**Requirements for the Masters Program in Chemistry**

**Department of Biology, Chemistry and Pharmacy**

**Freie Universität Berlin**

Non-official Translation of the Study Regulations and the Examination Regulations for the Master's Program in Chemistry from 14 March 2013

(only the German version of these regulations - published in FU-Mitteilungen [Gazette of the Freie Universität Berlin] No. 38 / 2013 - is valid)

**In accordance with** Section 14 paragraph 1 no. 2 of the Teilgrundordnung (Erprobungsmodell) [Partial University Constitution (Trial version)] of Freie Universität Berlin of 27 October 1998 (FU Mitteilung [Gazette of Freie Universität Berlin] 24/1998), the Department Council of the Department of Biology, Chemistry and Pharmacy of Freie Universität Berlin issued the following study regulations for the Master's Program in Chemistry of the Department of Biology, Chemistry and Pharmacy of Freie Universität Berlin on 14 March 2013:[1]

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**Annexes:**



[1] The executive board of Freie Universität Berlin confirmed these regulations on 26 August 2013.

## Section1
## Area of application

(1) These regulations apply to the aims, content and structure of the Masters program in Chemistry based on the examination regulations for the Master's program of 14 March 2013.

(2) This is a consecutive masters program in accordance with Section 23 paragraph 3 No. 1 a) of the law regulating higher education institutions in Berlin (Berliner Hochschulgesetz [Berlin Higher Education Act] – BerlHG) of 26 July 2011 (GVBI [Law and Ordinance Gazette] p. 378). The program is bilingual (German and English) and research oriented.

## Section 2
## Qualification aims

(1) Graduates have expanded and deepened their knowledge in the three topic areas of Inorganic Chemistry, Organic Chemistry and Physical Chemistry. They have strengthened their specialized knowledge in a topic area in chemistry of their own choice or gained cross-cutting qualifications by taking non-chemistry modules. They should be familiar with the terminologies of chemistry, its strengths and limitations, and should be able to apply their knowledge to new situations, possibly in interdisciplinary contexts. They have gained the knowledge and practical skills relating to the current state of research in selected fields. They can analyze chemical issues and assess them critically, developing independent solution strategies and estimating their impact in a wider context.

(2) Graduates can act on their own responsibility and independently fill gaps in their knowledge. They are able to develop creative solutions for scientific problems . Their skills include networking ability [?] and taking interdisciplinary aspects into account. They can coherently present project findings orally and in writing – also in English [in English and German?]– and can explain topics in chemistry to a range of different audiences in a way they can understand, for example younger students or a wider non-university public. They are able to form hypotheses, examine them critically and defend them in argument. They can communicate and cooperate in teams – including international teams - in a target-oriented way and sensitively take gender and diversity into account.

(3) Graduates are qualified to work towards a doctorate in Chemistry, to take up chemical research and development, chemical process and application technologies, production and analysis or to start their own company. The masters program also prepares graduates to gain further qualifications, e.g. in the patents field, in knowledge management, sales and marketing, education, management, the IT field, consulting or the media field.

## Section 3
## Program content

(1) Chemistry examines and describes the world's basic matter and the transformations of materials which occur in it. Modern chemistry is an experimental science which observes the world of matter and derives methods and concepts from it, develops them further and makes them usable for shaping the world. The masters program therefore focuses on the current state of research. Students learn concepts and experimental and theoretical methods by which the structure and behavior of atoms, molecules and solid-state bodies can be examined, described and predicted, complex molecules can be synthesized and associations of molecules analyzed. The program includes both theoretical and instrumental methods of analytical proof and explanation of structures as well as the theoretical background necessary to understand and apply them. Research projects give students the opportunity to apply the latest research methods and ideas to current research topics being examined in working groups. The program's elective modules provide the opportunity to link chemistry with other disciplines such as mathematics, physics, biology, medicine or materials sciences.

(2) The students learn to familiarize themselves with new issues independently and to research the current state of scientific knowledge on the subject. Using lectures and reports, they learn to

examine these issues, to report on them in written or oral form accurately and appropriately to a particular audience and to defend their findings in discussion. They learn to handle gender and diversity issues in practical groups and through supervising tutorials. Through their work with scientific research groups in the Institute for Chemistry and Biochemistry, whose membership is usually international, they learn – among other things - to take cultural differences into account.

## Section 4
## Structure and organization

(1) Students should obtain a total of 120 credit points (CP) [Leistungspunkte (LP)] in the masters program. The master's program is divided into:

1. a compulsory elective area comprising 35 CP,
2. a project area comprising 20 to 30 CP,
3. a specialization area comprising 10 to 20 CP,
4. an elective area comprising 15 CP
5. the master's thesis including lecture comprising 30 CP

(2) The modules offered in the compulsory elective area focus on the understanding of modern experimental and theoretical developments in chemistry, to give students a wide basic scientific qualification. The compulsory elective area is divided into three topic areas, Inorganic Chemistry, Organic Chemistry and Physical and Theoretical Chemistry, comprising 10 CP each, and a cross-topic area comprising 5 CP.

1. In the Inorganic Chemistry topic area, two modules comprising a total of 10 CP must be selected from the following modules and completed:

- Module: Coordination Chemistry (5 CP)
- Module: Principles of Radiochemistry (5 CP)
- Module: Organometallic Chemistry (5 CP)
- Module: Modern Methods of Structure Determination (5 CP)

2. In the Organic Chemistry topic area, two modules comprising a total of 10 CP must be selected from the following modules and completed:

- Module: Advanced Synthetic Methods (5 CP)
- Module: Physical Organic Chemistry (5 CP)
- Module: Stereoselective Synthesis (5 CP)
- Module: Natural Products Chemistry and Advanced Bioorganic Chemistry (5 CP)

3. In the Physical and Theoretical Chemistry topic area, two modules comprising a total of 10 CP must be selected from the following modules and completed:

- Module: Quantum Chemistry (5 CP)
- Module: Solids and Interfaces (5 CP)
- Module: Statistical Thermodynamics (5 CP)
- Module: Modern Methods in Spectroscopy (5 CP)

4. In addition, one of the following modules must be selected and completed in the cross-topic area:

- Module: Scientific Lectures and Presentations in Chemistry (5 CP)
- Module: Teaching Chemistry (5 CP)

(3) In order to gain an understanding of current experimental and theoretical developments, research projects in chemical subjects comprising 20 to 30 CP must be taken in the project area; these are offered through working groups at the Institute of Chemistry and Biochemistry at Freie Universität Berlin. Students must complete research projects in at least two working groups, including at least 15 CP in the topic areas of Inorganic Chemistry, Organic Chemistry or Physical and Theoretical Chemistry. Other research projects may also be selected from other

topic areas in chemistry. The choice of working group determines the topic area. Students may apply to take a research project outside the Institute of Chemistry and Biochemistry; the examination committee decides whether the application is accepted. The following modules are offered as research projects, which may be taken more than once within the scope of the credit points to be gained:

- Module: Research project in a scientific research group (5 CP)
- Module: Research project in a scientific research group (10 CP)
- Module: Research project in a scientific research group (15 CP)

(4) In the specialization area comprising 10 to 20 CP, students deepen their knowledge and specialize in a research-oriented or application-oriented topic area in chemistry in line with their individual skills and aims. Modules from the compulsory elective area as in paragraph 2 which have not yet been taken may be selected as specialization modules; the following modules in the topic areas given may also be selected:

1. Topic area Analytical Chemistry
   - Module: Scientific Measurement Data Collection and Processing (5 CP)
   - Module: Instrumental Analysis for Structure Assignment in Organic Chemistry (5 CP)

2. Topic area Inorganic Chemistry
   - Module: Applied Radiochemistry and Radiation Protection Course (5 CP)
   - Module: Bioinorganic Chemistry (5 CP)
   - Module: Modern Aspects of Non-metal Chemistry (5 CP)

3. Topic area Biochemistry:
   - Module: Principles of Biochemistry (5 CP)
   - Module: Current Topics in Biochemistry (5 CP)
   - Module: Introduction to Advanced Biochemistry (10 CP)

4. Topic area Macromolecular Chemistry:
   - Module: Introduction to Macromolecular Chemistry (5 CP)
   - Module: Advanced Macromolecular Chemistry (5 CP)

5. Topic area Organic Chemistry:
   - Module: Total Syntheses and Synthesis Design (5 CP)
   - Module: Supramolecular Chemistry (5 CP)
   - Module: Homogeneous Transition Metal Catalysis (5 CP)
   - Module: Systems Chemistry (5 CP)

6. Topic area Physical Chemistry:
   - Module: Chemical Processes on Surfaces and Interfaces (5 CP)
   - Module: Applied Electrochemistry: Batteries, Fuel Cells and other Applications (5 CP)
   - Module: Electron Structure Methods (5 CP)

7. Topic area Theoretical Chemistry:
   - Module: Molecular Dynamics (5 CP)
   - Module: Quantum Chemistry: Correlation Methods (5 CP)
   - Module: Density Functional Theory (5 CP)
   - Module: Relativistic Quantum Chemistry (5 CP)
   - Module: Quantum Reaction Dynamics (5 CP)

8. Topic area Environmental Chemistry:
   - Module: Environmental Chemistry: Air, Water, Soils (5 CP)
   - Module: Environmental Chemistry: Energy and Special Atmospheric Chemistry (5 CP)

(5) In the elective area comprising 15 CP, the students can either deepen their expertise in chemistry further or gain cross-cutting qualifications or professional knowledge and skills beyond the field of chemistry, depending on their interests and career aims. In addition to

modules in the compulsory elective and specialization areas, students may select the module Modern Aspects of Chemistry (5 CP) or modules from the following topic areas:

- Analytical quality assurance
- Bioinformatics
- Biology
- Chemical information and literature research
- Law on chemicals and patent law
- German language courses for students who are not German native speakers
- Advanced English language courses
- Ethical and social aspects of the sciences
- Gender and Diversity research
- Computer science and computer courses
- Business studies
- Mathematics
- Physics
- Journalism and communication studies
- Toxicology
- Environmental technology

(6) Modules taken in one of the topic areas in paragraph 1 nos. 2 to 4 may not exceed a total of 30 CP.

(7) The examination committee will decide whether to credit modules in specialization and elective areas not listed in these regulations. Students should apply to the examination committee before taking such a module; the attainments gained should be related to the context of the program. Modules at bachelor level may be taken in the fields listed in paragraph 1 nos. 1 to 4 up to a total of 15 CP.

(8) Modules identical or very similar in content to those already completed in the Bachelor program in Chemistry of the Department of Biology, Chemistry and Pharmacy of Freie Universität Berlin may not be selected as part of the master's program. In doubtful cases, the examination committee will decide; the point should be clarified before taking the module.

(9) The module descriptions in Annex 1 give information about content, qualification aims, teaching and learning units, time required, forms of active participation, usual duration, how often and at which institutions the module is offered. You are referred to the study regulations for the Bachelor's program in Chemistry at the Department of Biology, Chemistry and Pharmacy at Freie Universität Berlin for the modules Principles of Radiochemistry, Introduction to Macromolecular Chemistry, Molecule Dynamics, and Environmental Chemistry: Air, Water, and Soils. You are referred to the study regulations for the Bachelor's program in Biochemistry at the Department of Biology, Chemistry and Pharmacy at Freie Universität Berlin for the modules Principles of Biochemistry and Current Topics in Biochemistry. You are referred to the study regulations for the Master's program in Biochemistry at the Department of Biology, Chemistry and Pharmacy at Freie Universität Berlin for the module Introduction to Advanced Biochemistry. You are referred to the relevant study regulations for the modules you can select in accordance with paragraph 5 of these regulations; you will be informed about the relevant regulations when you are informed about the modules you can select.

(10) The sample study schedule in Annex 2 gives information about the recommended degree program table[i].

## Section 5
## Teaching and learning units

The following types of teaching units are provided in the Master's program:

1. Lectures (L) cover general concepts and theoretical principles. They deepen the student's knowledge of the subject, give confidence in using technical terminology and teach advanced concepts and methods of scientific analysis. They examine the current state of research and

highlight controversial aspects of current research. The principle teaching unit is the lecture by the relevant lecturers. Lectures may also contain a small tutorial component.

2. Tutorials (T) are usually held parallel to lectures and are intended to apply lecture content to selected concrete chemical examples, so deepening the understanding of the lecture subjects. They guide the students towards independent study as they work on tasks independently and in groups and discuss the issues critically. Students present their findings in the tutorial group, giving them the opportunity to test their progress in dialogue with the instructors and the tutorial group. The principle work form is solving problem sets and discussing solutions in groups.

3. Seminars (S) comprise the exploration of scientific and methodological issues and the critical examination of chemical theories, knowledge and possible applications. They are intended to promote the ability to work independently on an issue, to present the findings in a lecture tailored to a particular audience, to formulate hypotheses, defend them in discussion and discuss them critically in groups; the topics also include current controversies in chemical research. The principle work form is lectures by students and discussions of them by the seminar participants.

4. Practicals (P) are intended to teach the students practical working methods for the research-related implementation of syntheses, analyses and theoretical modelling. They are particularly suited to the guided exploration of issues and possible solutions and promote the learning of practical, manual and analytical skills in experiments carried out by the students themselves. The experiments are planned and evaluated in discussions with the instructors. Part of the students' own independent work (preparing the experiments and their theoretical background, literature research) can take place in the laboratory. These aspects of independent student work during laboratory opening hours are described in the module descriptions (Annex 1) as independent study in the laboratory. Practicals in the course of research projects in the working groups of the Institute of Chemistry and Biochemistry of Freie Universität Berlin guide the students increasingly towards independent research work by allocating to them their own thematically defined projects within the current research being carried out by the working group. They include a large amount of independent study time for research, analysis of the scientific issue, development of a solution concept, independently carrying out the practical research and preparing a report and a talk. Members of the working group provide assistance. The interaction with the supervising members of the working group is correspondingly intense, often taking place individually or in small groups. The principle work form is carrying out chemical experiments in the laboratory or calculations and modelling on the computer.

5. Safety-relevant practicals (sP) are practicals which are regularly necessary when dealing with hazardous substances. The interaction with the instructor is intense and long-term, often individually or in small groups.

6. Seminars on the computer using special software (SPC) during attendance phases are intended to teach about a defined subject area and the skills to work on an issue independently, presenting the findings and discussing them critically. The principle work form is joint work on the computer under guidance and the application of special software.

7. Supervision of tutorial groups (STS) gives students their first taste of teaching. They supervise tutorial groups of students on the Bachelor's program in Chemistry and give assistance in solving tasks given. Through leading discussions in the groups they gain confidence in guiding discussions. The principle work form is leading discussions in the tutorial groups.

## Section 6
## Academic advisory center and departmental advisory service

(1) General student advisory services are provided by the central academic advisory center and the psychological counselling service [Zentraleinrichtung Studienberatung und Psychologische Beratung] of Freie Universität Berlin.

(2) The departmental advisory service is carried out by departmental advisers of the Institute for Chemistry and Biochemistry at Freie Universität Berlin. The chair of the examination committee gives advice on examination issues.

## Section 7
## Study abroad

(1) Students are encouraged to take a period of study abroad. In the course of their studies abroad, students should take courses and examinations (attainments) which can be credited as equivalent to the modules which they would have taken during the same period at Freie Universität Berlin. You are referred to Section 5 paragraph 7 of the examination regulations for information on the possibility of completing the Master's thesis outside Freie Universität Berlin.

(2) Before starting to study abroad, the student should reach an agreement with the examination board and the relevant position at the university to be visited, covering the duration of the study period abroad, the attainments to be completed during the study period abroad which must be equivalent to the attainments in the Master's program and the credit points allocated to the attainments. Attainments which comply with the agreement will be credited.

(3) The second or third semester of the Master's program is recommended as a suitable time for study abroad.

## Section 8

## Taking effect and interim regulations

(1) These regulations take effect on the day after their publication in the FU Mitteilungen [Gazette of Freie Universität Berlin].

(2) At the same time the study regulations for the Master's program in Chemistry from 10 July 2002 (FU Mitteilungen No. 25/2002) amended on 24 May 2006 (FU Mitteilungen No. 55/2006) expire.

(3) These regulations apply to students who enroll in the Master's program at Freie Universität Berlin after these regulations have come into effect. Students who enrolled in the Master's program at Freie Universität Berlin before these regulations came into effect shall should continue their studies on the basis of the study regulations in accordance with paragraph 2, unless they apply to the responsible examination committee to continue their studies on the basis of these new regulations. On the occasion of a student's re-registration following their application, the examination committee decides to what extent the modules completed or started at the time of the application will be taken into account or how they are to be credited as attainments, whereby the requirements confidentiality and non-discrimination will be observed. The decision on the application for re-registration will come into effect at the beginning of the lecture phase of the semester following submission of the application. The re-registration cannot be revised.

(4) It will be possible to gain a degree on the basis of the study regulations in accordance with paragraph 2 up to the end of the summer semester 2015.

**Annex 1: Module descriptions**

**Explanations:**

The following module descriptions specify the following information for every module in the master's program except where you are referred to other regulations:

- Module name
- Person responsible for the module
- Module content and qualification aims
- Module teaching and learning units
- Students' study time estimated as necessary to complete the module successfully
- Forms of active participation
- The usual duration of the module
- How often the module is offered
- The applicability of the module

Statements on students' study time required take into account the following in particular:

- Active participation in the attendance phase
- Students' study time required to complete small tasks in the attendance phase
- Time for independent preparation and follow-up
- Working on study units in online study phases
- Preparation time for examinations
- The examinations

The notional times given for independent study (including preparation, follow-up and preparation for examinations) are intended as guidance to help the students in managing the working time required for the module.

The statements on study hours correspond to the number of credit points allocated to the module as a unit of measurement for the student's approximate study hours required to complete the module successfully.

Active participation, regular attendance (if required) at the teaching and learning units and successful completion of the module examinations are all prerequisites for gaining the credit points allocated to each module. For modules without an examination, the prerequisites for gaining the credit points allocated to the module are active participation and regular attendance (if required) at the teaching and learning units.

The number of credit points and other examination-related information on each module can be found in Annex 1 of the examination regulations for the Master's program.

Descriptions of the following modules in the master's program can be found in the study regulations of the programs of the Department of Biology, Chemistry and Pharmacy of Freie Universtität Berlin mentioned in Section 4 paragraph 9 and repeated here:

**Compulsory elective modules**

- Module: Principles of Radiochemistry: Bachelor's program in Chemistry

**Specialization modules**

- Module: Principles of Biochemistry: Bachelor's program in Biochemistry
- Module: Current Topics in Biochemistry: Bachelor's program in Biochemistry
- Module: Introduction to Advanced Biochemistry: Master's program in Biochemistry
- Module: Introduction to Macromolecular Chemistry: Bachelor's program Chemistry
- Module: Molecular Dynamics: Bachelor's program Chemistry
- Module: Environmental Chemistry: Air, Water, Soils: Bachelor's program Chemistry

The other modules in the master's program are described as follows:

**A. Compulsory elective modules**

**1. Topic area: Inorganic Chemistry**

| | | | | |
|---|---|---|---|---|
| **Module:** Coordination Chemistry | | | | |
| **University/department/institute:** Freie Universität Berlin/Department of Biology, Chemistry and Pharmacy/Institute of Chemistry and Biochemistry | | | | |
| **Responsible for the module:** module lecturers | | | | |
| **Admission requirements:** none | | | | |
| **Qualification aims:** The students have advanced knowledge of coordination chemistry and can apply it to issues new to them. They have mastered the theories on describing coordination compounds and know the main reaction types of such compounds. They are aware of the significance of coordination compounds in catalysis, their application as magnetic materials and in molecular electronics. They can solve problem sets from the topic areas covered independently or in groups. | | | | |
| **Content**: Bond theory and the reactions of coordination compounds; special classes of ligands such as e.g. non-innocent ligands; molecular magnetism and molecular electronics; general redox reactions of coordination compounds and mixed valence bonds; significance of coordination compounds in supramolecular chemistry and photochemistry; physical methods of characterising complexes; symmetry and stereochemistry of complexes; metal-metal bonds; selected homogeneous catalytic reactions. | | | | |
| **Teaching and learning units** | **Attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) | |
| Lecture | 3 | - | Attendance L<br>Preparation and follow-up L | 45<br>45 |
| Tutorial | 1 | Solving problem sets, contributing to discussions | Attendance T<br>Preparation and follow-up T<br>Examination preparation, examination | 15<br>15<br>30 |
| **Language of instruction** | | German or English | | |
| **Compulsory regular attendance** | | Attendance recommended | | |
| **Study time, total hours** | | 150 hours | | 5 CP |
| **Duration of module** | | One semester | | |
| **Module offered** | | Every summer semester | | |
| **Application** | | Master's program in Chemistry | | |

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| **Module:** Organometallic Chemistry |
| **University/department/institute:** Freie Universität Berlin/Department of Biology, Chemistry and Pharmacy/Institute of Chemistry and Biochemistry |
| **Responsible for the module:** module lecturers |
| **Admission requirements:** none |
| **Qualification aims**: The students have deepened their knowledge of organometallic chemistry and are familiar with the bond characteristics of the different classes of complexes with metal-carbon bonds. They can apply this knowledge to unknown organometallic compounds and analyze the bond characteristics. They can solve problem sets from the topic |

areas covered independently or in groups.

**Content**: Ways of synthesizing main group organyls in the groups 1, 2, 12, 13 and 14; cyclopentadienyl compounds of main group elements; bonds in transition metal compounds; metal carbonyls; metal carbonyl clusters; ligands related to CO; complexes with σ-donor ligands; carbene (alkylidene) complexes,carbyne complexes, olefin complexes, alkyne complexes, allyl and enyl complexes, cyclopentadienyl complexes, arene complexes, seven and eight-membered rings as ligands; lanthanoid compounds

| **Teaching and learning units** | **Attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) | |
|---|---|---|---|---|
| Lecture | 3 | - | Attendance L<br>Preparation and follow-up L<br>Attendance T | 45<br>45<br>15 |
| Tutorial | 1 | Solving problem sets, contributing to discussions | Preparation and follow-up T<br>Examination preparation, examination | 15<br>30 |
| **Language of instruction** | | German or English | | |
| **Compulsory regular attendance** | | Attendance recommended | | |
| **Study time, total hours** | | 150 hours | | 5 CP |
| **Duration of module** | | 1 semester | | |
| **Module offered** | | Every summer semester | | |
| **Application** | | Master's program in Chemistry | | |

**Module:** Modern Methods of Structure Determination

**University/department/institute:** Freie Universität Berlin/Department of Biology, Chemistry and Pharmacy/Institute of Chemistry and Biochemistry

**Responsible for the module:** module lecturers

**Admission requirements:** none

**Qualification aims**: The students are familiar with modern methods of structure determination such as e.g. X-ray diffraction or spectroscopic methods. They can apply their knowledge to characterize unfamiliar samples and can independently examine a structure issue using the appropriate methods. They also solve these problems jointly in the tutorial groups and can question their methods critically and defend them in discussion. They can present a selected structure issue and its solution correctly and appropriately to a particular audience.

**Content**: Specialized knowledge of structure analysis methods; diffraction methods, ESR, UV/Vis, IR, Raman spectroscopy; selected examples for the application of these methods to particular structure issues

| **Teaching and learning units** | **Attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) | |
|---|---|---|---|---|
| Lecture | 2 | - | Attendance L<br>Preparation and follow-up L<br>Attendance T | 30<br>30<br>30 |
| Tutorial | 2 | Solving problem sets, contributing to discussions | Preparation and follow-up T<br>Examination preparation, examination | 30<br>30 |
| **Language of instruction** | | German or English | | |
| **Compulsory regular attendance** | | Lecture: attendance recommended; tutorial: yes | | |
| **Study time, total hours** | | 150 hours | | 5 CP |
| **Duration of module** | | One semester | | |
| **Module offered** | | Every winter semester | | |
| **Application** | | Master's program in Chemistry | | |

**2. Topic area Organic Chemistry**

**Module**: Advanced Synthetic Methods

**University/department/institute:** Freie Universität Berlin/Department of Biology, Chemistry and Pharmacy/Institute of Chemistry and Biochemistry

**Responsible for the module:** module lecturers

**Admission requirements:** none

**Qualification aims**: The students have mastered advanced synthesis methods, in particular processes for C-C bonding. They are familiar with the properties of organometallic reagents and catalysts and recognize reactivity patterns in challenging target molecules. They can apply chemoselective and regioselective reactions in syntheses and synthesis planning and apply the principles of polarity reversal ("Umpolung") and protecting group strategies. They are familiar with new methods in radical and heterocyclic chemistry. They can analyze target molecules in view of suitable synthetic methods and develop suitable syntheses using the organic reactions introduced in this module, working independently and in groups.

| | | | | |
|---|---|---|---|---|
| **Content**: Synthetically important organometallic compounds and their reactions (main group and transition metals); metal-catalyzed C-C bonding processes and functionalization; polarity reversal ("Umpolung"); use of protecting groups for different functional groups; modern and (stereo) selective radical reactions; synthesis and chemistry of heterocycles | | | | |
| **Teaching and learning units** | **Attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) | |
| Lecture | 2 | - | Attendance L<br>Preparation and follow-up L | 30<br>30 |
| Tutorial | 2 | Working on problem sets, contributing to discussions | Attendance T<br>Preparation and follow-up T<br>Examination preparation, examination | 30<br>30<br>30 |
| **Language of instruction** | | German or English | | |
| **Compulsory regular attendance** | | Attendance recommended | | |
| **Study time, total hours** | | 150 hours | | 5 CP |
| **Duration of module** | | One semester | | |
| **Module offered** | | Every winter semester | | |
| **Application** | | Master's program in Chemistry | | |

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|---|---|---|---|---|
| **Module**: Physical Organic Chemistry | | | | |
| **University/department/institute:** Freie Universität Berlin/Department of Biology, Chemistry and Pharmacy/Institute of Chemistry and Biochemistry | | | | |
| **Responsible for the module:** module lecturers | | | | |
| **Admission requirements:** none | | | | |
| **Qualification aims**: The students have deepened their understanding of physical organic chemistry. They can independently analyze unknown reaction mechanisms and find ways of explaining them; they are familiar with the relevant types of short-lived intermediates and have detailed knowledge of non-ionic reactions under orbital control. Their expanded knowledge of potential energy surfaces, thermodynamics and kinetics enables them to evaluate the chemical reactivity of organic molecules in detail. They understand the influence of the surrounding environment on molecular properties. In the accompanying seminar, students also investigate controversial cases from current research, present them and discuss them critically in the group. | | | | |
| **Content**: Structure and bonding (frontier orbital methods, aromatics, non-aromatics, anti-aromatics); reaction coordinates (reaction dynamics, two-state reactivity); the relationship between thermodynamics and kinetics (the limits of Hammond's postulate, Hammett's Linear Free Energy Relationships, substituent effects); reaction mechanisms (short-lived intermediates and methods of proving them, pericyclic reactions and orbital control, carbenes, nitrenes, radicals, photochemistry); influences of the surrounding environment (solvation effects on acidities and nucleophiles, solvatochromism) | | | | |
| **Teaching and learning units** | **Attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) | |
| Lecture | 2 | - | Attendance L<br>Preparation and follow-up L | 30<br>30 |
| Seminar | 2 | Lectures, working on problem sets, contributing to discussions | Attendance S<br>Preparation and follow-up S<br>Examination preparation, examination | 30<br>30<br>30 |
| **Language of instruction** | | German or English | | |
| **Compulsory regular attendance** | | Attendance recommended | | |
| **Study time, total hours** | | 150 hours | | 5 CP |
| **Duration of module** | | One semester | | |
| **Module offered** | | Every summer semester | | |
| **Application** | | Master's program in Chemistry | | |

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| **Module**: Stereoselective Synthesis |
| **University/department/institute:** Freie Universität Berlin/Department of Biology, Chemistry and Pharmacy/Institute of Chemistry and Biochemistry |
| **Responsible for the module:** module lecturers |
| **Admission requirements:** none |
| **Qualification aims**: The students have deepened their understanding of the spatial arrangement of chemical structures and reactions and are familiar with the appropriate depiction of three-dimensional structures and their terminology. They have expanded their understanding of stereochemistry to include dynamic stereochemistry. They are familiar with stereoselective reactions and methods of controlling selectivity; they can apply their knowledge to the development of syntheses of complex, organic molecules. They can estimate the degree of difficulty of stereoselective syntheses and take this into account when planning syntheses, discussing these aspects critically in the group. |

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| **Content**: Stereochemical terminology and nomenclature; static stereochemistry; stereoisomers; conformational analysis; dynamic stereochemistry; (macro)cyclic stereocontrol; diastereoselective additions to carbonyl compounds; enolates and olefins; aldol reactions; principles and examples of asymmetric (organo) catalysis | | | | |
| **Teaching and learning units** | **Attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) | |
| Lecture | 2 | - | Attendance L<br>Preparation and follow-up L | 30<br>30 |
| Tutorial | 2 | Working on problem sets, contributing to discussions | Attendance T<br>Preparation and follow-up T<br>Examination preparation, examination | 30<br>30<br>30 |
| **Language of instruction** | | German or English | | |
| **Compulsory regular attendance** | | Attendance recommended | | |
| **Study time, total hours** | | 150 hours | | 5 CP |
| **Duration of module** | | One semester | | |
| **Module offered** | | Every summer semester | | |
| **Application** | | Master's program in Chemistry | | |

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|---|---|---|---|---|
| **Module**: Natural Products Chemistry and Advanced Bioorganic Chemistry | | | | |
| **University/department/institute:** Freie Universität Berlin/Department of Biology, Chemistry and Pharmacy/Institute of Chemistry and Biochemistry | | | | |
| **Responsible for the module:** module lecturers | | | | |
| **Admission requirements:** none | | | | |
| **Qualification aims**: The students know the chemical and physical properties of biopolymers and their monomers. They are capable of developing syntheses for the main classes of natural products and can analyze, assess and describe their structures, their supramolecular chemistry and their material properties and demonstrate the links to biochemistry. They can carry out independent research into current aspects (including controversial aspects) of bioorganic chemistry, present them accurately in lectures tailored to a particular audience and discuss them critically in groups. | | | | |
| **Content**: Synthesis of nucleotides; modern synthesis processes for peptides and proteins; enzyme catalysis; synthesis of complex carbohydrates and saccharides; synthesis and special aspects of lipids and polyketides; post-translational modifications of proteins; current topics in bioorganic chemistry (e.g. labelling and diagnostics, siRNA, drug delivery) | | | | |
| **Teaching and learning units** | **Attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) | |
| Lecture | 2 | - | Attendance L<br>Preparation and follow-up L | 30<br>30 |
| Seminar | 2 | Scientific talks on current topics, discussions | Attendance S<br>Preparation and follow-up S<br>Examination preparation, examination | 30<br>30<br>30 |
| **Language of instruction** | | German or English | | |
| **Compulsory regular attendance** | | Attendance recommended | | |
| **Study time, total hours** | | 150 hours | | 5 CP |
| **Duration of module** | | One semester | | |
| **Module offered** | | Every winter semester | | |
| **Application** | | Master's program in Chemistry | | |

**3. Topic area Physical and Theoretical Chemistry**

| | | | |
|---|---|---|---|
| **Module**: Quantum Chemistry | | | |
| **University/department/institute:** Freie Universität Berlin/Department of Biology, Chemistry and Pharmacy/Institute of Chemistry and Biochemistry | | | |
| **Responsible for the module:** module lecturers | | | |
| **Admission requirements:** none | | | |
| **Qualification aims**: The students know the principles of the quantitative description of molecular structure using quantum mechanical methods of theoretical chemistry. They know the physical and mathematical principles of the relevant computer programs and can apply their knowledge to solve problem sets, independently or in a group. | | | |
| **Content**: *Ab initio* and semi-empirical methods of quantum chemistry; Hartree-Fock method; basis sets; density functional theory; introduction to correlation methods; potential energy surfaces for chemical reactions; introduction to the underlying algorithms of popular quantum chemistry programs | | | |
| **Teaching and learning units** | **Attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) |

| | | | | |
|---|---|---|---|---|
| Lecture | 2 | - | Attendance L<br>Preparation and follow-up L<br>Attendance T | 30<br>30<br>30 |
| Tutorial | 2 | Solving problem sets, contributing to discussions | Preparation and follow-up T<br>Examination preparation, examination | 30<br>30 |
| **Language of instruction** | | German or English | | |
| **Compulsory regular attendance** | | Attendance recommended | | |
| **Study time, total hours** | | 150 hours | | 5 CP |
| **Duration of module** | | One semester | | |
| **Module offered** | | Every other semester | | |
| **Application** | | Master's program in Chemistry | | |

| | | | | |
|---|---|---|---|---|
| **Module**: Solids and Interfaces | | | | |
| **University/department/institute:** Freie Universität Berlin/Department of Biology, Chemistry and Pharmacy/Institute of Chemistry and Biochemistry | | | | |
| **Responsible for the module:** module lecturers | | | | |
| **Admission requirements:** none | | | | |
| **Qualification aims**: The students have deepened their knowledge of the chemistry of solids and interfaces and can apply it in a range of (new) contexts. They are familiar with the methods of structure examination of solids and interfaces and can estimate the methods' applicability and limitations. They can solve problem sets independently and in a team. | | | | |
| **Content**: Bond types and bond energies of solids; systematics and determination of crystal structures, crystals and crystal lattices; mathematical principles of structure determination; electrical conductivity and electron theory of metals (band model); specific heat and lattice oscillation phenomena; surfaces; surface crystallography; thermodynamics and kinetics of surface processes | | | | |
| **Teaching and learning units** | **Attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) | |
| Lecture | 2 | - | Attendance L<br>Preparation and follow-up L<br>Attendance T | 30<br>30<br>30 |
| Tutorial | 2 | Solving problem sets, contributing to discussions | Preparation and follow-up T<br>Examination preparation, examination | 30<br>30 |
| **Language of instruction** | | German or English | | |
| **Compulsory regular attendance** | | Attendance recommended | | |
| **Study time, total hours** | | 150 hours | | 5 CP |
| **Duration of module** | | One semester | | |
| **Module offered** | | Every other semester | | |
| **Application** | | Master's program in Chemistry | | |

| | | | | |
|---|---|---|---|---|
| **Module**: Statistical Thermodynamics | | | | |
| **University/department/institute:** Freie Universität Berlin/Department of Biology, Chemistry and Pharmacy/Institute of Chemistry and Biochemistry | | | | |
| **Responsible for the module:** module lecturers | | | | |
| **Admission requirements:** none | | | | |
| **Qualification aims**: The students are aware of how macroscopic thermodynamic properties arise from microscopic molecular properties; they are capable of using statistical thermodynamics as a bridge between atomic structure/chemical bonding and quantum chemistry on the one hand and thermodynamics and solids and interfaces on the other hand. They can apply their knowledge in a range of contexts to solve tasks independently and in groups. | | | | |
| **Content**: Mathematical principles; physical and quantum mechanical principles; microcanonical, canonical and grand canonical ensembles; partition functions and thermodynamic functions; quantum statistical thermodynamics for fermions and bosons; applications e.g. in the fields of balances and reaction; solids and interfaces; mixtures. | | | | |
| **Teaching and learning units** | **Attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) | |
| Lecture | 2 | - | Attendance L<br>Preparation and follow-up L<br>Attendance T | 30<br>30<br>30 |
| Tutorial | 2 | Solving problem sets, contributing to discussions | Preparation and follow-up T<br>Examination preparation, examination | 30<br>30 |
| **Language of instruction** | | German or English | | |
| **Compulsory regular attendance** | | Attendance recommended | | |
| **Study time, total hours** | | 150 hours | | 5 CP |
| **Duration of module** | | One semester | | |

| | | | |
|---|---|---|---|
| **Module offered** | Every other semester | | |
| **Application** | Master's program in Chemistry | | |
| | | | |
| **Module**: Modern Methods in Spectroscopy | | | |
| **University/department/institute:** Freie Universität Berlin/Department of Biology, Chemistry and Pharmacy/Institute of Chemistry and Biochemistry | | | |
| **Responsible for the module:** module lecturers | | | |
| **Admission requirements:** none | | | |
| **Qualification aims**: The students have deepened their understanding of modern methods of spectroscopy for examining the structures and dynamics of molecules, liquids and condensed matter and can apply this knowledge in a range of contexts to solving problem sets in groups. | | | |
| **Content**: Brief recapitulation of the principles of optical spectroscopy; terahertz spectroscopy, fluorescence spectroscopy, photoelectron spectroscopy, X-ray spectroscopy, short pulse and ultra-short pulse spectroscopy, spectroscopy with electrons and neutrons; light, electron and neutron scattering; methods of spectromicroscopy; applications of modern spectroscopy in chemistry, the environment and life sciences | | | |
| **Teaching and learning units** | **Attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) |
| Lecture | 2 | - | Attendance L 30<br>Preparation and follow-up L 30<br>Attendance T 30<br>Preparation and follow-up T 30<br>Examination preparation, examination 30 |
| Tutorial | 2 | Solving problem sets, contributing to discussions | |
| **Language of instruction** | | German or English | |
| **Compulsory regular attendance** | | Attendance recommended | |
| **Study time, total hours** | | 150 hours | 5 CP |
| **Duration of module** | | One semester | |
| **Module offered** | | Every other semester | |
| **Application** | | Master's program in Chemistry | |

### 4. Cross-topic area

| | | | |
|---|---|---|---|
| **Module**: Scientific Lectures and Presentations in Chemistry | | | |
| **University/department/institute:** Freie Universität Berlin/Department of Biology, Chemistry and Pharmacy/Institute of Chemistry and Biochemistry | | | |
| **Responsible for the module:** module lecturers | | | |
| **Admission requirements:** none | | | |
| **Qualification aims**: The students are familiar with the current research findings from the colloquiums and lecture series at the Institute of Chemistry and Biochemistry. They can carry out independent research into chemistry-related topics in the relevant specialist literature and present them appropriately to their audience and according to accepted standards. They are capable of assessing literature critically, formulating and testing hypotheses and defending them to a group in discussion. The student's lecture topics are also related to gender and diversity aspects, socially relevant topics related to chemistry and topics from the history of chemistry. | | | |
| **Content**: The scientific lectures, mostly by visiting lecturers, cover current topics of chemical research. The students are given lecture topics from two of the three study areas Inorganic Chemistry, Organic Chemistry and Physical/Theoretical Chemistry. The supervisors are free in their choice of current topics from chemistry or related fields and may also set interdisciplinary topics related to e.g. socially relevant aspects of chemistry or the topic of women in the sciences. The lecture topics should not overlap with the research project topics. | | | |
| **Teaching and learning units** | **Attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) |
| Seminar | 2 | Attending 14 scientific lectures, preparing and holding a lecture | Attendance S 30<br>Preparation and follow-up S 60<br>Examination preparation, examination 60 |
| **Language of instruction** | | German or English | |
| **Compulsory regular attendance** | | Yes | |
| **Study time, total hours** | | 150 hours | 5 CP |
| **Duration of module** | | One semester | |
| **Module offered** | | Every semester | |
| **Application** | | Master's program in Chemistry | |

| | |
|---|---|
| **Module**: Teaching Chemistry | |

| | | | | |
|---|---|---|---|---|
| **University/department/institute:** Freie Universität Berlin/Department of Biology, Chemistry and Pharmacy/Institute of Chemistry and Biochemistry | | | | |
| **Responsible for the module:** module lecturers | | | | |
| **Admission requirements:** none | | | | |
| **Qualification aims**: The students gain their first experience of teaching in the teaching units of the Chemistry Bachelor program, preparing them for future teaching duties, for example during doctoral studies. They are capable of preparing and carrying out tutorials to accompany lectures, actively leading the discussions in the tutorial group as an efficient teaching unit. They can identify and influence group dynamic processes appropriately, taking gender and diversity aspects into account and reacting sensitively to the students' different cultural backgrounds. They can recognize and analyze problems of comprehension and provide alternative explanations; they have experience in leading discussions. | | | | |
| **Content**: After an introductory discussion the students are active in the tutorial groups accompanying lectures in the bachelor program; working with the tutorial group; assisting with comprehension problems and solutions of the problem sets within the group for one semester, including regular feedback with the lecturer responsible for the bachelor module; organising, carrying out and evaluating an assessment with the participants in the tutorial group. | | | | |
| **Teaching and learning units** | **Attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) | |
| Seminar | 5 clock hours | - | Seminar S<br>Attendance STS<br>Preparation of tutorials<br>Evaluation with analysis | 5<br>30<br>90<br>25 |
| Tutorial group supervision | 2 | Supervising the tutorial group, regular active participation, carrying out an evaluation and participating in advisory discussions about the success of the tutorial supervised | | |
| **Language of instruction** | | German or English | | |
| **Compulsory regular attendance** | | yes | | |
| **Study time, total hours** | | 150 hours | | 5 CP |
| **Duration of module** | | One semester | | |
| **Module offered** | | Every semester | | |
| **Application** | | Master's program in Chemistry | | |

**B. Project area**

| | | | | |
|---|---|---|---|---|
| **Module**: Research project in a scientific research group | | | | |
| **University/department/institute:** Freie Universität Berlin/Department of Biology, Chemistry and Pharmacy/Institute of Chemistry and Biochemistry | | | | |
| **Responsible for the module:** module lecturers | | | | |
| **Admission requirements:** none | | | | |
| **Qualification aims**: The students are familiar with the scientific research methodology of the research group's topic area. They take an appropriate scientific approach to working on issues in state-of-the-art research, presenting and discussing their research findings orally and in writing according to the recognized standards of the subject. They fit into the research group which is usually consists of members from very different cultural backgrounds. They are able to work constructively in an international team and to take gender and diversity aspects into account. | | | | |
| **Content**: The students work on a current project from the research topics of the research group under supervision by its members. This includes researching the scientific background, practical implementation of the project, presentation and critical discussion of the findings in the research group's research seminar, usually in English, and written documentation of the project. | | | | |
| **Teaching and learning units** | **Attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) | |
| Seminar | 5 clock hours | Presentation and Discussion | Attendance S<br>Preparation and follow-up S<br>Attendance P<br>*Supervised practical*<br>*Independent study in lab*<br>Preparation and follow-up P<br>Examination preparation, examination | 5<br>5<br><br>25<br>75<br>15<br>25 |
| Practical | 2 | Carrying out practical experiments and documentation | | |
| **Language of instruction** | | German or English | | |
| **Compulsory regular attendance** | | yes | | |
| **Study time, total hours** | | 150 hours | | 5 CP |
| **Duration of module** | | Four weeks full-time; if attending other teaching units at the same time the course duration is correspondingly longer | | |
| **Module offered** | | Not regularly | | |
| **Application** | | Master's program in Chemistry | | |

| **Module**: Research project in a scientific research group | |
|---|---|
| **University/department/institute:** Freie Universität Berlin/Department of Biology, Chemistry and Pharmacy/Institute of Chemistry and Biochemistry | |
| **Responsible for the module:** module lecturers | |
| **Admission requirements:** none | |
| **Qualification aims**: The students are familiar with the scientific research methodology of the working group's topic area. They take an appropriate scientific approach to working on issues in the current state of research, presenting and discussing their research findings orally and in writing according to the recognized standards of the subject. They fit into the research group which is usually formed of members from very different cultural backgrounds. They are able to work constructively in an international team and to take gender and diversity aspects into account. | |
| **Content**: The students work on a current project from the research topics of the working group under supervision by its members. This includes researching the scientific background, practical implementation of the project, presentation and critical discussion of the findings in the working group's research seminar, usually in English, and written documentation of the project. | |

| **Teaching and learning units** | **Attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) | |
|---|---|---|---|---|
| Seminar | 10 clock hours | Presentation and Discussion | Attendance S<br>Preparation and follow-up S<br>Attendance P | 10<br>10 |
| Practical | 3 | Carrying out practical experiments and documentation | *Supervised practical*<br>*Independent study in lab*<br>Preparation and follow-up P<br>Examination preparation, examination | 35<br>165<br>30<br>50 |

| | | |
|---|---|---|
| **Language of instruction** | German or English | |
| **Compulsory regular attendance** | yes | |
| **Study time, total hours** | 300 hours | 10 CP |
| **Duration of module** | Eight weeks full-time; if attending other teaching units at the same time the course duration is correspondingly longer | |
| **Module offered** | Every semester on agreement | |
| **Application** | Master's program in Chemistry | |

| **Module**: Research project in a scientific research group | |
|---|---|
| **University/department/institute:** Freie Universität Berlin/Department of Biology, Chemistry and Pharmacy/Institute of Chemistry and Biochemistry | |
| **Responsible for the module:** module lecturers | |
| **Admission requirements:** none | |
| **Qualification aims**: The students are familiar with the scientific research methodology of the working group's topic area. They take an appropriate scientific approach to working on issues in the current state of research, presenting and discussing their research findings orally and in writing according to the recognized standards of the subject. They fit into the research group which is usually formed of members from very different cultural backgrounds. They are able to work constructively in an international team and to take gender and diversity aspects into account. | |
| **Content**: The students work on a current project from the research topics of the working group under supervision by its members. This includes researching the scientific background, practical implementation of the project, presentation and critical discussion of the findings in the working group's research seminar, usually in English, and written documentation of the project. | |

| **Teaching and learning units** | **Attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) | |
|---|---|---|---|---|
| Seminar | 15 clock hours | Presentation and Discussion | Attendance S<br>Preparation and follow-up S<br>Attendance P | 15<br>15 |
| Practical | 4 | Carrying out practical experiments and documentation | *Supervised practical*<br>*Independent study in lab*<br>Preparation and follow-up P<br>Examination preparation, examination | 45<br>255<br>45<br>75 |

| | | |
|---|---|---|
| **Language of instruction** | German or English | |
| **Compulsory regular attendance** | yes | |
| **Study time, total hours** | 450 hours | 15 CP |
| **Duration of module** | Twelve weeks full-time; if attending other teaching units at the same time the course duration is correspondingly longer | |
| **Module offered** | Every semester on agreement | |
| **Application** | Master's program in Chemistry | |

**C. Specialization area**

**1. Topic area Analytical Chemistry**

| **Module**: Scientific Measurement Data Collection and Processing | | | | |
|---|---|---|---|---|
| **University/department/institute:** Freie Universität Berlin/Department of Biology, Chemistry and Pharmacy/Institute of Chemistry and Biochemistry | | | | |
| **Responsible for the module:** module lecturers | | | | |
| **Admission requirements:** none | | | | |
| **Qualification aims**: The students know important measurement and working techniques from the field of scientific laboratory practice. They are familiar with the basic methodological and subject-related principles of measurement within scientific parameters. They are competent in evaluating systematic and stochastic errors which may occur. They can use data processing equipment for reducing and further processing experimental data. They are capable of preparing suitably labelled diagrams from measuring data series for publication in scientific journals. | | | | |
| **Content**: Methodological delimitation of laboratory experiments from everyday experience; digital and analogue data collection in laboratory experiments; determining the parameters by the complementary test results; use of specialized software to collect and process data; preparing publishable depictions for scientific journals; principles of scientific error analysis | | | | |
| **Teaching and learning units** | **Attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) | |
| Lecture | 2 | - | Attendance L<br>Preparation and follow-up L | 30<br>30 |
| Tutorial | 2 | Solving tasks, discussion, developing data analysis and visualization programs, preparing diagrams | Attendance T<br>Preparation and follow-up T<br>Examination preparation, examination | 30<br>30<br>30 |
| **Language of instruction** | | German or English | | |
| **Compulsory regular attendance** | | Attendance recommended | | |
| **Study time, total hours** | | 150 hours | | 5 CP |
| **Duration of module** | | One semester | | |
| **Module offered** | | Every semester | | |
| **Application** | | Master's program in Chemistry<br>Bachelor's program in Chemistry for teaching<br>60 CP module provision<br>Bachelor's program in Biochemistry | | |

| **Module**: Instrumental Analysis for Structure Assignment in Organic Chemistry | | | | |
|---|---|---|---|---|
| **University/department/institute:** Freie Universität Berlin/Department of Biology, Chemistry and Pharmacy/Institute of Chemistry and Biochemistry | | | | |
| **Responsible for the module:** module lecturers | | | | |
| **Admission requirements:** none | | | | |
| **Qualification aims**: The students can apply modern analytical processes to the structure assignment of organic compounds and to analyze reaction mechanisms and can analyze the data. They know the principles of the technical instruments and measurement methods and can select the appropriate experiments for a wide range of scientific issues, estimating their performance and limitations. They can independently evaluate the data quality and interpret the measurement results. | | | | |
| **Content**: Structure assignment of organic compounds using NMR, IR, UV and CD spectroscopy and mass spectrometry including chromatography processes (HPLC, GC); theoretical and technical principles of the instruments; measuring principles; pulse sequences for NMR experiments such as NOE, NOESY, ROESY, COSY, EXSY, DOSY, HMBC, HMQC and temperature-dependent NMR for structural analysis; signal assignment; evaluation of dynamic processes; application fields and limitations of a range of MS ionization processes such as EI, CI, APCI, ESI, MALDI, FAB, FD/LIFDI, DART and MS analyzers such as TOF, sector field, quadrupole, ion trap, FTICR, Orbitrap, ICPMS; chemistry in the highly diluted gas phase (CID, IRMPD, ECD, H/D exchange); practical tasks (preparing samples, carrying out simple measurements, presenting complicated experiments, evaluation and data interpretation, problem sets) | | | | |
| **Teaching and learning units** | **Attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) | |
| Lecture | 2 | - | Attendance L<br>Preparation and follow-up L | 30<br>30 |
| Tutorial | 2 | Experiments using the institute's equipment, contributions to discussion, working on problem sets | Attendance T<br>Preparation and follow-up T<br>Examination preparation, examination | 30<br>30<br>30 |
| **Language of instruction** | | German or English | | |

| | | |
|---|---|---|
| **Compulsory regular attendance** | Lecture: attendance recommended; tutorial: yes | |
| **Study time, total hours** | 150 hours | 5 CP |
| **Duration of module** | One semester | |
| **Module offered** | Every winter semester | |
| **Application** | Master's program in Chemistry | |

**2. Topic area Inorganic Chemistry**

| | | | | |
|---|---|---|---|---|
| **Module**: Applied Radiochemistry and Radiation Protection Course | | | | |
| **University/department/institute:** Freie Universität Berlin/Department of Biology, Chemistry and Pharmacy/Institute of Chemistry and Biochemistry | | | | |
| **Responsible for the module:** module lecturers | | | | |
| **Admission requirements:** Module: Principles of Radiochemistry | | | | |
| **Qualification aims**: The students have deepened their knowledge of dealing with radioactive materials and of the legal radiation protection regulations for working with open radioactive materials and sealed radioactive sources. They have mastered facts about radiochemistry and the search for solutions in the measurement of radioactive radiation. They have all the theoretical principles to gain the expert qualifications for appointment as radiation protection officers of groups 2.2, 4.1, and 4.2. | | | | |
| **Content**: Scientific principles of radiation protection; biological radiation effects, working with open radioactive materials; radiation protection law; dosimetry; structural radiation protection; dealing with radioactive waste; radiation protection calculations; practical operation of instrumentation to detect ionizing radiation; decontamination; practical application of radioactive compounds in science and technology; measuring alpha, beta and gamma radiation and calculations for practical radiation protection | | | | |
| **Teaching and learning units** | **Attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) | |
| Lecture | 5 days of 6 clock hours each | - | Attendance L<br>Preparation and follow-up L<br>Attendance sP | 30<br>30<br>40 |
| Safety-relevant practical | 1 week full-time | Carrying out practical experiments and documentation | Preparation and follow-up sP<br>Examination preparation, examination | 20<br>30 |
| **Language of instruction** | | German | | |
| **Compulsory regular attendance** | | Lecture: yes; practical: yes | | |
| **Study time, total hours** | | 150 hours | | 5 CP |
| **Duration of module** | | Two-week block | | |
| **Module offered** | | Every semester | | |
| **Application** | | Master's program in Chemistry | | |

| | | | | |
|---|---|---|---|---|
| **Module:** Bioinorganic Chemistry | | | | |
| **University/department/institute:** Freie Universität Berlin/Department of Biology, Chemistry and Pharmacy/Institute of Chemistry and Biochemistry | | | | |
| **Responsible for the module:** module lecturers | | | | |
| **Admission requirements:** none | | | | |
| **Qualification aims**: The students are familiar with the role of metals and metal proteins in life processes. They have also deepened their knowledge of modern aspects of bioinorganic chemistry. | | | | |
| **Content**: Development of the contemporary environment; biological function of main group elements; transition metals in biological systems; ion pumps; ion channels; ligands in biological systems; iron as an important element in biology; zinc proteins; metals at the core of photosynthesis and nitrogen fixation; molybdenum and cobalt enzymes; biomineralization and biomaterials; modern aspects of bioinorganic chemistry | | | | |
| **Teaching and learning units** | **Attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) | |
| Lecture I | 2 | - | Attendance L I<br>Preparation and follow-up L I<br>Attendance L II | 30<br>45<br>15 |
| Lecture II | 1 | | Preparation and follow-up L II<br>Examination preparation, examination | 30<br>30 |
| **Language of instruction** | | German or English | | |
| **Compulsory regular attendance** | | Attendance recommended | | |
| **Study time, total hours** | | 150 hours | | 5 CP |
| **Duration of module** | | One semester | | |
| **Module offered** | | Every other semester | | |
| **Application** | | Master's program in Chemistry | | |

| | | | | |
|---|---|---|---|---|
| **Module**: Modern Aspects of Non-metal Chemistry | | | | |
| **University/department/institute:** Freie Universität Berlin/Department of Biology, Chemistry and Pharmacy/Institute of Chemistry and Biochemistry | | | | |
| **Responsible for the module:** module lecturers | | | | |
| **Admission requirements:** none | | | | |
| **Qualification aims**: The students are familiar with the principles of the chemistry of phosphorus and other selected main group elements and can apply their knowledge. They have mastered the nomenclature and know the principle classes of substances, their reactions and the importance of these elements and their compounds in industry, technology and the environment. They can solve problem sets on the topic areas covered independently and in groups. | | | | |
| **Content**: Production and properties of phosphorus; structure and importance of the element phosphorus; synthesis, structure and reactivity of phosphorus compounds. Modern concepts of organic phosphorus chemistry; phosphanes and low-coordinated phosphorus compounds and their coordination chemistry; synthesis of P-stereogenic phosphorus compounds and their application in selected homogeneous catalytic reactions. Current aspects of non-metal chemistry of further main group elements | | | | |
| **Teaching and learning units** | **Attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) | |
| Lecture I | 2 | - | Attendance L I<br>Preparation and follow-up L I<br>Attendance L II<br>Preparation and follow-up L II<br>Examination preparation, examination | 30<br>45<br>15<br>30<br>30 |
| Lecture II | 1 | - | | |
| **Language of instruction** | | German or English | | |
| **Compulsory regular attendance** | | Attendance recommended | | |
| **Study time, total hours** | | 150 hours | | 5 CP |
| **Duration of module** | | One semester | | |
| **Module offered** | | Every other semester | | |
| **Application** | | Master's program in Chemistry | | |

**3. Topic area Biochemistry:** see information in Section 4 paragraph 9 and on the first page of the module information

**4. Topic area Macromolecular Chemistry**

| | | | | |
|---|---|---|---|---|
| **Module**: Advanced Macromolecular Chemistry | | | | |
| **University/department/institute:** Freie Universität Berlin/Department of Biology, Chemistry and Pharmacy/Institute of Chemistry and Biochemistry | | | | |
| **Responsible for the module:** module lecturers | | | | |
| **Admission requirements:** Introduction to Macromolecular Chemistry | | | | |
| **Qualification aims**: The students have deepened their understanding of macromolecular chemistry. They know the fundamental principles and specific mechanisms of polymerization reactions; the influence on structure and properties of the resulting polymers and can discuss the application areas and limitations which result. They know modern methods and processes for preparing different polymers on a laboratory scale and an industrial scale. They are familiar with examples of current research areas of polymer chemistry and examples of applications of functional polymer materials. They can carry out independent literature research on special areas of polymer chemistry and can present the findings accurately and appropriately to a group. | | | | |
| **Content**: Anionic polymerization (living polymerization, polyether, polyolefins, polyacrylate, copolymers), cationic polymerization (polyether, polyolefins), radical and controlled radical polymerization (emulsion polymerization, suspension polymerization, kinetics, ATRP, RAFT, NMP); metal mediated polymerization (polyolefin, *Aufbaureaktion*, Ziegler-Natta polymerization, metallocene catalysts, late transition metal catalysts, metathesis polymerization); polycondenzation (polyester, polyamide, polycarbonate, polyurethane) with elementary steps in each case; kinetics; influence on the polymer structure; properties, applications and examples; special application fields (biomaterials, electronics, organic synthesis, ion exchangers); industrial polymer chemistry | | | | |
| **Teaching and learning units** | **Attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) | |
| Lecture | 40 hours | - | Attendance L<br>Preparation and follow-up L<br>Attendance S<br>Preparation and follow-up S<br>Examination preparation, examination | 40<br>20<br>20<br>40<br>30 |
| Seminar | 20 hours | Contributions to discussion, seminar lecture | | |

| | | |
|---|---|---|
| **Language of instruction** | English | |
| **Compulsory regular attendance** | Lecture: attendance recommended; seminar: yes | |
| **Study time, total hours** | 150 hours | 5 CP |
| **Duration of module** | Block course in the first half of the lecture phase | |
| **Module offered** | Every winter semester | |
| **Application** | Master‘s program in Chemistry; Master’s program in Polymer Science | |

**5. Topic area Organic Chemistry**

| | | | | |
|---|---|---|---|---|
| **Module**: Total Syntheses and Synthesis Design | | | | |
| **University/department/institute:** Freie Universität Berlin/Department of Biology, Chemistry and Pharmacy/Institute of Chemistry and Biochemistry | | | | |
| **Responsible for the module:** module lecturers | | | | |
| **Admission requirements:** none | | | | |
| **Qualification aims**: The students have deepened their understanding of synthesis planning using retrosynthesis. They can analyze complex unknown target molecules in order to develop reasonable syntheses. They can identify typical structural motifs and are able to find ways to construct them while taking into account their reactivity, chemoselectivity, and regiochemical and stereochemical aspects. From the retrosynthesic analysis of complex target molecules, they derive suitable total syntheses, also for complex molecules. The students have solved retrosynthesic problems, including examples from current research, independently in the seminars and present and discuss them critically in the group. | | | | |
| **Content**: The concept of retrosynthesis; synthons; rules; typical structural elements; typical retrosynthesic steps; classical and current examples of total synthesis of complex natural products and other organic molecules; regiochemical and stereochemical aspects of retrosynthesis; translating retrosyntheses in the corresponding total syntheses using related examples | | | | |
| **Teaching and learning units** | **Attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) | |
| Lecture | 2 | - | Attendance L<br>Preparation and follow-up L | 30<br>30 |
| Seminar | 1 | Lectures, working on problem sets, contributing to discussions | Attendance S<br>Preparation and follow-up S<br>Examination preparation, examination | 15<br>45<br>30 |
| **Language of instruction** | | German or English | | |
| **Compulsory regular attendance** | | Attendance recommended | | |
| **Study time, total hours** | | 150 hours | | 5 CP |
| **Duration of module** | | One semester | | |
| **Module offered** | | Not regularly | | |
| **Application** | | Master’s program in Chemistry | | |

| | | | | |
|---|---|---|---|---|
| **Module**: Supramolecular Chemistry | | | | |
| **University/department/institute:** Freie Universität Berlin/Department of Biology, Chemistry and Pharmacy/Institute of Chemistry and Biochemistry | | | | |
| **Responsible for the module:** module lecturers | | | | |
| **Admission requirements:** none | | | | |
| **Qualification aims**: The students know the fundamental concepts of supramolecular chemistry and typical host molecules and have a detailed understanding of non-covalent interactions between molecules. They can apply the concepts of supramolecular synthesis to unknown complexes and find ways to produce them. They are familiar with methods of analysing non-covalent interactions and structural characterization of supramolecular complexes and know the importance of supramolecular chemistry for functional molecules, in materials and in living systems. In the accompanying seminar, students research controversial cases in current research, present them and discuss them critically within the group. | | | | |
| **Content**: Non-covalent interactions (e.g. H-bridges, electrostatic interactions with hydrophobic effects); typical host molecules (e.g. calixarenes, resorcinarenes, crown ethers, cucurbituril, cyclodextrins); concepts of supramolecular synthesis (e.g. templates, self-assembly, self-sorting, allosteric regulation, multivalent and cooperative binding); methods of characterising supramolecular complexes (e.g. NMR and UV/Vis titrations, calorimetric processes, mass spectrometry); functional molecules (e.g. molecular switches, shuttle-bus rotaxanes, sensors); supramolecular materials (non-covalent polymers, gelators, liquid crystals); supramolecular interactions in and between biological molecules (protein folding, ion channels, photo systems, cell membranes) | | | | |
| **Teaching and learning units** | **Attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) | |

| | | | | |
|---|---|---|---|---|
| Lecture | 2 | - | Attendance L<br>Preparation and follow-up L<br>Attendance S<br>Preparation and follow-up S<br>Examination preparation, examination | 30<br>30<br>15<br>45<br><br>30 |
| Seminar | 1 | Lectures, working on problem sets, contributing to discussions | | |
| **Language of instruction** | | German or English | | |
| **Compulsory regular attendance** | | Attendance recommended | | |
| **Study time, total hours** | | 150 hours | | 5 CP |
| **Duration of module** | | One semester | | |
| **Module offered** | | Not regularly | | |
| **Application** | | Master's program in Chemistry | | |

**Module**: Homogeneous Transition Metal Catalysis

**University/department/institute:** Freie Universität Berlin/Department of Biology, Chemistry and Pharmacy/Institute of Chemistry and Biochemistry

**Responsible for the module:** module lecturers

**Admission requirements:** none

**Qualification aims**: The students have deepened their understanding of homogeneous transition metal catalysis and its importance for organic synthesis on both laboratory and industrial scales. They are familiar with the important methods of homogeneously catalyzed processes, their scope and limitations. They know methods and concepts for clarifying reaction mechanisms and can interpret experiments in the light of mechanistic ideas. They can estimate the influence of reaction parameters based on mechanistic ideas and derive suggestions for optimising and developing catalytic reactions. They are familiar with current issues in homogeneous transition metal catalysis, can research relevant findings, present them to a group and critically discuss them.

**Content**: Reactivity and structure of transition metal complexes; elementary reaction steps (ligand exchange, oxidative addition, reductive elimination, insertions, eliminations) and their kinetics; hydrogenation; cross couplings (C-C- und C-heteroatom bond formation), hydroformylation, carbonylation reactions, olefin metathesis, olefin polymerization and olefin oligomerization

| **Teaching and learning units** | **Attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) | |
|---|---|---|---|---|
| Lecture | 2 | - | Attendance L<br>Preparation and follow-up L<br>Attendance S<br>Preparation and follow-up S<br>Examination preparation, examination | 30<br>30<br>15<br>45<br><br>30 |
| Seminar | 1 | Lectures, working on problem sets, contributing to discussions | | |
| **Language of instruction** | | German or English | | |
| **Compulsory regular attendance** | | Attendance recommended | | |
| **Study time, total hours** | | 150 hours | | 5 CP |
| **Duration of module** | | One semester | | |
| **Module offered** | | Not regularly | | |
| **Application** | | Master's program in Chemistry | | |

**Module**: Systems Chemistry

**University/department/institute:** Freie Universität Berlin/Department of Biology, Chemistry and Pharmacy/Institute of Chemistry and Biochemistry

**Responsible for the module:** module lecturers

**Admission requirements:** none

**Qualification aims**: The students know the behavior of complex chemical systems and understand the development of emergent properties in chemical networks. They can establish relationships to other complex systems in the everyday world.

**Content**: Dynamic combinatorial libraries; self-organization; transformation cascades in dynamic self-organizing systems; self-sorting processes and network topologies; minimal replicators and their integration in dynamic systems; properties of autocatalytic peptide networks; oscillating reactions and their application in gels and polymers; symmetry breaking and homochirogenesis; chemical models for homeostasis and autopoiesis; adaptive materials

| **Teaching and learning units** | **Attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) | |
|---|---|---|---|---|
| Lecture | 2 | - | Attendance L<br>Preparation and follow-up L<br>Attendance S<br>Preparation and follow-up S<br>Examination preparation, | 30<br>30<br>15<br>45 |
| Seminar | 1 | Lectures, working on problem sets, contributing to | | |

| | | | | |
|---|---|---|---|---|
| | | discussions | examination | 30 |
| **Language of instruction** | | German or English | | |
| **Compulsory regular attendance** | | Attendance recommended | | |
| **Study time, total hours** | | 150 hours | | 5 CP |
| **Duration of module** | | One semester | | |
| **Module offered** | | Not regularly | | |
| **Application** | | Master's program in Chemistry | | |

**6. Topic area Physical Chemistry**

| **Module**: Chemical Processes on Surfaces and Interfaces | | | | |
|---|---|---|---|---|
| **University/department/institute:** Freie Universität Berlin/Department of Biology, Chemistry and Pharmacy/Institute of Chemistry and Biochemistry | | | | |
| **Responsible for the module:** module lecturers | | | | |
| **Admission requirements:** none | | | | |
| **Qualification aims**: The students have gained a deeper insight into processes on surfaces. This includes an understanding of the thermodynamics, the kinetics and the dynamics of these processes and the methods used to gain this information. The students have made concrete links to current research, gaining insight into the everyday work of a physical chemist. | | | | |
| **Content**: Structure and dynamics of surfaces and interfaces; methods of surface analysis and characterization; interaction of adsorbates on surfaces; chemical reactions on surfaces and discussion of the atomic principles and also the thermodynamic or kinetic description of the processes | | | | |
| **Teaching and learning units** | **Attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) | |
| Lecture | 3 | - | Attendance L<br>Preparation and follow-up L<br>Examination preparation, examination | 45<br>60<br>45 |
| **Language of instruction** | | German or English | | |
| **Compulsory regular attendance** | | Attendance recommended | | |
| **Study time, total hours** | | 150 hours | | 5 CP |
| **Duration of module** | | One semester | | |
| **Module offered** | | Not regularly | | |
| **Application** | | Master's program in Chemistry | | |

| **Module**: Applied Electrochemistry: Batteries, Fuel Cells and other applications | | | | |
|---|---|---|---|---|
| **University/department/institute:** Freie Universität Berlin/Department of Biology, Chemistry and Pharmacy/Institute of Chemistry and Biochemistry | | | | |
| **Responsible for the module:** module lecturers | | | | |
| **Admission requirements:** none | | | | |
| **Qualification aims**: The students have deepened their knowledge and know the current applications of electrochemistry, including everyday applications. They have experience of the current state of fundamental research and understand the steps in the process chain leading to application. In the accompanying seminar, students research examples of current research, present them and discuss them critically in the group. | | | | |
| **Content**: Principles (double layer models, Nernst equation, Butler-Volmer equation, Tafel equation, electrochemical cells), batteries for storing energy (structure using the example of a lithium ion battery, discussion of challenges and limitations of battery technology, use of modern materials and concepts such as Li-O and Li-S, redox-flow batteries); fuel cells for energy conversion (development of fuel cell technology, comparison of low temperature systems (polymer electrolyte membrane fuel cell – PEMFC, Direct methanol fuel cell – DMFC) and high temperature systems (solid oxide fuel cell – SOFC), design of new materials and production processes); materials and methods (carbon materials in fuel cells and batteries, carbon nanotubes, graphene, new electrolytes (solid and liquid)); methods for in-situ examination of batteries and fuel cells; current research topics in focus: water electrolysis, chloralkali electrolysis, concept of photoelectrochemical hydrogen generation; electrochemical sensors; electroluminescence; electrophoresis; corrosion protection | | | | |
| **Teaching and learning units** | **Attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) | |
| Lecture | 2 | - | Attendance L<br>Preparation and follow-up L<br>Attendance S<br>Preparation and follow-up S<br>Examination preparation, examination | 30<br>30<br>30<br>30<br>30 |
| Seminar | 2 | Contributions to discussion | | |
| **Language of instruction** | | German or English | | |

| | | |
|---|---|---|
| **Compulsory regular attendance** | Attendance recommended | |
| **Study time, total hours** | 150 hours | 5 CP |
| **Duration of module** | One semester | |
| **Module offered** | Not regularly | |
| **Application** | Master's program in Chemistry | |

| | |
|---|---|
| **Module**: Electron structure methods | |
| **University/department/institute:** Freie Universität Berlin/Department of Biology, Chemistry and Pharmacy/Institute of Chemistry and Biochemistry | |
| **Responsible for the module:** module lecturers | |
| **Admission requirements:** none | |
| **Qualification aims**: The students have detailed knowledge of the theoretical and experimental principles of electron structures for periodic systems. They can determine the electronic band structure of a crystal using theoretical and experimental methods and can interpret the band structure using symmetry arguments; they are able to derive solid state properties from their findings. | |
| **Content**: Crystal structure and space groups; quantum chemistry for periodic systems; spectroscopic methods of determining electron structure, e.g. angle-resolved photoemission spectroscopy, scanning tunnelling spectroscopy, inverse photoemission, 2-photon photoemission | |

| **Teaching and learning units** | **Attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) | |
|---|---|---|---|---|
| Lecture | 2 | - | Attendance L<br>Preparation and follow-up L<br>Attendance SPC<br>Preparation and follow-up SPC<br>Examination preparation, examination | 30<br>30<br>30<br>30<br>30 |
| Seminar on the computer using special software | 2 | Working on problem sets and computer simulations | | |

| | | |
|---|---|---|
| **Language of instruction** | German or English | |
| **Compulsory regular attendance** | Lecture: attendance recommended; seminar: yes | |
| **Study time, total hours** | 150 hours | 5 CP |
| **Duration of module** | One semester | |
| **Module offered** | Not regularly | |
| **Application** | Master's program in Chemistry | |

**7. Topic area Theoretical Chemistry**

| | |
|---|---|
| **Module**: Quantum Chemistry: Correlation Methods | |
| **University/department/institute:** Freie Universität Berlin/Department of Biology, Chemistry and Pharmacy/Institute of Chemistry and Biochemistry | |
| **Responsible for the module:** module lecturers | |
| **Admission requirements:** none | |
| **Qualification aims**: The students have detailed knowledge of the theoretical principles of quantum chemistry correlation methods. They are familiar with quantum chemical program packages, can independently carry out quantum chemical correlation calculations for simple systems and prepare computer-aided visualizations of the calculated data. | |
| **Content**: Molecular Hamiltonian operator and electronic wave functions; Gaussian basis sets and pseudopotentials; the Hartree-Fock theory and the correlation methods based on it. Introduction to quantum chemical program packages and computer-aided visualization of the data calculated | |

| **Teaching and learning units** | **Attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) | |
|---|---|---|---|---|
| Lecture | 2 | - | Attendance L<br>Preparation and follow-up L<br>Attendance SPC<br>Preparation and follow-up SPC<br>Examination preparation, examination | 30<br>30<br>30<br>30<br>30 |
| Seminar on the computer using special software | 2 | Working on problem sets and computer simulations | | |

| | | |
|---|---|---|
| **Language of instruction** | German or English | |
| **Compulsory regular attendance** | Lecture: attendance recommended; seminar: yes | |
| **Study time, total hours** | 150 hours | 5 CP |
| **Duration of module** | One semester | |
| **Module offered** | Every third semester | |
| **Application** | Master's program in Chemistry | |

| | |
|---|---|
| **Module**: Density Functional Theory | |

**University/department/institute:** Freie Universität Berlin/Department of Biology, Chemistry and Pharmacy/Institute of Chemistry and Biochemistry

**Responsible for the module:** module lecturers

**Admission requirements:** none

**Qualification aims**: The students have detailed knowledge of the theoretical principles of ground-state and excited-states density functional theory. They are familiar with quantum chemical program packages, can apply density functional theory confidently and carry out structural optimization and frequency analyzes.

**Content**: Principles of density functional theory; development of exchange-correlation functions; application fields and precision of different density functional methods; molecular properties and excited states described by time-dependent density functional theory. Algorithms to optimize molecular structure and frequency analysis. Introduction to quantum chemical program packages focusing on density functional methods and computer-aided interpretation of the data calculated

| **Teaching and learning units** | **Attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) | |
|---|---|---|---|---|
| Lecture | 2 | - | Attendance L<br>Preparation and follow-up L<br>Attendance SPC<br>Preparation and follow-up SPC<br>Examination preparation, examination | 30<br>30<br>30<br>30<br>30 |
| Seminar on the computer using special software | 2 | Working on problem sets and computer simulations | | |
| **Language of instruction** | | German or English | | |
| **Compulsory regular attendance** | | Lecture: attendance recommended; seminar: yes | | |
| **Study time, total hours** | | 150 hours | | 5 CP |
| **Duration of module** | | One semester | | |
| **Module offered** | | Every third semester | | |
| **Application** | | Master's program in Chemistry | | |

**Module**: Relativistic Quantum Chemistry

**University/department/institute:** Freie Universität Berlin/Department of Biology, Chemistry and Pharmacy/Institute of Chemistry and Biochemistry

**Responsible for the module:** module lecturers

**Admission requirements:** none

**Qualification aims**: The students have knowledge of the theory of relativity and its effects on the electronic structure of molecules. They can carry out simple relativistic quantum chemistry calculations and know a range of methods of approaching relativistic quantum chemistry.

**Content**: Special relativity theory; quantization and spin; Dirac equation for one-electron and multi-electron systems; methods of relativistic quantum chemistry; relativistic pseudopotentials

| **Teaching and learning units** | **Attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) | |
|---|---|---|---|---|
| Lecture | 2 | - | Attendance L<br>Preparation and follow-up L<br>Attendance SPC<br>Preparation and follow-up SPC<br>Examination preparation, examination | 30<br>30<br>30<br>30<br>30 |
| Seminar on the computer using special software | 2 | Working on problem sets and computer simulations | | |
| **Language of instruction** | | German or English | | |
| **Compulsory regular attendance** | | Lecture: attendance recommended; seminar: yes | | |
| **Study time, total hours** | | 150 hours | | 5 CP |
| **Duration of module** | | One semester | | |
| **Module offered** | | Not regularly | | |
| **Application** | | Master's program in Chemistry | | |

**Module**: Quantum Reaction Dynamics

**University/department/institute:** Freie Universität Berlin/Department of Biology, Chemistry and Pharmacy/Institute of Chemistry and Biochemistry

**Responsible for the module:** module lecturers

**Admission requirements:** none

**Qualification aims**: The students know the theoretical concepts and methods of describing time-dependent quantum mechanics of chemical reactions and can carry out the relevant computer simulations and visualizations.

**Content**: Time-dependent quantum mechanics; wave-packet dynamics; adiabatic and non-adiabatic dynamics; molecular transitions and reactions after excitation by laser pulses; numerical methods and computer simulations for solving time-dependent quantum mechanical problems

| Teaching and learning units | Attendance (Semester hours per week = SH) | Forms of active participation | Study time (hours) | |
|---|---|---|---|---|
| Lecture | 2 | - | Attendance L<br>Preparation and follow-up L<br>Attendance SPC<br>Preparation and follow-up SPC<br>Examination preparation, examination | 30<br>30<br>30<br>30<br>30 |
| Seminar on the computer using special software | 2 | Working on problem sets and computer simulations | | |
| **Language of instruction** | | German or English | | |
| **Compulsory regular attendance** | | Lecture: attendance recommended; seminar: yes | | |
| **Study time, total hours** | | 150 hours | | 5 CP |
| **Duration of module** | | One semester | | |
| **Module offered** | | Every third semester | | |
| **Application** | | Master's program in Chemistry | | |

**8. Topic area Environmental Chemistry**

| **Module**: Environmental Chemistry: Energy and Special Atmospheric Chemistry | |
|---|---|
| **University/department/institute:** Freie Universität Berlin/Department of Biology, Chemistry and Pharmacy/Institute of Chemistry and Biochemistry | |
| **Responsible for the module:** module lecturers | |
| **Admission requirements:** none | |
| **Qualification aims**: The students are familiar with important cross-disciplinary principles of environmental chemistry in relation to energy and energy conversion; they have deepened their knowledge of atmospheric chemistry. They are familiar with the principle interactions of the physical-chemical processes of energy conversion and of the atmosphere. They are capable of classifying and evaluating the impact of humans on the environment in detail, and are thus able to analyze complex interactions in the environment, to understand original publications on environmental research on a broad basis and to carry out independent scientific research in the environmental field. They have a good foundation of knowledge as a basis for a professional career in environmental protection. | |
| **Content**: Energy and energy conversion; energy stocks; periodically working machines with practical examples; energy storage; fossil energy sources; production of liquid and gaseous energy sources; use of fossil energy sources including technical applications (power stations; combined heat and power generation); renewable energy sources (photovoltaics, photothermal energy collection, solar power stations, wind power, hydro power (tides, waves); geothermal sources; biogenic energy sources (biogas, biosludge, waste incineration); atomic fission and fusion; properties of moist air; humidity measurements; atmospheric instability; aerosols and precipitation; nucleation; clouds and cloud chemistry; aerosols and clouds in the stratosphere; special topics in atmospheric chemistry (chemistry of photooxidants, hydrochlorofluorocarbons and their replacements, chemistry of the stratosphere and upper atmosphere, chemistry of planetary atmospheres, spread and degradation of persistent organic pollutants, indoor emissions); special environmental measuring processes (remote sensing and in-situ measuring processes); chemical models to simulate environmental changes | |

| Teaching and learning units | Attendance (Semester hours per week = SH) | Forms of active participation | Study time (hours) | |
|---|---|---|---|---|
| Lecture I | 2 | - | Attendance L I<br>Preparation and follow-up L I<br>Attendance L II<br>Preparation and follow-up L II<br>Examination preparation, examination | 30<br>30<br>30<br>30<br>30 |
| Lecture II | 2 | - | | |
| **Language of instruction** | | German | | |
| **Compulsory regular attendance** | | Attendance recommended | | |
| **Study time, total hours** | | 150 hours | | 5 CP |
| **Duration of module** | | Two semesters | | |
| **Module offered** | | Every semester | | |
| **Application** | | Master's program in Chemistry | | |

**D. Elective area**

| **Module**: Modern Aspects of Chemistry | |
|---|---|
| **University/department/institute:** Freie Universität Berlin/Department of Biology, Chemistry and Pharmacy/Institute of Chemistry and Biochemistry | |
| **Responsible for the module:** module lecturers | |
| **Admission requirements:** none | |

| | | | |
|---|---|---|---|
| **Qualification aims**: The students have deepened their knowledge of two special topics in chemistry. They have also gained insight into the state of current research and the everyday professional lives of chemists. | | | |
| **Content**: The topics are chosen according to availability. | | | |
| **Teaching and learning units** | **Attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) |
| Lecture I | 2 | Test | Attendance L I 30<br>Preparation and follow-up L I 45<br>Attendance L II 15<br>Preparation and follow-up L II 30<br>Examination preparation, examination 30 |
| Lecture II | 1 | Test | |
| **Language of instruction** | | German or English | |
| **Compulsory regular attendance** | | Attendance recommended | |
| **Study time, total hours** | | 150 hours | 5 CP |
| **Duration of module** | | One semester | |
| **Module offered** | | Every semester | |
| **Application** | | Master's program in Chemistry | |

**Annex 2: . Sample degree program table[i] for the Master's program**

<table>
<tr><th>Semester (FS)</th><th>Topic area Inorganic Chemistry</th><th>Topic area Organic Chemistry</th><th>Topic area Phys. & Theor. Chemistry</th><th>Cross-topic area</th><th>Project area</th><th>Specialization area</th><th>Electives</th><th>Master's thesis</th></tr>
<tr><td>1st FS<br>30 CP</td><td>Compulsory elective module 1 Inorg. Chem.<br>5 CP</td><td>Compulsory elective module 1 Org. Chem.<br>5 CP</td><td>Compulsory elective module 1 Phys. & Theor. Chem.<br>5 CP</td><td rowspan="2"></td><td rowspan="2">Research project 1 (also possible in semester breaks)<br>15 CP</td><td></td><td>Elective module 1<br>5 CP</td><td rowspan="4"></td></tr>
<tr><td>2nd FS<br>30 CP</td><td>Compulsory elective module 2 Inorg. Chem.<br>5 CP</td><td></td><td>Compulsory elective module 2 Phys. & Theor. Chem.<br>5 CP</td><td rowspan="2">Specialization module 1<br>5 CP</td><td>Elective module 2<br>5 CP</td></tr>
<tr><td>3rd FS<br>30 CP</td><td rowspan="2"></td><td>Compulsory elective module 2 Org. Chem.<br>5 CP</td><td rowspan="2"></td><td>Cross-topic module<br>5 CP</td><td rowspan="2">Research project 2 (also possible in semester breaks)<br>15 CP</td><td>Specialization module 2<br>5 CP</td><td>Elective module 3<br>5 CP</td></tr>
<tr><td>4th FS<br>30 CP</td><td colspan="5"></td><td>Master's thesis & Master's lecture<br>30 CP</td></tr>
<tr><td>120 CP</td><td>10</td><td>10</td><td>10</td><td>5</td><td>30</td><td>10</td><td>15</td><td>30</td></tr>
</table>