EBERHARD KARLS
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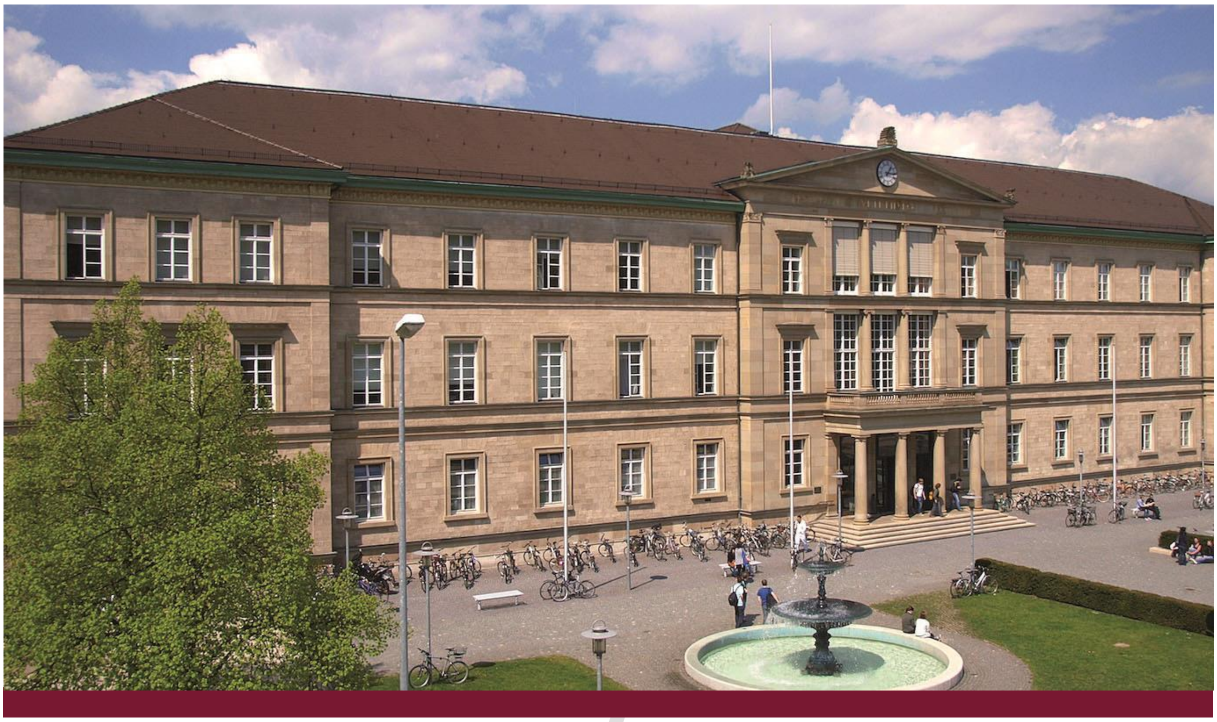
TÜBINGEN



Syllabus

Nano-Science

Master of Science (M. Sc.)

Winter term 2018/2019

Version: Febuary 1st, 2018

Faculty of Science
Department of Physics

Content

1. Entry qualification of the degree program

A prerequisite for enrollment in the master program Nano-Science is a bachelor's or equivalent degree in Nano-Science or related subject with reference to Nano-Science, or in Physics, Chemistry or Biology with a grade of 3.0 or better. In these subjects basic knowledge and basic experience in the nanoscientific core disciplines (quantum mechanics, physics of soft matter, physical chemistry, biophysics, special microscopy, nanotechnology, nanostructural sciences) have to be documented at at least 18 ECTS credits.

This master program is an international study program, which can be studied completely in English. An adequate knowledge of English (level B2 of the Common European Framework of Reference for Languages) is required. Because several elective modules are taught in German, we recommend an adequate knowledge of German on level B2 (off the Common European Framework of Reference for Languages) as well.

Further information about the entry qualifications are determined in the selections statute for the master program Nano-Science (see www.uni-tuebingen.de/de/24301).

2. Qualification objectives of the degree program

The objectives of the master program Nano-Science are derived from the individual nanoscience-relevant competencies the graduates acquired during their selected modules from the Departments of Biology, Chemistry, and Physics and the corresponding partial disciplines.

Although the degree program allows setting priorities in one of the involved disciplines (biology, chemistry, and physics), the design and the choice of its contents ensure an extraordinary interdisciplinary education of the graduates. In addition, the graduates will have internalized the different scientific cultures of the involved disciplines and their scientific approach, which enables them to interdisciplinary communication and successful work in nanoscience-relevant interfaces.

The graduates will not just be able to depict Nano-Science-relevant information and issues from the disciplines of biology, chemistry and physics, but to deeply understand and apply them in a unique way. Furthermore, the students will be able to transfer their acquired skills systematically on new nanoscience related problems and issues. It is noteworthy that the graduates of the degree program are able to analyze and to solve nanoscientific and nanotechnological problems synthetically, interdisciplinary and with a high synergetic potential, in a way the single disciplines biology, chemistry and physics are not capable of.

Furthermore, the compulsory module „Independent Studies" enables graduates integrating swiftly into a new working environment, identifying quickly nanoscience related problems, and contributing to their solution.

On the one hand, the graduates of this course program are very well prepared for academic and non-academic basic research on the field of nanoscience with its high requirements on interdisciplinarity in natural sciences. On the other hand, the graduates will be able to work successfully analytically and application oriented at the interface of applied, molecular and cell biological life science (nanobiology, nanomedical technology, personalized medicine, nanophysics and nanochemistry) in industrial and service enterprises.

3. Summary of modules

3.1 Overview by modules

(according to the module overview in the study and examination regulations)

Number	Compulsory (P)/ Elective (W)	Module title	Recommended semester	Credit points
M1	P	Basic Module Biology	1	9
M2	P	Basic Module Chemistry	1	9
M3	P	Basic Module Physics	2	9
M4	W	Focus Module 1	1-2	9
M5	W	Focus Module 2	1-2	9
M6	W	Focus Module 3	1-2	9
M7	P	Nano-Science IV	1-2	6
M8	W	Independent Studies	3	27
M9	P	Master Seminar	3-4	6
M10	P	Master Thesis	4	27

3.2 Overview by program of study

<table>
<tr><th>Semester</th><th>Credit points</th><th colspan="4"></th></tr>
<tr><td>1.</td><td>30</td><td>Basic Module Biology (M1)</td><td>Basic Module Chemistry (M2)</td><td>Focus Module 1 (M4)</td><td rowspan="2">Nano-Science IV (M7)</td></tr>
<tr><td>2.</td><td>30</td><td>Basic Module Physics (M3)</td><td>Focus Module 2 (M5)</td><td>Focus Module 3 (M6)</td></tr>
<tr><td>3.</td><td>30</td><td colspan="3">Independent Studies (M8)</td><td rowspan="2">Master Seminar (M9)</td></tr>
<tr><td>4.</td><td>30</td><td colspan="3">Master Thesis (M10)</td></tr>
</table>

4. Module descriptions

4.1. Compulsory modules

Module number: M1	**Title of module:** Basic Module Biology		**Type of module:** Compulsory module
ECTS-Points	9 ECTS		
Workload - Attendance - Self study	Workload: 270 h	Attendance: 90 h / 6 SWS	Self study: 180 h
Duration	1 semester		
Frequency	Winter semester, each academic year		
Language	German and English		
Course types	Lecture, practical course, seminar		
Content	Current Topics in Principles of Bioanalytical Methods (Lecture 2 SWS + practical course 2 SWS + seminar 2 SWS): The lecture covers the basics of modern molecular biological, biochemical and analytical methods, which will be deepened in the seminar and the practical course.		
Objectives	Students - have advanced knowledge of molecular analysis in modern biology. - are able to assess, classify and evaluate the advantages and disadvantages of the diverse methods used in modern biochemistry and molecular biology. - are able to reconstitute and to link conceptual analytical methods for processing nanoscientific and nanotechnological problems in life sciences .		
Academic performance	Regular participation in the seminar and practical course.		
Method of assessment/ grading	Written exam		
Head of the module	Dr. Üner Kolukisaoglu, Dr. Mark Stahl		
Lecturers	Dr. Üner Kolukisaoglu, Dr. Mark Stahl, and further lecturers of the Faculty of Science.		
Usability	This module forms the basis for the participation at several focus modules of the Department of Biology. Furthermore, it can be credited in several master programs of the Department of Biology.		
Prerequisites	None		

Module number: M2	Title of module: Basic Module Chemistry			Type of module: Compulsory module
ECTS-Points	9 ECTS			
Workload - Attendance - Self study	Workload: 270 h		Attendance: 90 h / 6 SWS	Self study: 180 h
Duration	1 semester			
Frequency	Winter semester, each academic year			
Language	German and English			
Course types	Lectures			
Content	<u>Sol-Gel processes (ACMn12; lecture 1 SWS):</u> Basics of the Sol-Gel process: sol, aerosol, gel, hydrolysis and condensation, gelation, drying, aging; synthesis strategies: control of the parameters: pH, temperature, water equivalent, models of growing, template synthesis, non-, meso- and macro-porous materials, options of the Sol-Gel-process: aerogels, porous materials, xerogels, dense glasses and ceramics, ceramic films and Silsesquioxane. <u>New carbon materials (OCM6; lecture 1 SWS):</u> Fullerenes, carbon nanotubes, graphs: fabrication, properties (physical, spectroscopic, chemical), functionalization (covalent and non-covalent); small pi-conjugated molecules (Acenes, Coronene, Perylendiimide, Phthalocyanine) and oligomers for OTFT, OLED and solar cells: relation between structure and properties, methods of synthesis, characterization. <u>Phenomenological material science (MWM1; lecture 2 SWS):</u> Electrons: electronic structure, band structure and band schema, density of states and charge-carrier density; phonons: dispersion and spectra, thermal properties, heat capacity, thermal expansion, heat transfer; Mechanical Properties: strain and elongation, Hook's law, elastic and plastic deformation, hardness and hardening; Electrical conductivity: metals and semi-conductors, ionic conductors, mixed conductivity, temperature dependence, alternating-current conductivity, frequency dependence; Dielectric and optical properties: polarization, dispersion phenomena. <u>Nanochemie (Lecture 2 SWS):</u> Historic nanotechnology, top-down- and bottom-up-techniques, synthesis and characterization of gold and silver nanoparticles, metal cluster in gas phase, Jellium-model, magic numbers, Wade-rules, metalloid clusters, Quantum Dots, semi-conductor nanoparticles (SCNP), quantum size effect, chemical and mechanical aspects of the colloid synthesis, chemistry and bonding behavior of important ligands, chemical control of size, shape and phase of SCNPs, optoelectronical applications of SCNPs, synthesis and characterisation of nanoporous materials, templat-assisted synthesis, metal-organic and covalent frameworks (MOFs and COFs), zeolithes, zeolith-like materials (Alumophosphates, Gallophosphates), periodic mesoporous silica, mesoporous oxides, metalalkoxides, hybrid-materials, ship-in-a-bottle-synthesis, applications of nanoporous materials.			
Objectives	Students - have advanced knowledge in the areas of coordination chemistry, metal-organic chemistry, biochemistry and solid-state chemistry. - are able to discuss and to interpret advanced techniques for the synthesis of nanoscale solids. - know how to apply different strategies for synthesis, relations between structure/properties and nanoscale materials. They know how to develop and to check the manufacture and application of such materials theoretically and practically.			
Method of assessment/ grading	Oral examination in the end of the module (details are announced at the beginning of the specific lectures).			

Head of the module	Prof. Dr. Andreas Schnepf
Lecturers	Prof. Dr. Reiner Anwander, Prof. Dr. Hermann Mayer, Prof. Dr. Holger Bettinger, Prof. Dr. Thomas Chassé, and further lecturers of the Department of Chemistry.
Usability	This module is the basis for the participation on different Focus Modules in the Department of Chemistry. In addition, it can be credited in different master programs of the Department of Chemistry.
Prerequisites	None

Module number: M3	**Title of module:** Basic Module Physics		**Type of module:** Compulsory module
ECTS-Points	9 ECTS		
Workload **- Attendance** **- Self study**	Workload: 270 h	Attendance: 90 h / 6 SWS	Self study: 180 h
Duration	1 Semester		
Frequency	Summer semester, each academic year		
Language	German and English		
Course types	Lecture and exercise course		
Content	Soft Matter Physics (Lecture 4 SWS + exercises 2 SWS): Experimental results and theoretical concepts for systems with building blocks from the nanometer to the micrometer scale. Systems: Polymers, lipids, colloids, liquid crystals. Effective interactions: electrostatics in solutions, entropic forces, chemical bonding vs. physical association. Equilibrium- and non-equilibrium thermodynamics and –statistics.		
Objectives	Students are able to describe, to interpret and to apply experimental results and theoretical concepts of soft matter physics.		
Academic performance	Regular participation in the exercise course.		
Method of assessment/ grading	Oral examination		
Head of the module	Prof. Dr. Martin Oettel		
Lecturers	Prof. Dr. Martin Oettel, PD Dr. Hans-Joachim Schöpe, Prof. Dr. Erik Schäffer		
Usability	This module is the basis for the participation on different focus modules in the Departments of Physics.		
Prerequisites	None		

Module number: M7	**Title of module:** Nano-Science IV		**Type of module:** Compulsory module
ECTS-Points	6 ECTS		
Workload **- Attendance** **- Self study**	Workload: 180 h	Attendance: 90 h / 6 SWS	Self study: 90 h
Duration	2 semesters		
Frequency	Winter semester, each academic year		
Language	German and English		
Course types	Lecture and/or seminar		
Content	Cellular Nanomachines (Lecture 2 SWS): This lecture introduces molecular machines, which work in biological cells, and explains their biophysical mechanisms. Amongst others, it introduces molecular motors, which interact with the cytoskeleton and DNA. Advanced Topics in Nanoscience (Seminar 2 SWS) Students develop and present in-depth contributions on the analysis and applications of materials on the nanoscale by themselves. Advanced Topics in Nanochemistry (Seminar 2 SWS) Students develop and present advanced current contributions on the field of synthesis and application of materials on the nanoscale by themselves.		
Objectives	Students - have advanced knowledge of biopolymers, molecular machines and their functional principles. - are able to recognize and to classify the efficiency limits and the efficiency of molecular processes and machines. - have a in-depth understanding of molecular machines that allows them to transfer physical concepts of its operating principles to nanotechnological or biotechnological applications. - are able to present, discuss, and analyze research oriented topics. - understand advanced chemical aspects in the area of nanoscience. They are able to develop, present, and classify solutions independently.		
Academic performance	Seminar presentation		
Method of assessment/ grading	Oral exam		
Head of the module	Prof. Dr. Erik Schäffer, Prof. Dr. Andreas Schnepf, Prof. Dr. Martin Oettel		
Lecturers	Prof. Dr. Erik Schäffer, Prof. Dr. Andreas Schnepf, Prof. Dr. Martin Oettel, and further lecturers of the Faculty of Science.		
Usability	This module is designed to accompany the modules M1, M2 and M3 in this master program. In addition, it can be credited in different master programs of the Departments of Biology, Chemistry, and Physics.		
Prerequisites	None		

Module number: M8	**Title of module:** Independent Studies		**Type of module:** Compulsory module
ECTS-Points	27 ECTS		
Workload - Attendance - Self study	Workload: 810 h	Attendance:	Self study:
Duration	1 Semester		
Frequency	Every semester		
Language	German and English		
Course types	Optional Lectures, seminars, exercise course, internship		
Content	Within the scope of this module the students shall study and work intensively on their specific fields of interest within nanoscience, after consultation with the supervisor of this module. These fields of interest shall be developed and defined in a dialogue with the responsible lecturer, whereat the learning objectives are specified in course schemes and objective agreements. In coordination with the supervising lecturer, these studies can be carried out at the University of Tübingen as well as at other universities or research institutes in or outside of Germany or within an internship at a company.		
Objectives	Students - have extended experience on alternative fields, e. g. in research institutions, industry, foreign countries. - link their interdisciplinary and intercultural interests and abilities. - develop and focus their study and research interests on a sub-sector of nanoscience.		
Method of assessment/ grading	Seminar presentation and/or written final report (both without grading). Further details will be announced at the beginning of this module.		
Head of the module	Prof. Dr. Erik Schäffer, Prof. Dr. Andreas Schnepf, Prof. Dr. Martin Oettel, PD Dr. Hans-Joachim Schöpe, Dr. Claudio Schrenk		
Lecturers	Lecturers of the Departments of Biology, Chemistry, and Physics.		
Usability	This module can be credited in different master programs of the Departments of Biology, Chemistry, and Physics.		
Prerequisites	Successful participation in the modules M1-M5.		

Module number: M9	Title of module: Master Seminar		Type of module: Compulsory module
ECTS-Points	6 ECTS		
Workload - Attendance - Self study	Workload: 180 h	Attendance: 90 h / 6 SWS	Self study: 90 h
Duration	2 semesters		
Frequency	Each semester		
Language	German and English		
Course types	Lecture, seminar, exercise course		
Content	Data Analysis with Statistics (Lecture 1 SWS + exercise course 1 SWS): Lecture about the basics of descriptive statistics and inferential statistics, as well as curve-fitting and regression analysis; deepening within the exercise course. Seminar (2 SWS): Within this seminar, students present their experiences and results from the modules M8 and M10.		
Objectives	Students - are able to apply common statistical procedures. - are able to exchange interdisciplinary issues, arguments, and perspectives across disciplinary borders. - make decisions on the basis of statistical data and assess the quality of these decisions. - are able to apply specific presentation techniques. They can represent and explain links between different disciplines.		
Academic performance	Regular participation in the seminar; seminar presentation.		
Method of assessment/ grading	Written exam		
Head of the module	Dr. Anita Jannasch, PD Dr. Hans Joachim Schöpe, Dr. Claudio Schrenk		
Lecturers	Dr. Anita Jannasch, PD Dr. Hans Joachim Schöpe, Dr. Claudio Schrenk		
Usability	This module is designed to accompany the modules M8 and M10 of this master program.		
Prerequisites	None		

Module number: M10	**Title of module:** Master Thesis		**Type of module:** Compulsory module
ECTS-Points	27 ECTS		
Workload **- Attendance** **- Self study**	Workload: 810 h	Attendance: 600 h	Self study: 210 h
Duration	1 semester		
Frequency	Each semester		
Language	German and English		
Course types	Master thesis		
Content	After consultation with the supervisor of the thesis.		
Objectives	Students - develop a research question by themselves. - transfer scientific and technical issues into practical research projects. - apply methods of different disciplines and are able to link them. - present the results of their research project to an audience of experts as well as interdisciplinary.		
Method of assess-ment/ grading	Written thesis (Master thesis)		
Head of the module	Lecturers of the Departments of Biology, Chemistry, and Physics.		
Lecturers	Lecturers of the Departments of Biology, Chemistry, and Physics.		
Usability	-		
Prerequisites	Successful participation in the modules M1-M8.		

4.2. Elective modules

The focus modules M4, M5 and M6 have to be selected from the following elective modules of the Departments of Biology, Chemistry, and Physics. All three modules have to be selected at least from two subject areas.

Elective modules of the Department of Biology

Module number: BWMA/B	**Title of module:** Focus Module Biology A/B	**Type of module:** Elective Module
ECTS-Points	9 ECTS	
Workload **- Attendance** **- Self study**	In total: 270 h	
Duration	1 semester	
Frequency	Each semester	
Language	German and English	
Course types	Lecture, seminar, exercise course, practical lecture	
Content	The module consist of courses offered by the master programs Cellular and Molecular Biology of Plants, Microbiology, Molecular Cell Biology & Immunology, and Neurobiology with reference to nanoscience and nanotechnology. Furthermore, courses of the Department of Biology are included that are offered specifically for the master program Nano-Science. From these courses, at least so many have to be completed successfully that they sum up to a minimum of 6 SWS.	
Objectives	Students - are able to analyze and classify specific conditions including those in the area of microbiology, molecular cell biology and immunology, neurobiology, and developmental genetics of plants, depending on the chosen lecture. - are able to transfer this knowledge to nanoscientific issues.	
Academic performance	Depending on the course: participation, presentation, scientific text, essay, written protocol.	
Method of assessment/ grading	Depending on the course: written exam, presentation or oral exam	
Head of the module	Dr. Üner Kolukisaoglu	
Lecturers	Lecturers of the Department of Biology.	
Usability	This module can be credited in several master courses of the Department of Biology.	
Prerequisites	Depending on the course: advanced knowledge in biology.	

Module number: BWMC	**Title of module:** Focus Module Biology C		**Type of module:** Elective Module
ECTS-Points	9 ECTS		
Workload - Attendance - Self study	Workload: 270 h	Attendance: 180 h	Self study: 90 h
Duration	1 semester		
Frequency	Each semester		
Language	German and English		
Course types	Practical project		
Content	Practical project work in a laboratory of the Department of Biology.		
Objectives	Students - know how to use and to apply molecular lab techniques. - are able to carry out independent project tasks. - know how to analyze and to assess these project tasks. - are able to apply qualified techniques for the presentation of their research results.		
Method of assessment/ grading	Seminar presentation (without grading) and project report; details will be announced at the beginning of the course.		
Head of the module	Prof. Dr. Erik Schäffer		
Lecturers	Lecturers of the Department of Biology.		
Usability	This module can be credited in several master courses of the Department of Biology.		
Prerequisites	None		

Elective modules of the Department of Chemistry

Module number: CWMA	**Title of module:** Focus Module Chemistry A		**Type of module:** Elective Module
ECTS-Points	9 ECTS		
Workload **- Attendance** **- Self study**	Workload: 270 h	Attendance: 90 h / 6 SWS	Self study: 180 h
Duration	Two semesters		
Frequency	Every semester		
Language	German		
Course types	Lectures		
Content	Out of the following lectures, at least so many have to be completed successfully that they sum up to a minimum of 6 SWS. <u>Advanced metal-organic chemistry 1 (ACM1; lecture 2 SWS)</u> Reaction mechanisms of coordinated compounds, Carbene complexes, selected examples of homogeneous catalysis, weakly coordinating anions. <u>Advanced metal-organic chemistry 2 (ACMn2; lecture 1 SWS):</u> Structure, properties and reactivity of selected metal-organic reagents, in particular σ-bounded alkyl and aryl compounds of the groups 1 to 4 as well as 11 and 12; Opportunities to control and to influence the reactivity and selectivity during its use within the synthesis. <u>Metal-organic chemistry of Lanthanides (ACMn3; lecture 1 SWS):</u> History of rare-earth elements, production/ separation of lanthanides, Lanthanide contraction, synthesis of inorganic compounds (Hydrides, Borides, Carbides, Nitrides, Oxides, Halogenides, Nitrates), synthesis of metal-organic compounds (Alkoxides, Amides, Alkyles, Cyclopentadienyles), new synthesis strategies, ligands, nanostructures materials. <u>Advanced solid state chemistry (ACMn4; lecture 1 SWS):</u> Syntheses and crystal structures of inorganic solid state rare-earth elements and transition metals, e.g. Hydrides, Borides, Carbides, Nitrides, Oxides, Granates, Oxocuprates, Chalkogenides, Halogenides, metal-rich systems and clusters, comparison of the chemical bonds of d- and f-metals, magnetism, electronic structure, f-d-configuration transition, bonding characteristics, spectroscopy, luminescence, structure-property relationships and applications. <u>Element organic chemistry 1 (ACMn6; lecture 1 SWS):</u> Element organic chemistry of the main group elements, synthesis, structure, characteristics, and MO theoretical description of main group organyles, 4z2e bonds, structural chemistry of Li-Organyles, alkali-metal-mediated-metalation, Production and structural chemistry of Al-organyles, super-acids, Hammets acidity function, weak coordinating anions, polycations of Chalkogenes. <u>Element organic chemistry 2 (ACMn7; lecture 1 SWS):</u> Element organic chemistry of the main group elements in lower oxidation states, subvalent halides of the main group elements, co condensation technique, element-element multiple bounds, CGMT model, Zintl anions, pseudoelement concept, cluster connections. <u>Methods of inorganic research 1 (ACMn21; lecture 1 SWS):</u> Advanced NMR spectroscopy, multi nuclear experiments, temperature dependent studies, decoupling techniques.		

	Methods of inorganic research 2 (ACMn22; lecture 1 SWS): Electronic absorption and emission spectroscopy, IR- and Raman-spectroscopy, Mößbauer spectroscopy, synthetic and spectroscopic aspects of isotopic label-ling. After prior consultation with the head of the module, students can choose a course of the focus modules chemistry B/C/D, alternatively.
Objectives	Students - own advanced knowledge in the areas coordination chemistry, metal organic chemistry, organic chemistry, main group chemistry, and solid state chemistry, depending on the chosen courses. - are able to compare and assess methods of the areas mentioned above. - are able to link these methods for developing new techniques. - are able to describe, classify and apply advanced techniques for the analyses of nanoscale and crystalline solids.
Academic performance	Regular participation.
Method of assessment/ grading	Oral exam
Head of the module	Prof. Dr. Andreas Schnepf, Dr. Claudio Schrenk
Lecturers	Lecturers of the Department of Chemistry.
Usability	This module can be credited in several master courses of the Department of Chemistry.
Prerequisites	None

Module number: CWMB	**Title of module:** Focus Module Chemistry B		**Type of module:** Elective Module
ECTS-Points	9 ECTS		
Workload - Attendance - Self study	Workload: 270 h	Attendance: 90 h / 6 SWS	Self study: 180 h
Duration	Two semesters		
Frequency	Every semester		
Language	German		
Course types	Lectures		
Content	Out of the following lectures, at least so many have to be completed successfully that they sum up to a minimum of 6 SWS. <u>Physical organic chemistry (OCM2; lecture 2 SWS):</u> Bonding theories (field of forces, VB, MO), thermochemistry (increment systems), conformation analysis, electronic effects, solutions and non-covalent interactions, molecular recognition and supra molecular chemistry; Kinetics: Principles and reaction mechanisms, isotopy effects, substituent effects, linear free enthalpy relations; elucidation of mechanisms. <u>Synthesis strategies (OCM3; lecture 2 SWS):</u> Reasons for syntheses, retrosynthetic concepts (convergent versus linear syntheses, Transform, Retron, Synthon), FGI (functional group inter-conversions), access to dissonant systems (polarity reversal, Cyclopropan, dissonant components, hemolytic splitting), syntheses of chains (C-C links, C=C links, Usability of alkines, relocations), synthesis strategies of circles, annulated systems and polycyclescles. <u>Reactive intermediates (OCM5; lecture 2 SWS):</u> Carbocations (carbenium ions and carbonium ions), carbanions, radicals and diradicales, carbenes, nitrenes: production of reactive intermediates (photochemical, thermal, chemical), energy and structure (gas phase vs. solution, hyper conjugation, classical and non-classical), proof of evidence and spectroscopy (absorption chemistry, isolation in inert media, time-resolution spectroscopy), reaction characteristics: rearrangements, intermolecular reactions; applications in synthesis (metal-mediated production). <u>Reactions and functional groups (OC1b2; lecture 2 SWS):</u> Reactions of carbonyl bonds and carboxylic acid derivatives, relocations, reductions and oxidations. After prior consultation with the head of the module, students can choose a course of the focus modules chemistry A/C/D, alternatively.		
Objectives	Students - own advanced knowledge in the areas of organic chemistry, synthesis planning, and the performance of syntheses, depending on the chosen courses. - are able to contrast and to assess methods of the areas mentioned above. - are able to link these methods for developing new techniques.		
Academic performance	Regular participation		
Method of assessment/ grading	Depending on the course: written of oral exam.		
Head of the module	Prof. Dr. Andreas Schnepf, Dr. Claudio Schrenk		
Lecturers	Lecturers of the Department of Chemistry.		
Usability	This module can be credited in several master courses of the Department of Chemistry.		
Prerequisites	None		

Module number: CWMC	Title of module: Focus Module Chemistry C		Type of module: Elective Module
ECTS-Points	9 ECTS		
Workload - Attendance - Self study	Workload: 270 h	Attendance: 90 h / 6 SWS	Self study: 180 h
Duration	2 semesters		
Frequency	Each semester		
Language	German		
Course types	Lectures		
Content	Out of the following lectures, at least so many have to be completed successfully that they sum up to a minimum of 6 SWS. <u>Cross-cutting theoretical concepts of spectroscopy (PCM1; lecture 2 SWS):</u> The lecture researches the dynamics of interactions between a 2-niveau system and electromagnetic (E.M.) radiation based on the time-depending Schroedinger equation. Four chapters are drawn up with the following keywords: 1) weak broad banded stimulation: Fermi´s golden rule, spectral density of states, connection with Einstein coefficient. 2) 2-niveau system in resonance with strong E.M. radiation: Rabi-oscillations, time-dependent inducted transition moment. 3) Description of induced polarization, relaxation mechanisms, free induction decay, coherent and incoherent emission (fluorescence), homogeneous and inhomogeneous line broadening, density matrix formalization, pulsed excitation, echo spectroscopy, 3-niveau system, saturation. 4) magnetism, Bloch´s equation, chemical shift, transversal and longitudinal relaxation. <u>Applications based on physical chemistry: solids, interfaces, model systems (PCM2; lecture 2 SWS):</u> The lecture deepens statistical thermodynamics, calculation of properties of important model systems based on quantum statistics. It develops the basics of the description of lattice vibrations and electronic properties of solids based on structure and symmetry. Starting with the band model, it describes electronic and optical characteristics of metals, semiconductors, and insulators. The lecture discusses the interactions of electromagnetic radiation with solids and their applications. It deals with the real structure of solids with thermodynamic rules, and it analyses the processes at interfaces, equilibria, as well as charge and material transport. <u>Optical microscopy (PCM8; lecture 2 SWS):</u> Optical microscopy: resolution limit, confocal microscopy, far-field and near-field of a Hertzian dipole, field distribution in the focal point with radial- and azimuthal illumination. Optical single-molecule spectroscopy: detection limits, single photons, time-correlated single photon counting, photon statistics, optical signals of single molecules vs. ensemble, surface-enhanced Raman-spectroscopy, Nanoparticles and Q-Dots, methods to overcome the resolution limit: 1) with diffraction limiting optics (STED, etc.), 2) with evanescent optical fields, optical characteristics of metals, particle-plasmons, optical antennae. Scanning probe microscopy: atomic force microscopy, scanning tunneling microscopy, tip-enhanced optical near-field microscopy and –spectroscopy. <u>Methods of quantum chemistry (TCM1; lecture 2 SWS):</u> Systematic deduction of Hartree-Fock theory with the postulates of quantum mechanics; electron correlation methods: configuration interaction, Møller-Plesset perturbation theory, coupled cluster theory and basics of the density-functional theory.		

	After prior consultation with the head of the module, students can choose a course of the focus modules chemistry A/B/D, alternatively.
Objectives	Students - have advanced knowledge in the areas of physical chemistry, theoretical chemistry and characterization of materials, depending on the chosen courses. - are able to contrast, assess, and link the methods of the above mentioned areas for developing new techniques.
Academic performance	Regular participation
Method of assessment/ grading	Oral exam
Head of the module	Prof. Dr. Andreas Schnepf, Dr. Claudio Schrenk
Lecturers	Lecturers of the Department of Chemistry.
Usability	This module can be credited in the different master programs of the Department of Chemistry.
Prerequisites	None

Module number: CWMD	Title of module: Focus Module Chemistry D		Type of module: Elective Module
ECTS-Points	9 ECTS		
Workload - Attendance - Self study	Workload: 270 h	Attendance: 90 h / 6 SWS	Self study: 180 h
Duration	2 semesters		
Frequency	Every semester		
Language	German		
Course types	Lectures		
Content	Out of the following lectures, at least so many have to be completed successfully that they sum up to a minimum of 6 SWS. Molecular Electrochemistry (ANM3; lecture 2 SWS): Electrode reactions, transport processes at electrodes, electron transfer to molecules, electrochemical cells; electro analysis, polarography, chrono-amperometry, cyclic voltametry, spectro electrochemistry, electrochemical Quartz microbalance and scanning electron microscopy, methods for quantitative and qualitative identification of redox active molecules; electrochemical reaction mechanisms, simulation; compound conversion and electro synthesis, electrochemical bond formation and separation, electrochemical induced substitutions and protective groups techniques, electrochemical generated bases, mediated and electro enzymatic reactions, paired, combinatorial and industrial electrolysis. Sensors (ANM7; lecture 2 SWS): General introduction to gas sensors, gas sensor performance, gas sensors based on semiconducting metal oxides (SMOX), Operando SMOX, electrochemical cell, gas sensors based on polymers, polymer technology, Operando polymers, chemometrics, gas sensors: applications (prerequisite are taught in PCM6 and PCM9). Modern NMR-methods in Organic Chemistry (ANM14; lecture 1 SWS): Extended theory of NMR-spectroscopy: complex pulses and its description with product operations (product operation formalism), overview of two dimensional homo- and heteronuclear mapping techniques: homonuclear correlated NMR-spectroscopy: H,H correlation spectroscopy (H,H-COSY), total correlation spectroscopy (TOCSY); heteronuclear correlated spectroscopy: C,H correlation spectroscopy (C,H-COSY), heteronuclear single quantum coherence spectroscopy (HSQC), heteronuclear multiple quantum coherence spectroscopy (HMQC), heteronuclear multiple bond correlation spectroscopy (HMBC); detection of spatial interactions: nuclear Overhauser effect spectroscopy (NOESY), rotating frame Overhauser effect spectroscopy (ROESY), transferred nuclear Overhauser effect spectroscopy (tr-NOESY), saturation transfer difference spectroscopy (STD); special NMR-methods: diffusion ordered NMR-spectroscopy (DOSY), residual Dipolar couplings (RDCs) as NMR-parameter for the structure elucidation of organic molecules. Methods of inorganic research 4 (ACMn24; lecture 1 SWS): NMR-interactions in solid bodies: anisotropy of chemical shifts, direct dipole-dipole linking, indirect spin-spin linking, core-quadrupol linking; magic-angle-spinning; homonuclear decoupling; intersection polarization; single crystal-NMR, powdery samples, amorphous systems; dynamics. Methods of inorganic research 5 (ACMn25; lecture 1 SWS): Pulse techniques for the correlation or separation of interactions, mapping techniques.		

	Methods of inorganic research 6 (ACMn26; lecture 1 SWS): Part 1: Practical course and basic principles of X-ray diffraction with reference examples, necessary conditions, correct interpretation of the results and quality estimations, possible pitfalls and problems. Part 2: further development of the method (multipol sophistication), visualization and analysis of electron densities due to high-resolution X-ray diffraction: analysis of chemical bonds and interatomic interactions in the experiment (atoms-in-molecules concept), determination of chemical and physics characteristics (atomic charges, dipole, Lewis-acids and Lewis-basic centers), current research examples. After prior consultation with the head of the module, students can choose a course of the focus modules chemistry A/B/C, alternatively.
Objectives	Students - have advanced knowledge in physical and analytical chemistry, characterization, and measurement analysis, depending on the chosen courses. - can contrast, assess, and link the methods of the above mentioned areas to develop new techniques.
Academic performance	Regular participation
Method of assessment/ grading	Oral exam
Head of the module	Prof. Dr. Andreas Schnepf, Dr. Claudio Schrenk
Lecturers	Lecturers of the Department of Chemistry.
Usability	This module can be credited in the different master programs of the Department of Chemistry.
Prerequisites	None

Module number: CWME	**Title of module:** Focus Module Chemistry E		**Type of module:** Elective Module
ECTS-Points	9 ECTS		
Workload - Attendance - Self study	Workload: 270 h	Attendance: 180 h	Self study: 90 h
Duration	1 semester		
Frequency	Each Semester		
Language	German and English		
Course types	Practical course		
Content	Practical project work in a laboratory of the Department of Chemistry.		
Objectives	Students - are able to use and apply modern chemical laboratory techniques. - are able to take part in project work, independently. - are able to analyze and assess their results. - apply qualified techniques to present their research results.		
Method of assessment/ grading	Seminar presentations and project report. Details will be announced at the beginning of the lecture.		
Head of the module	Prof. Dr. Andreas Schnepf, Dr. Claudio Schrenk		
Lecturers	Lecturers of the the Department of Chemistry.		
Usability	This module can be credited in the different physics master programs of the Department of Chemistry.		
Prerequisites	Focus module chemistry A, B, C or D.		

Elective modules of the Department of Physics

Module number: PWMA	**Title of module:** Focus Module Physics A		**Type of module:** Elective Module
ECTS-Points	9 ECTS		
Workload **- Attendance** **- Self study**	Workload: 270 h	Attendance: 90 h / 6 SWS	Self study: 180 h
Duration	1 semester		
Frequency	Winter semester, each academic year		
Language	German		
Course types	Lecture and exercise course		
Content	<u>Condensed Matter (BMEPKM; lecture 4 SWS + exercise course 2 SWS):</u> Structure, dynamics and mechanics of condensed matter (crystals, liquid crystals, liquids). Electronic structure of solids I: Free electron gas and Bloch-waves, crystal-lattice, phonons. Electronic structure of solids II: Energy bands, metals, semiconductors, isolators; order phenomena and phase transitions, magnetism, supra conductivity.		
Objectives	Students - have advanced knowledge in physics of condensed matter. - understand the physical basics of material properties. - link the connections between theory and application. - are able to combine and link experimental analytical methods conceptually for processing issues in material science and nanotechnology.		
Academic performance	Regular participation in the exercise course.		
Method of assessment/ grading	Written exam		
Head of the module	Prof. Dr. Frank Schreiber, Prof. Dr. Reinhold Kleiner		
Lecturers	Prof. Dr. Frank Schreiber, Prof. Dr. Reinhold Kleiner		
Usability	This module can be credited in the physics bachelor program.		
Prerequisites	None		

Module number: PWMB	**Title of module:** Focus Module Physics B		**Type of module:** Elective Module
ECTS-Points	9 ECTS		
Workload **- Attendance** **- Self study**	Workload: 270 h	Attendance: 90 h / 6 SWS	Self study: 180 h
Duration	1 semester		
Frequency	Summer semester, each academic year		
Language	German		
Course types	Lecture and exercise course		
Content	Physics of nanostructures (BMEPPN; lecture 4 SWS + exercise 2 SWS): Introduction: Solid state physics in reduced dimensions; manufacturing techniques and methods for characterization; semiconductor-interfaces and building units; semiconductor-nanostructures; interfaces in metallic systems and building units (magnetic and supraconducting); metallic, supraconducting and magnetic nanostructures; interfaces between isolators; organic systems and biological materials; carbon-based systems (Carbon Nanotubes and Graphene); micro machines.		
Objectives	Students - have advanced knowledge in physics of nanostructures and interfaces. - understand the physical basics of properties on the nanoscale. - are able to link the connections between theory and application of nanomaterials. - are able to combine and link experimental analytical methods conceptual for processing issues in material science and nanotechnology.		
Academic performance	Regular participation in the exercise course.		
Method of assessment/ grading	Written exam		
Head of the module	Prof. Dr. Dieter Kölle, Prof. Dr. David Wharam		
Lecturers	Prof. Dr. Dieter Kölle, Prof. Dr. David Wharam, and lecturers of the Department of Physics.		
Usability	This module can be credited in the physics bachelor program.		
Prerequisites	None		

Module number: PWMC	**Title of module:** Focus Module Physics C		**Type of module:** Elective Module
ECTS-Points	9 ECTS		
Workload **- Attendance** **- Self study**	Workload: 270 h	Attendance: 90 h / 6 SWS	Self study: 165 h
Duration	2 semesters		
Frequency	Each semester		
Language	German and English		
Course types	Lecture, practical course and exercises		
Content	Out of the following courses, at least so many have to be completed successfully that they sum up to a minimum of 6 SWS. <u>Physics of molecular and biological nanostructures (Lecture 2 SWS)</u> Physical basics and applications of biological and bio-inspired systems: Cellular systems, DNA Computer, Biosensors, Microfluidics, Neurons. <u>NanoBioPhysics and Scanning Probe Microscopy (Lecture 2 SWS)</u> Families of scanning probe microscopes, measurement of small forces, AFM technology, elastic properties of nanostructures, mechanical resonators, friction on the nanoscale, magnetic nanostructures, mechanical unfolding of single molecules, molecular glues, bio mineralization. <u>Physics of molecular and biological matter (Lecture 2 SWS)</u> Introduction: What is molecular, soft and biological matter; Interactions in molecular and biological systems; H-bonds and DNA; van-der-Waals-forces; water: special properties and role as solvent; ions in solution and Debye length; hydrophobic forces; entropic forces; selected organic and biological matter and its properties; polymers, DNA, proteins; liquid crystals; surface active molecules; organic thin film systems, lipid layers; organic dyes and semiconductors, conductive polymers. <u>Experimental Techniques in Nanoscience and Biophysics (Lecture 2 SWS)</u> Introduction in experimental techniques, error statistics, general concepts, Spectroscopy, microscopy, scattering, preparation, vacuum technique. <u>Numerical Techniques I (Lecture + exercises 2 SWS)</u> Introduction to MATLAB: plotting, program structures, fitting, data analysis. <u>Numerical Techniques II (Lecture + exercises 2 SWS)</u> Visualization, simple simulations, process control. <u>Electron microscopy and spectroscopy (Lecture 2 SWS)</u> Basics of diffraction, wave-particle-dualism, features of electron microscopes and their components, lens aberrations and resolution power of electron-optical lenses, crystallography, kinematic and dynamic diffraction theory in the case of two rays, crystallographic defect analysts and stereomicroscopy, elastic and inelastic scattering theory, spectroscopy, case studies. <u>Electron microscopy Practical course (Practical course 3 SWS)</u> Adjustment of REM and TEM, secondary electron figures and EDX-analysis with REM, dynamic diffraction and two-ray-cases with TEM, defined tilting of specimen in TEM, adjustment of diffraction pictures, recording of pictures with the CCD-Camera, EDX-Spectroscopy with TEM.		
Objectives	Students - are able to describe, classify and apply the basics of nanophysics or scanning- and transmission electron microscopy, depending on the chosen courses. - are able to record the incoming data and analyze them numerically.		

Method of assess-ment/ grading	Depending on the chosen courses: oral presentation, report or oral exam, solving of exercises. Details will be announced at the beginning of the module. At least 4 SWS (6 ECTS) have to be graded.
Head of the module	Prof. Dr. Martin Oettel
Lecturers	Prof. Dr. Tilman Schäffer, Prof. Frank Schreiber, Prof. Dr. Oliver Eibl, Prof. Dr. Martin Oettel, Dr. Alexander Gerlach, Dr. Hans-Joachim Schöpe, Dr. Fajun Zhang
Usability	This module can be credited in the physics bachelor program.
Prerequisites	None

Module number: BWMD	**Title of module:** Focus Module Physics D		**Type of module:** Elective Module
ECTS-Points	9 ECTS		
Workload **- Attendance** **- Self study**	Workload: 270 h	Attendance: 180 h	Self study: 90 h
Duration	1 semester		
Frequency	Each semester		
Language	German and English		
Course types	Practical course		
Content	Practical project work in a laboratory of the Department of Physics.		
Objectives	Students - apply and analyze physical laboratory techniques and/or numerical methods from the field of theory of soft matter/statistical physics. - work independently on research projects. - are able to analyze and assess their achieved results. - apply qualified techniques to present research results.		
Method of assess-ment/ grading	Seminar presentations and project report. Details will be announced at the begin-ning of the lecture.		
Head of the module	Prof. Dr. Martin Oettel		
Lecturers	Lecturers of the Department of Physics.		
Usability	This module can be credited in different programs of the Department of Physics		
Prerequisites	For this module, the students need an individual admission from a lecturer of the Department of Physics and a verification from the Head of the module.		