle Literatureliste wird jeweils zu Semesterbeginn verteilt. **Seminar Bioprocess Control** Übersichten und Primärliteratur aus internationalen Journalen.
7	**Further information** **Lecturer(s):** Lecture 1: Kalesse Lecture 2: Scheper, Blume Exercise: Kalesse Seminar: Scheper, Blume
8	**Organisational unit** Faculty of Natural Sciences, Institute of Organic Chemistry, Chemistry Teaching Unit; http://www.oci.uni-hannover.de
9	**Person responsible for module** Kalesse

◎ ◎ ◎ ◉ ◎ Zeitaufgelöste Spektroskopie an Nanomaterialien /
Time-Resolved Spectroscopy Characterization Methods for Nanomaterials

<table>
<tr><td colspan="3">Module title Time-Resolved Spectroscopy Characterization Methods for Nanomaterials</td><td>Module code</td></tr>
<tr><td colspan="3">Degree programme MSc Chemistry</td><td>Module type Required elective module</td></tr>
<tr><td>Credit points 4</td><td colspan="2">Module availability Winter semester</td><td>Language German/Englisch</td></tr>
<tr><td>Area of expertise None</td><td colspan="2">Recommended semester 1st, 2nd, 3rd semester</td><td>Module duration 1 semester</td></tr>
<tr><td colspan="4">Student workload</td></tr>
<tr><td colspan="2">120 hours</td><td>42 contact hours</td><td>78 h independent study</td></tr>
<tr><td colspan="4">Further use of module
None</td></tr>
<tr><td>1</td><td colspan="3">Learning objectives

Aim
Provide an extended comprehension and thorough skills in characterizing the optical properties of (colloidal) nanomaterials with time-resolved spectroscopy methods. Students will be able to understand, evaluate and assess the potential of the nanomaterials studied for innovative optoelectronics (for advanced master students).

The module shall provide the students with the following specialised and key knowledge and skills:

On successful completion of the module, students are able to

1. understand and describe the principles of time-resolved and ultrafast-spectroscopy methods.
2. assess the suitability and selection and combination of different time-resolved spectroscopy methods for the characterization of the nanomaterials studied.
3. understand and accurate description of photochemical and photophysical processes in nanomaterials by using time-resolved spectroscopy methods.
4. Characterize the suitability of different nanomaterials for specific optoelectronic applications by using time-resolved spectroscopy.
5. describe and categorize current developments in optoelectronics of nanomaterials.</td></tr>
<tr><td>2</td><td colspan="3">Module content
Subject-specific module content:

Lecture

• Principles of light-matter interaction
• Principles in time-resolved spectroscopy outlined by current research examples in nanomaterials and organic molecules
• Photochemical and photophysical processes, e.g. Jablonski diagrams
• Time-resolved fluorescence spectroscopy for characterizing nanomaterials, lifetimes of (photo)excited states
• Ultrafast spectroscopy methods</td></tr>
</table>

	• Transient absorption spectroscopy, (amplified) femtosecond laser pulses, pump-probe experiments, evaluating the data • Current examples from research **Laboratory exercise** • Nanomaterials synthesized by the students (e.g. fluorescing, plasmonic and heterostructured) with optical properties (including absorption, emission and plasmonic properties) from the UVVis to the NIR will be characterized for their suitability for optoelectronics by time-resolved spectroscopy methods. • 1. Time-resolved fluorescence spectroscopy with nanomaterials synthesized, TCSPC measurements give insight into fluorescence lifetimes of photoexcited charge carriers, assessment of the suitability of materials (for different applications). • 2. Transient absorption spectroscopy with nanomaterials synthesized: Introduction to the experimental technique, preparation and conducting measurements, data evaluation and comparison with results obtained in no. 1, assessment of the suitability of the materials (for different applications). **General content:** • Examination and investigation of current literature for a broader understanding of the content studied • Application of methods used in physics for chemistry • Acquiring of safety regulations and standards when working with visible and invisible laser radiation • Critical evaluation of the experimental data
3	**Mode of teaching** ◎ ◎ ◎ ◎ ◉ Lecture Time-Resolved Spectroscopy Characterization Methods for Nanomaterials (2 semester hours) ◎ ◎ ◉ ◎ ◎ Laboratory exercise Time-Resolved Spectroscopy Characterization Methods for Nanomaterials (1 semester hour)
4a	**Participation requirements** **Module assessment:** None
4b	**Recommended prior knwoledge** Advanced knowledge in physical chemistry
5	**Requirements for award of credit points** **Coursework:** Laboratory exercise Time-Resolved Spectroscopy Characterization Methods for Nanomaterials **Assessment:** Written examination 60 minutes or oral examination 30 minutes
6	**Literature** W. Demtröder, Laserphysik 2 – Experimentelle Techniken, Springer Spektrum, 2012 J.R. Lakowicz, Principles of Fluorescence Spectroscopy, Springer, 2006 R.R. Alfano, The Supercontinuum Laser Source – The Ultimate White Light, Springer 2016 Empfehlenswerte aktuelle Literatur wird zu Beginn der Veranstaltung vorgestellt. **Laboratory exercise Time-Resolved Spectroscopy Characterization Methods for Nanomaterials** Detailed description of the experiments and extended literature and references will be supplied before conducting the experiments.

7	**Further information** **Lecturer(s):** Lecture: Lauth Laboratory exercise: Lauth, Bigall, Dorfs
8	**Organisational unit** Faculty of Natural Sciences, Institute of Physical Chemistry and Electrochemistry, Chemistry Teaching Unit; http://www.pci.uni-hannover.de
9	**Person responsible for module** Lauth