UNIVERSITÄT BAYREUTH

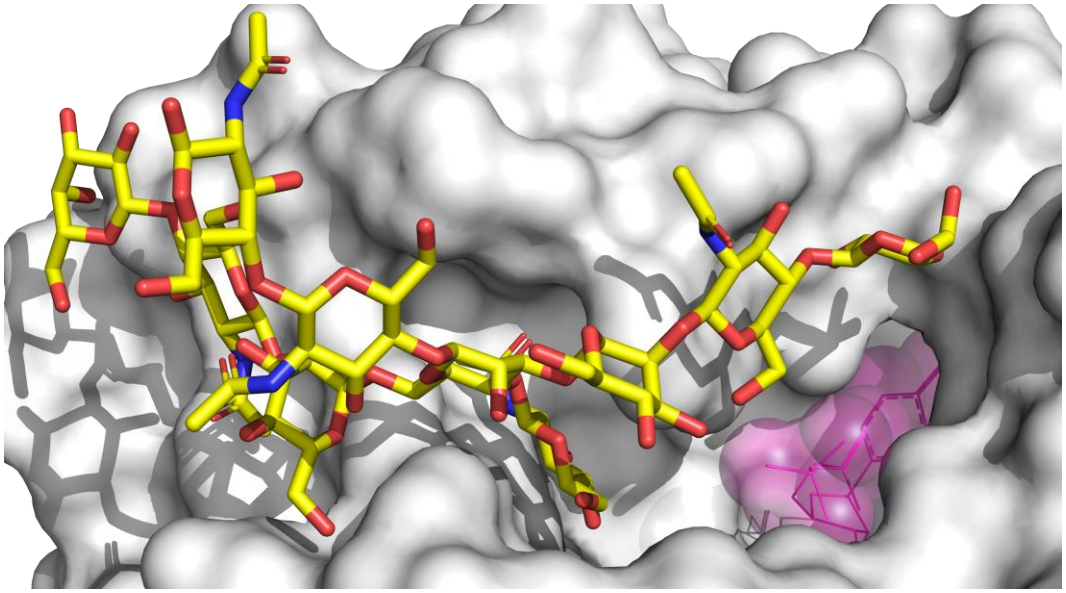
Faculty for Biology, Chemistry and Earth Sciences

Module Handbook

for the Master Program

„Natural Products and Drug Chemistry“

Version from: 08.10.2026



Content

Page

Introduction and Overview 3

Modules in the field of "Low-Molecular-Weight Natural Products and Drugs“

Winter Semester

B101 Biosynthesis of Natural Products 5
B102 Catalysis and Sustainable Synthesis 6
B103 Stereoselective Organic Synthesis 7
B104 Homogeneous Catalysis 8
B108 Fundamentals of Advanced Organic Laboratory 9
B109 Instrumental Bioanalytics and Food Analysis 10

Summer Semester

B201 Alkaloids – Biosynthesis and Total Synthesis 12
B202 Drug Design 13
B203 Analytics and Screening of Natural Products and Drugs 14
B208 Fundamentals of Advanced Organic Laboratory 15
B209 Catalyst Design 16

Modules in the field of "Macromolecular Targets and Structures"

Winter Semester

B105 Molecular Modelling 17
B106 Chemometrics 18
B107 Solid-state Inorganic Materials: Nanochemistry 19

Summer Semester

B205 Biophysical Chemistry – Multidimensional NMR Spectroscopy of Biomacromolecules 20
B206 (Bio-)Analytics: QM and Metrology in the Chemical Laboratory 21

Elective Module 22

B210 Research Proposal 23

Research Modules of the 3rd Semester 24

B301 Advanced Laboratory I
B302 Advanced Laboratory II

B400 Master Thesis 25

Appendix 1: Module Overview 26

Introduction and Overview

High-quality food and pharmaceuticals ensure our daily medical care, nutrition, and quality of life. Innovation in these fields, i.e. the development of new, tailor-made drugs, requires comprehensive knowledge of synthetic organic chemistry and a profound understanding of drug interactions with biological systems. The Master program in *Natural Products and Drug Chemistry* is centrally positioned in this broad subject area and also includes relevant aspects of the neighbouring sciences of biology, biochemistry, pharmacy and medicine. It provides in-depth knowledge about the synthesis, biosynthesis and analysis of natural products, drugs and functional substances, as well as the molecular principles of their interactions in a biological context. The structures and properties of biomolecules, be they small molecules ("ligands") or macromolecular targets ("targets"), also form a major part of the curriculum. The program thus combines the complex contents of modern synthetic chemistry with biological and medical-pharmaceutical aspects. The offered modules provide students with a multifaceted selection of choices, but also allow them to focus on a particular area. With the acquired competences, graduates are qualified for professional activities in research, development, production and services in the field of classical chemistry on the one hand. On the other hand, the interdisciplinary education opens attractive career prospects in the modern fields of life sciences, agricultural sciences and health care.

The Master program "*Natural Products and Drug Chemistry"* can be started either in the winter or summer semester. The *first-year modules* usually consist of lectures and practical laboratory courses to develop experimental skills in addition to theory. Nine modules are offered in the winter semester, six of which are from the field "Low-Molecular-Weight Natural Products and Drugs" (Biosynthesis of Natural Products; Catalysis and Sustainable Synthesis; Stereoselective Organic Synthesis; Homogeneous Catalysis; Fundamentals of Advanced Organic Laboratory; Instrumental Bioanalytics and Food Analysis) and three from the area "Macromolecular Targets and Structures" (Molecular Modelling; Chemometrics; Solid-state Inorganic Materials: Nanochemistry). Students will choose three modules from these. The fourth module can be chosen freely from the other chemistry courses offered in this or other Master programs in chemistry and related disciplines.

In the summer semester, seven modules are offered, five of which are in the area of low-molecular-weight compounds (Alkaloids – Biosynthesis and Total Synthesis; Drug Design; Analytics and Screening of Natural Products and Drugs; Fundamentals of Advanced Organic Laboratory; Catalyst Design) and two in the biomacromolecular area (Biophysical

Chemistry – Multidimensional NMR Spectroscopy of Biomacromolecules; (Bio-)Analytics: QM and Metrology in the Chemical Laboratory). Students are free to choose three of them. In addition, students prepare a plan for their own scientific research project ("Research Plan"). The examinations for the modules of the first and second semesters are conducted either as oral or written examinations. The types of examination for each module are listed in the respective module description. Further details of the examinations (e.g. scope and duration of the examinations) can be found in § 11 of the Examination and Study Regulations (Prüfungs- und Studienordnung, PSO).

In the *third and fourth semester*, two advanced laboratory courses (Advanced Laboratories I and II) worth a total of 30 credits must be completed. One of these modules can be completed externally, e.g. as an industrial internship and/or abroad. The content of the Master thesis on a current topic in natural and medicinal product chemistry can already be chosen at the end of the second semester, so that independent scientific work on it is possible in parallel to the research modules, building on the module "Research Proposal" as preliminary work. The Master thesis, worth 30 credits, can thus be completed over a period of 12 months, with an increasing workload in the fourth semester.

A total of at least 120 credit points (winter semester: 28; summer semester: 32; 3rd & 4th semester: 60 in total) must be obtained in the Master program in *Natural Products and Drug Chemistry*. An overview of the courses offered in the Master program can be found in Appendix 1.

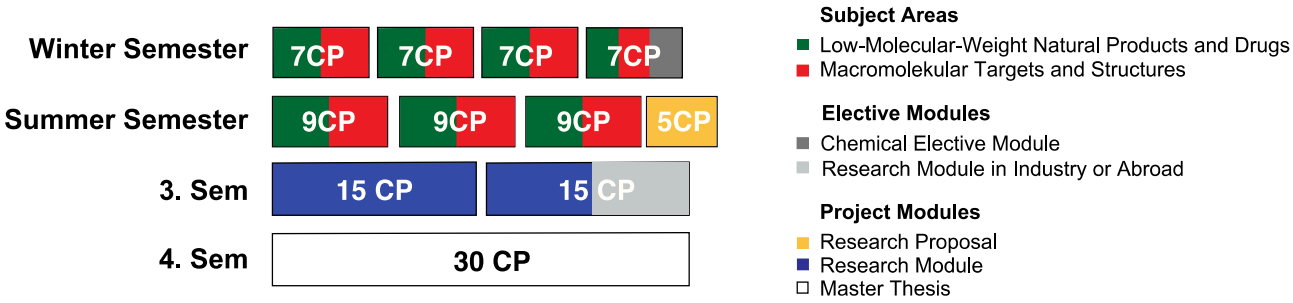


Figure: Modular Structure, Subject Areas, and Credit Points of the Master Program "Natural Products and Drug Chemistry"

Coordinator of the Master Program *Natural Products and Drug Chemistry:*

Prof. Frank Hahn, University of Bayreuth

email: frank.hahn@uni-bayreuth.de, phone: +49-921-553660

Module B101: Biosynthesis of Natural Products

Responsible persons: Module: Prof. R. M. Koenigs (Organic Chemistry II)
Lecture: Prof. R. M. Koenigs, Prof. F. Hahn
Lab course: Lecturers of Organic Chemistry

Learning objectives:

Provides a deeper understanding of the biosynthetic pathways of natural products, their basic structural types and their relationship to biological activity.

Course units and temporal allocation:	HPW	Semester
• Lecture	2	WS
• Lab course (block course, date by arrangement)	6	WS

Course content:

- **Lecture:** The general biosynthetic pathways for natural products are presented and those of the most important, such as fatty acids, amino acids, carbohydrates, nucleic acids, polyketides, terpenes, vitamins, alkaloids and their secondary metabolites, are discussed in detail. The interaction between humans and natural products is examined on the basis of selected examples.
- **Lab course:** Individual aspects of natural products chemistry are taught by working on a current research project in one of the participating working groups. The results are summarised in a report and presented in a seminar lecture.

Entrance requirements:

None.

Assessment:	Weighting
• Graded oral or written examination on the lecture	70%
• Graded lab course with report and seminar presentation	30%

The module grade will only be given after successful completion of both parts.

Student workload:

• Lecture: 2 hours plus 2 hours preparation and wrap-up for 15 weeks	60 hours
• Exam preparation	30 hours
• Lab course with report and seminar presentation	120 hours
Total workload:	210 hours

ECTS credit points: 7

Module B102: Catalysis and Sustainable Synthesis

Responsible persons: Module: Prof. S. Das (Organic Chemistry I)
Lecture: Prof. S. Das
Lab course: Lecturers of Organic Chemistry

Learning objectives:

Will provide deeper understanding of different catalysis aspects for the synthesis of pharmaceuticals, fine chemicals, monomers, and fuels.

Course units and temporal allocation:	HPW	Semester
• Lecture	2	WS
• Lab course (block course, date by arrangement)	6	WS

Course content:

- **Lecture:** The general catalytic strategies will be discussed by keeping more focus onto photocatalysis, electrocatalysis and thermocatalysis. Basics of all these catalysis aspects will be exemplified along with their application for the synthesis of drug molecules. Additionally, activation of small molecules such as CO_2, O_2 will be discussed and their applications into organic synthesis will also studied. Furthermore, catalysis for the synthesis of monomer of polymers will be depicted in this course.
- **Lab course:** Individual aspects of catalysis and sustainable synthesis are taught by working on a current research project in one of the participating research groups. The results are summarized in a report and presented in a seminar lecture.

Entrance requirements:

None.

Assessment:	Weighting
• Graded oral or written examination on the lecture	70%
• Graded lab course with report and seminar presentation	30%

The module grade will only be given after successful completion of both parts.

Student workload:

• Lecture: 2 hours plus 2 hours preparation and wrap-up for 15 weeks	60 hours
• Exam preparation	30 hours
• Lab course with report and seminar presentation	120 hours
Total workload:	210 hours

***ECTS credit points:* 7**

Module B103: Stereoselective Organic Synthesis

Responsible persons: Module: Prof. F. Hahn (Organic Chemistry IV)
Lecture: Prof. M. Breuning, Prof. F. Hahn
Lab course: Lecturers of Organic Chemistry

Learning objectives:

Methods, concepts and reactions of modern stereoselective organic synthesis are taught at an advanced level.

Course units and temporal allocation:	HPW	Semester
• Lecture	2	WS
• Lab course (block course, date by arrangement)	6	WS

Course content:

- **Lecture:** Important reactions and methods of stereoselective organic synthesis are covered. In the first part, which deals with diastereoselective methods, the fundamentals of stereoselective synthesis are taught and methods for the selective construction of *E*- and *Z*-configured alkenes and of stereocentres (e.g. additions to α-chiral carbonyl compounds and alkenes, aldol additions) as well as auxiliary-mediated procedures for the synthesis of enantiomerically pure compounds are presented. The second part focuses on enantioselective catalytic methods: biocatalysis, organocatalysis, reduction and oxidation processes, allylation/crotylation and ring closure reactions. The knowledge imparted is deepened by means of examples of natural substance syntheses and industrial processes.
- **Lab course:** Individual aspects of stereoselective organic syntheses are taught by working on a current research project in one of the participating research groups. The results are summarized in a report and presented in a seminar lecture.

Entrance requirements:

None.

Assessment:	Weighting
• Graded oral or written examination on the lecture	70%
• Graded lab course with report and seminar presentation	30%

The module grade will only be given after successful completion of both parts.

Student workload:

• Lecture: 2 hours plus 2 hours preparation and wrap-up for 15 weeks	60 hours
• Exam preparation	30 hours
• Lab course with report and seminar presentation	120 hours
Total workload:	210 hours

ECTS credit points: 7

Module B104: Homogeneous Catalysis

Responsible persons: Module: Prof. R. Kempe (Inorganic Chemistry II)
Lecture: Prof. R. Kempe
Lab course: Lecturers of Inorganic Chemistry

Learning objectives:

The students gain insight into polymerization catalysis and improve their knowledge in organometallic chemistry.

Course units and temporal allocation:	HPW	Semester
• Lecture	2	WS
• Lab course (3 weeks, block course, date by arrangement)	6	WS

Course content:

- **Lecture:** The following topics are discussed: reactivity of the metal carbon bond, catalytic applications of organometallic compounds and coordinative polymerizations.
- **Lab course:** The students will improve their skills in working with highly air and moisture sensitive compounds and use them in teamwork with PhD students and postdocs to address catalysis relevant questions.

Entrance requirements:

None.

Assessment:	Weighting
• Graded oral or written examination on the lecture	70%
• Graded lab course with report and seminar presentation	30%

The module grade will only be given after successful completion of both parts.

Student workload:

• Lecture: 2 hours plus 2 hours preparation and wrap-up for 15 weeks	60 hours
• Exam preparation	30 hours
• Lab course with report and seminar presentation	120 hours
Total workload:	210 hours

***ECTS credit points:* 7**

Module B108: Fundamentals of Advanced Organic Laboratory

Responsible persons: Module: Lecturers of Organic Chemistry
Lab course: Lecturers of Organic Chemistry

Learning objectives:

This laboratory course aims to provide students with advanced practical skills in modern synthetic organic chemistry. Students will learn essential laboratory techniques required for advanced organic synthesis and gain hands-on experience with analytical methods used for structure elucidation and reaction monitoring, including NMR spectroscopy and related spectroscopic and chromatographic techniques. The acquired skills are reinforced through the execution of multi-step syntheses ranging from commonly applied fundamental organic transformations to reactions approaching the complexity of contemporary research projects. Upon completion, students will be able to perform advanced synthetic procedures, evaluate reaction outcomes, and interpret analytical data independently.

Course units and temporal allocation:	HPW	Semester
• Lab course (4 weeks, block course, date will be communicated)	8	WS

Course content:

- **Lab course:** The course provides practical training in advanced organic synthesis and compound characterization. Students carry out synthetic transformations ranging from commonly used organic reactions to advanced procedures relevant to contemporary research. The course emphasizes reaction setup, purification techniques, safe laboratory practice, and analytical characterization using NMR spectroscopy and related methods. Documentation and evaluation of experimental results form an integral part of the course.

Entrance requirements:

None.

Assessment:	Weighting
• Graded lab course with laboratory report	7 CP

The module grade will only be given after successful completion of the laboratory course and submission of all required laboratory reports.

Student workload:	
• Practical laboratory work	120 hours
• Preparation and post-processing of experiments	40 hours
• Data analysis and interpretation	20 hours
• Preparation of laboratory reports	30 hours
Total workload:	210 hours

***ECTS credit points:* 7**

Module B109: Instrumental Bioanalytics and Food Analysis

Responsible persons: Module: Prof. A. Römpp (Bioanalytics and Food Analytics)
Lecture: Prof. A. Römpp
Lab course: Chair of Bioanalytics and Food Analytics

Learning objectives:

Students acquire advanced theoretical knowledge and practical experience in the application and evaluation of modern instrumental analytical methods. Particular emphasis is placed on developing a comprehensive understanding of complex analytical datasets and the critical interpretation of experimental results. Students learn to assess the quality and significance of both their own findings and published scientific studies. Through the combination of lectures, seminars, and laboratory work, students strengthen their ability to design analytical workflows, conduct experiments, process and interpret data, and communicate scientific results effectively.

Course units and temporal allocation:	HPW	Semester
• Lecture	2	WS
• Seminar	2	WS
• Lab course (block course after lecture period)	3	WS

Course content:

- **Lecture:** The lecture introduces advanced aspects of instrumental analytical chemistry. Particular emphasis is placed on mass spectrometry and Raman spectroscopy for the analysis of small molecules such as metabolites, secondary metabolites, peptides, and pharmaceutical compounds. Applications from food analysis and biomedical research are discussed. Special attention is given to imaging techniques and in situ analytical methods that enable rapid analysis with minimal sample preparation.
- **Seminar:** Current research literature related to topics covered in the lecture and laboratory course is discussed in detail. Students deepen their understanding of analytical methods, data interpretation, and current developments in instrumental bioanalysis and food analysis.
- **Lab course:** Students work on selected topics from the lecture in small groups. The laboratory course covers sample preparation, experimental analysis, data processing, and interpretation of analytical results. Particular emphasis is placed on the practical application of instrumental methods and the critical evaluation of experimental data.

Entrance requirements:

None.

Assessment:	Weighting
• Graded oral or written examination on the lecture	3 CP
• Graded seminar presentation	2 CP
• Graded lab course with report	2 CP

The module grade will only be given after successful completion of all three parts.

Student workload:	
• Contact hours (lecture and lab course)	135 hours
• Preparation and wrap-up for 15 weeks	50 hours
• Exam preparation	25 hours
Total workload:	210 hours

***ECTS credit points:* 7**

Module B201: Alkaloids – Biosynthesis and Total Synthesis

Responsible persons: Module: Prof. M. Breuning (Organic Chemistry III)
Lecture: Prof. M. Breuning
Lab course: Lecturers of Organic Chemistry

Learning objectives:

Extensive knowledge of the natural product class of alkaloids will be provided: their biogenesis, structures, biological/medical significance and total synthesis.

Course units and temporal allocation:	HPW	Semester
• Lecture	2	SS
• Lab course (block course, date by arrangement)	8	SS

Course content:

- **Lecture:** The focus is on the natural product class of alkaloids, which is characterized by multifaceted biosynthetic pathways and high structural diversity and complexity. After an introduction to general methods for the elucidation of biosynthetic pathways and a basic overview of this broad class of natural products, the four major alkaloid classes, the ornithine-, lysine-, phenylalanine/tyrosine- and tryptophan-derived alkaloids, as well as alkaloids of other origins will be discussed in detail: Typical representatives of the individual classes and their mostly plant-derived producers are presented; the biosynthesis of the alkaloids, starting from the basic building blocks via the central intermediates to the corresponding natural products, is outlined. Important drugs derived from highly bioactive alkaloids, their structural commonalities with the lead compound and their mechanisms of action are shown. Elegant and pioneering chemical total syntheses of selected alkaloids are presented and discussed step by step.
- **Lab course:** Individual aspects of natural product chemistry are taught by working on a current research project in one of the participating research groups. The results are summarized in a report and presented in a seminar lecture.

Entrance requirements:

None.

Assessment:	Weighting
• Graded oral or written examination on the lecture	60%
• Graded lab course with report and seminar presentation	40%

The module grade will only be given after successful completion of both parts.

Student workload:

• Lecture: 2 hours plus 2 hours preparation and wrap-up for 15 weeks	60 hours
• Exam preparation	30 hours
• Lab course with report and seminar presentation	180 hours
Total workload:	270 hours

***ECTS credit points:* 9**

Module B202: Drug Design

Responsible persons: Module: Prof. R. M. Koenigs (Organic Chemistry II)
Lecture: Prof. R. M. Koenigs
Lab course: Lecturers of Organic Chemistry

Learning objectives:

This course provides an in-depth exploration of the scientific principles and methods involved in the design and synthesis of modern drugs. Students will learn the fundamental concepts of drug discovery, focusing on the molecular mechanisms of drug action, and the strategies used to design small molecules that can interact effectively with biological targets.
The course also covers the various stages of drug development, from the discussion of drug targets towards lead compound identification to clinical trials.
Students will learn to synthesize natural and non-natural biologically active compounds using modern synthesis methods. Basic synthesis routes are as present as complex reaction mechanisms. The students learn the ability to plan the synthesis of bioactive, pharmacologically interesting compounds. In this process, aspects of pharmacology are recognized in their relationship to basic chemical structures and used for the development of new "active compounds".

Course units and temporal allocation:	HPW	Semester
• Lecture	2	SS
• Lab course (4 weeks, block course, date by arrangement)	8	SS

Course content:

- **Lecture:** The major classes of targets in drug discovery are introduced and modern synthetic methods towards pharmaceutically active compounds for each class are discussed in detail. Topics covered in detail include G-protein coupled receptors, ion channels, analytical tools in drug discovery, modern methods in catalysis, protein synthesis, total synthesis.
- **Lab course:** Theoretical knowledge will be reinforced by experiments on the following topics: transition metal catalysis, photochemistry and -catalysis, radical reactions, late stage functionalization reactions, synthesis of biologically active compounds, structural characterisation of products using spectroscopic methods.

Entrance requirements:

None.

Assessment:	Weighting
• Graded oral or written examination on the lecture	5 CP
• Graded lab course with report and seminar presentation	4 CP

The module grade will only be given after successful completion of both parts.

Student workload:

• Lecture: 2 hours plus 2 hours preparation and wrap-up for 15 weeks	60 hours
• Exam preparation	30 hours
• Lab course with report and seminar presentation	180 hours
Total workload:	270 hours

***ECTS credit points:* 9**

Module B203: Analytics and Screening of Natural Products and Drugs

Responsible persons: Module: Dr. U. Lacher (Organic Chemistry I)
Lecture: Dr. U. Lacher
Lab course: Dr. U. Lacher

Learning objectives:

Knowledge is taught on the isolation, quantification and screening of natural products and drugs.

Course units and temporal allocation:	HPW	Semester
• Lecture	2	SS
• Lab course (4 weeks, block course, fixed date)	8	SS

Course content:

- **Lecture:** Methods for extraction, isolation, separation and quantification (GC, HPLC), as well as for structure analysis (spectroscopy) of natural products and drugs are presented. In addition, the most important methods for screening for various types of activity are discussed, e.g. fluorimetric assays for cytotoxicity, inhibition of specific enzymes and proteins, and cell morphological changes; agar diffusion tests for antibiotic activity; immunoblotting and electrophoresis for the quantification of DNA and proteins.
- **Lab course:** The methods are exercised on selected, standardised separation and screening problems and are intensified by participation in some of the current research projects of the involved working groups as well as by a lecture on a current topic.

Entrance requirements:

None.

Assessment:	Weighting
• Graded oral or written examination on the lecture	60%
• Graded lab course with report and seminar presentation	40%

The module grade will only be given after successful completion of both parts.

Student workload:

• Lecture: 2 hours plus 2 hours preparation and wrap-up for 15 weeks	60 hours
• Exam preparation	30 hours
• Lab course with report and seminar presentation	180 hours
Total workload:	270 hours

***ECTS credit points:* 9**

Module B208: Fundamentals of Advanced Organic Laboratory

Responsible persons: Module: Lecturers of Organic Chemistry
Lab course: Lecturers of Organic Chemistry

Learning objectives:

This laboratory course aims to provide students with advanced practical skills in modern synthetic organic chemistry. Students will learn essential laboratory techniques required for advanced organic synthesis and gain hands-on experience with analytical methods used for structure elucidation and reaction monitoring, including NMR spectroscopy and related spectroscopic and chromatographic techniques. The acquired skills are reinforced through the execution of multi-step syntheses ranging from commonly applied fundamental organic transformations to reactions approaching the complexity of contemporary research projects. Upon completion, students will be able to perform advanced synthetic procedures, evaluate reaction outcomes, and interpret analytical data independently.

Course units and temporal allocation:	HPW	Semester
• Lab course (5 weeks, block course, date will be communicated)	10	SS

Course content:

- **Lab course:** The course provides practical training in advanced organic synthesis and compound characterization. Students carry out synthetic transformations ranging from commonly used organic reactions to advanced procedures relevant to contemporary research. The course emphasizes reaction setup, purification techniques, safe laboratory practice, and analytical characterization using NMR spectroscopy and related methods. Documentation and evaluation of experimental results form an integral part of the course.

Entrance requirements:

None.

Assessment:	Weighting
• Graded lab course with laboratory report	9 CP

The module grade will only be given after successful completion of the laboratory course and submission of all required laboratory reports.

Student workload:	
• Practical laboratory work	160 hours
• Preparation and post-processing of experiments	45 hours
• Data analysis and interpretation	25 hours
• Preparation of laboratory reports	40 hours
Total workload:	270 hours

ECTS credit points: **9**

Module B209: Catalyst Design

Responsible persons: Module: Prof. R. Kempe (Inorganic Chemistry II)
Lecture: Lecturers of Inorganic Chemistry II
Lab course: Lecturers of Inorganic Chemistry II

Learning objectives:

The students gain insight into the field of catalyst design.

Course units and temporal allocation:	HPW	Semester
• Lecture	2	SS
• Lab course (3 weeks, block course, date by arrangement)	8	SS

Course content:

- **Lecture:** During the lecture the following topics are discussed: basics and concepts of catalyst design: explorative coordination chemistry, mechanistic studies, and combinatorial catalysis research.
- **Lab course:** In the laboratory course the students develop skills to run catalytic experiments and use them in teamwork with PhD students and post-docs to address open, catalysis relevant, questions.

Entrance requirements:

None.

Assessment:	Weighting
• Graded oral or written examination on the lecture	5 CP
• Graded lab course with report and seminar presentation	4 CP

The module grade will only be given after successful completion of both parts.

Student workload:	
• Lecture: 2 hours plus 2 hours preparation and wrap-up for 15 weeks	60 hours
• Exam preparation	30 hours
• Lab course with report	180 hours
Total workload:	270 hours

ECTS credit points: **9**

Module B105: Molecular Modelling

Responsible persons: Module: Prof. M. Ullmann (Biochemistry V)
Lecture: Prof. M. Ullmann
Lab course: Prof. M. Ullmann

Learning objectives:

Starting from the structure, properties and synthesis of biomacromolecules, an interdisciplinary approach is taken to demonstrate the potential of targeted modification of biomolecules for biomedical purposes.

Course units and temporal allocation:	HPW	Semester
• Lecture	2	WS
• Lab course (2 weeks, block course, fixed date)	6	WS

Course content:

- **Lecture:** The theoretical basics of molecular modelling (molecular force fields, biomolecular electrostatics, classical and statistical mechanics), their numerical implementations (molecular dynamics simulations, energy minimisation and normal mode analysis, Monte Carlo simulations), basics of quantum chemical methods as well as the modelling of biochemical reactions and ligand binding are covered.
- **Lab course:** Various techniques (including analysis of biomolecular structures, calculation of electrostatic properties of biomolecules, normal mode analysis and introductory quantum chemical methods) will be applied to selected case studies to teach students the practical application of these methods.

Entrance requirements:

Basic knowledge of structural biochemistry and basic knowledge of UNIX for the practical course are strongly recommended. The module can only be selected if the module Molecular Modelling has not been attended in the Bachelor's degree program.

Assessment:	Weighting
• Graded oral or written examination on the lecture	100%
• Successful participation in the ungraded lab course with protocol	

The module grade will only be given after successful completion of both parts.

Student workload:

• Lecture: 2 hours plus 2 hours preparation and wrap-up for 15 weeks	60 hours
• Exam preparation	30 hours
• Lab course with report	120 hours
Total workload:	210 hours

ECTS credit points: 7

Module B106: Chemometrics

Responsible persons: Module: Prof. S. Schwarzinger (NMR center)
Lecture: Prof. S. Schwarzinger
Lab course: Prof. S. Schwarzinger

Learning objectives:

The module gives an overview of chemometrics, i.e. the analysis of chemical data using statistical methods (including AI), and in this context important spectroscopic techniques and their chemometric application in chemistry, food testing and medical diagnostics. Participants will acquire basic knowledge that will enable them not only to understand research work in the field of chemometrics, but also to carry it out independently.

Course units and temporal allocation:	HPW	Semester
• Lecture (block course)	2	WS
• Lab course (2 weeks, block course, fixed date)	5	WS

Course content:

- **Lecture:** Overview of chemometrics – from its beginnings to AI. Specifics of application to spectroscopic data (e.g.: IR, MS, NMR, isotope ratios, trace elements, etc.). Experimental basics: from sample preparation to final model. Overview of classification and regression methods and related data pretreatment. Introduction to the development of non-directional analytical methods and corresponding validation concepts. Application examples: from inorganic chemistry to food analysis (authenticity analysis) and diagnostics. Topic-related exercises complement the lecture.
- **Lab course:** Students learn to prepare, evaluate and critically interpret spectroscopic data for chemometric evaluations. Part of the lab course is a seminar with a graded presentation.

Entrance requirements:

Basic theoretical and practical knowledge in chemistry, especially in analytics and spectroscopy.

Assessment:	Weighting
• Graded oral or written examination on the lecture	70 %
• Lab course with report and seminar presentation	30 %
•	

The module grade will only be given after successful completion of both parts.

Student workload:

• Lecture: 2 hours plus 2 hours preparation and wrap-up for 15 weeks	60 hours
• Exam preparation	30 hours
• Lab course with report and seminar presentation	120 hours
Total workload:	210 hours

ECTS credit points: 7

Module B107: Solid-State Inorganic Materials: Nanochemistry

Responsible persons: Module: Prof. J. Breu (Inorganic Chemistry I)
Lecture: Prof. J. Breu, Prof. J. Senker
Lab course: Lecturers of Inorganic Chemistry

Learning objectives:

The main aim of this module is to provide a sound and broad knowledge about current developments of solid inorganic materials with a focus on nanochemistry.

Course units and temporal allocation:	HPW	Semester
• Lecture	2	WS
• Lab course (3 weeks, block course, date by arrangement)	6	WS

Course content:

- **Lecture:** During the lecture properties, applications and theoretical considerations of solid inorganic functional materials will be presented. Special care will be given to mechanistic aspects of synthetic routes as well as to modern strategies of characterization. The following items will be discussed: i) Inorganic Nanotechnology including the build-up of inorganic colloids, pigments, nano-rods and -wires. ii) Inorganic composite and filling materials including biogenic minerals like nacre and bone tissue. iii) Crystal engineering and polymorphism of molecular systems as well as their influence on drug design. iv) Supramolecular inorganic chemistry and host guest systems. v) Semi-crystalline and amorphous materials including glasses, glass ceramics, phase change materials and photonic crystals.
- **Lab course:** The students will deepen their practical skills by working with PhD students and postdocs in the group of the lecturers.

Entrance requirements:

None.

Assessment:	Weighting
• Graded oral or written examination on the lecture	70%
• Graded lab course with report and seminar presentation	30%

The module grade will only be given after successful completion of both parts.

Student workload:

• Lecture: 2 hours plus 2 hours preparation and wrap-up for 15 weeks	60 hours
• Exam preparation	30 hours
• Lab course with report and seminar presentation	120 hours
Total workload:	210 hours

ECTS credit points: 7

Module B205: Biophysical Chemistry – Multidimensional NMR Spectroscopy of Biomacromolecules

Responsible persons: Module: Dr. K. Schweimer (Biochemistry IV)
Lecture: Dr. K. Schweimer
Lab course: Dr. K. Schweimer

Learning objectives:

Theoretical knowledge and practical skills of modern methods of NMR spectroscopy for the analysis of biomacromolecules.

Course units and temporal allocation:	HPW	Semester
• Lecture	2	SS
• Exercises	2	SS
• Lab course (2 weeks, block course, fixed date)	5	SS

Course content:

- **Lecture:** Knowledge and techniques of NMR spectroscopy of biomacromolecules are taught: Quantum mechanical description of NMR experiments (product operator formalism), two- and higher-dimensional homo- and heteronuclear correlation experiments, triple resonance experiments for isotopically labelled proteins, cross relaxation and NOESY experiments, assignment of backbone and side-chain resonances of proteins, Fourier transposition and data processing, structure dependence of NMR parameters.
- **Lab course:** Practical work and exercises on the following topics will be carried out and intensified Performing various NMR experiments on the spectrometer (1D and 2D spectra), assigning the 3D spectra of a small protein.

Entrance requirements:

None. Basic knowledge in physical chemistry is recommended.

Assessment:	Weighting
• Graded oral or written examination on the lecture	100%
• Successful participation in the ungraded lab course with protocol and in the exercises	

The module grade will only be given after successful completion of both parts.

Student workload:

• Lecture: 2 hours plus 2 hours preparation and wrap-up for 15 weeks	60 hours
• Exam preparation	30 hours
• Lab course with report and seminar presentation	180 hours
Total workload:	270 hours

***ECTS credit points:* 9**

Module B206: (Bio-)Analytics: QM and Metrology in the Chemical Laboratory

Responsible persons: Module: Prof. S. Schwarzinger (NMR center)
Lecture: Prof. S. Schwarzinger
Lab course: Prof. S. Schwarzinger

Learning objectives:

Acquisition of theoretical and practical knowledge in (bio)analytics, especially the basics of the analytical process and metrology (science of measurement). In connection with this, an overview of quality management, selected analytical techniques and OMICS is given.

Course units and temporal allocation:	HPW	Semester
• Lecture	2	SS
• Lab course (2 weeks, block course, fixed date)	7	SS

Course content:

- **Lecture:** Analytics is a metrological (measuring) science. This lecture introduces the analytical process and the fundamentals of metrology and results evaluation, and provides an overview of closely related quality management in the laboratory. Applications and fundamentals from the fields of spectroscopy (e.g.: qNMR as an example of quantitative reference method, IR etc.), separation methods and mass spectrometry are presented, as well as an introduction to OMICS methods with focus on metabonomics. Topic-related exercises complement the lecture.
- **Lab course:** Students learn to view the analytical process in its entirety, to interpret analytical results critically and to formulate them in a legally sound manner. Part of the lab course is a seminar with a graded presentation.

Entrance requirements:

Basic theoretical and practical knowledge in chemistry, especially in analytics and spectroscopy.

Assessment:	Weighting
• Graded oral or written examination on the lecture	60%
• Graded lab course with report	30%
• Oral presentation in the seminar	10%

The module grade will only be given after successful completion of both parts.

Student workload:

• Lecture: 2 hours plus 2 hours preparation and wrap-up for 15 weeks	60 hours
• Exam preparation	30 hours
• Lab course with report and seminar presentation	180 hours
Total workload:	270 hours

ECTS credit points: **9**

Elective Modules

An additional module with 7 ECTS credit points must be taken. This module can be taken from the other chemical courses offered in this program or from another chemically or biologically oriented Master program at the University of Bayreuth, in particular

- Natural Products and Drug Chemistry,
- Biochemistry and Molecular Biology,
- Materials Chemistry and Catalysis,
- Polymer Science,

***ECTS credit points:* 7**

Module B210: Research Proposal

Responsible persons: a lecturer involved in the lecture canon*

Learning objectives:

Students will acquire core competencies for independent scientific research by being guided to plan a project, to acquire the scientific literature, and to present the research results and the project in oral and written form.

Course units and temporal allocation:	HPW	Semester
• Writing a research proposal	8	2
• Seminar on the research topic	1	2

Course content:

Students prepare a written research proposal, in which the research area of a planned thesis is described and the scientific problem and experimental approach to solve it are outlined, in order to acquire competences in planning scientific projects. They are guided to independently develop the basics of a research area and the experimental methodology based on the scientific literature. The research plan is presented in a seminar to train presentation skills.

It is recommended to use the research proposal as a preparation for the forthcoming Master thesis.

Entrance requirements:

None.

Assessment:	Weighting
• Graded written research proposal	60%
• Graded oral presentation in the group seminar	40%

The module grade will only be given after successful completion of both parts.

Student workload:

• Group seminar with oral presentation including preparation and wrap-up	30 hours
• Writing a research proposal	120 hours
Total workload:	150 hours

***ECTS credit points:* 5**

* Other lecturers may be accepted upon prior application, provided that
- the topic of the planned research plan corresponds to the objectives of the Master degree program,
- the examination board approves him/her before the start of the research plan.

If you are planning a research project with a lecturer outside the Master program, please contact the chair of the examination board at least one month in advance.

Modules B301 and B302:* Advanced Laboratoryl and II

Responsible persons: Module: a lecturer involved in the lecture canon

Learning objectives:

Students should gain an insight into the research practice of chemical working groups and acquire and train experimental skills through independent laboratory work under supervision. The ability to work in a team will be practised and presentation techniques will be acquired and tested.

Course units and temporal allocation:	HPW	Semester
• Research project	19	3/4
• Group seminar presentation	1	3/4

Course content:

The course covers a current research project of the chosen working group. The module includes experimental work in the laboratory, literature search, and participation in the group seminar. The research results are presented in a written report and an oral presentation with discussion.

Entrance requirements:

None.

Assessment:	Weighting
• Graded lab course with a report.	100%

Student workload:

• Laboratory work including preparation and wrap-up	350 hours
• Group seminar with oral presentation including preparation and wrap-up	100 hours
Total workload:	450 hours

***ECTS credit points:* 15**

* One of the two Advanced Laboratories can be done externally, e.g. abroad, in industry, in an external research institute or in a working group at the University of Bayreuth that is not part of the lecture canon, provided that

- the topic of the planned Advanced Laboratory corresponds to the objectives of the Master program,
- a lecturer from the University of Bayreuth who is involved in the lecture canon is available as a supervisor, and
- the examination board approves the external Advanced Laboratory before it starts.

If you are planning to do an external Advanced Laboratory, please contact the chair of the examination board at least one month in advance.

Module B400: Master Thesis*

Responsible persons: Module: a lecturer involved in the lecture canon

Learning objectives:

Students are expected to work independently on a research project under supervision and to report their findings in writing.

Course units and temporal allocation: Semester

- Work on a research project and prepare a written thesis 3/4
- Presentation of the Master Thesis contents

Course content:

The learning content relates to the current research projects of the chosen working group.

Entrance requirements:

According to the examination regulations, 45 credit points from finished modules are required.

Assessment:

Written version of the Master thesis.

Student workload:

Total workload: 900 hours

ECTS credit points: **30**

* In exceptional cases, the Master thesis can be done externally, e.g. abroad, in industry, in an external research institute or in a working group at the University of Bayreuth that is not part of the lecture canon, provided that

- the topic of the planned research module corresponds to the objectives of the Master program,
- a lecturer from the University of Bayreuth who is involved in the lecture canon is available as a supervisor and
- the examination board approves the external Master thesis before it starts.

If you are planning to undertake an external Master thesis, please contact the chair of the examination board at least one month in advance.

Appendix 1: Module Overview

Winter Semester (28 CP)*

Field	Low-Molecular-Weight Natural Products and Drugs						Macromol. Targets and Structures			Elective Module#
Title	Biosynthesis of Natural Products	Catalysis and Sustainable Synthesis	Stereoselective Organic Synthesis	Homogeneous Catalysis	Fundamentals of Advanced Organic Laboratory§	Instrumental Bioanalytics and Food Analysis	Molecular Modelling	Chemometrics	Solid-state Inorganic Materials: Nanochemistry	
Module	B 101	B 102	B 103	B 104	B 108	B 109	B 105	B 106	B 107	
CP	7	7	7	7	7	7	7	7	7	7
V (HPW)	2	2	2	2	-	2	2	2	2	
P (HPW)	6	6	6	6	8	5	6	5	6	
Selection	**3 of 9§**									**1**

The elective module can be chosen from the other chemical courses offered in this program or from other chemical Master programmes at the University of Bayreuth: ***Biochemistry & Molecular Biology***, ***Materials Chemistry & Catalysis*** or ***Polymer Science***.

Summer Semester (32 CP)*

Field	Low-Molecular-Weight Natural Products and Drugs					Macromol. Targets and Structures		Research Proposal
Title	Alkaloids – Biosynthesis and Total Synthesis	Drug Design	Analytics and Screening of Natural Products and Drugs	Fundamentals of Advanced Organic Laboratory§	Catalyst Design	Biophysical Chemistry – Multidimensional NMR Spectroscopy of Biomacromolecules	(Bio-)Analytics: QM and Metrology in the Chemical Laboratory	
Module	B 201	B 202	B 203	B 208	B 209	B 205	B 206	B210
CP	9	9	9	9	9	9	9	5
V (HPW)	2	2	2	-	2	2	2	9
P (HPW)	8	8	8	10	8	7	7	
Selection	**3 of 7§**							**---**

* CP = credit points; V = lecture; P = lab course; S = seminar HPW = hours per week

3./4. Semester (60 CP including Master Thesis)*

Title	Advanced Laboratory I[#]	Advanced LaboratoryII[#]	Master Thesis
Module	B 301	B 302	B 400
CP	15	15	30
S (HPW)	1	1	900 hours
P (HPW)	19	19	

[#] One Advanced Laboratory can be completed externally, e.g. abroad, in industry, at an external research institute or in a research group at the University of Bayreuth that is not involved in the lecture canon.

[§] Only one of the two 'Fundamentals of Advanced Organic Laboratory' modules can be selected. B 108 is only suitable for beginners in the winter semester, B 208 is only suitable for beginners in the summer semester.