JACOBS UNIVERSITY

Chemistry

Bachelor's Degree Program (BSc)

Contents

As of September 1, 2014 the School of Engineering and Science and the School of Humanities and Social Sciences have been replaced by the Focus Areas Health, Mobility and Diversity. Handbooks and policies might still refer to the old structure of Schools.
If this is the case, references to the School of Engineering and Science include courses offered within the following disciplines:

- Electrical Engineering and Computer Science
- Life Sciences
- Logistics
- Mathematical Sciences
- Natural and Environmental Sciences

References to the School of Humanities and Social Sciences include courses offered within the following disciplines:

- Economics and Management
- History
- Humanities
- Law
- Psychology
- Social Sciences
- Statistics and Methods

1 Chemistry at Jacobs University

1.1 Concept

Chemistry is the science at the heart of innovation. Mastery of this subject provides the intellectual footing and research skills to strategize and develop the solutions for mankind's most urgent and foreseeable problems: energy, environment, food, and health. At Jacobs University Chemistry, we equip our students with the knowledge, research techniques, and the problem-solving skills to tackle these future challenges while simultaneously furthering their academic or industry careers; whether in the public or the private sector, in research or in management, in chemistry or beyond chemistry. We do this by offering a broad education in the chemical sciences, while incorporating the modern concepts of nanomolecular science. As a consequence, students graduating with a B.Sc. degree in chemistry from Jacobs University are in an excellent position to then specialize in a specific field of chemistry or nanomolecular science, or consider the adjacent fields ranging from biochemistry to environmental protection.

1.2 Program and Specific Advantages

The Chemistry major at Jacobs University combines the long tradition of a thorough education in Chemistry with the opportunity to participate in research projects already at a very early stage of the studies. The program consists of three years of lectures and the corresponding laboratory classes and leads to the Bachelor of Science (B.Sc.) in Chemistry. The first year lays the foundation in chemistry, the other natural sciences, and mathematics. The second year focuses on the core education in Organic, Inorganic, and Physical Chemistry. Lectures and exercises furnish theoretical knowledge, while extensive laboratory modules put in place the required practical skills. The third year is devoted to specialization courses (for example Biochemistry, Computational Chemistry, or Nanomolecular Science) and guided laboratory research. During this final year, the students carry out their own guided research project in the laboratory of a faculty member in Chemistry. This research culminates in a Bachelor Thesis. The Jacobs University Chemistry program provides a stimulating study environment. As classes are small, there is good and supportive interaction of the Chemistry Faculty with the students, with regular contact and support in theoretical questions, research, and the development of written and oral communication skills. The program and faculty members promote undergraduates, at an early stage, to get involved in a funded research project that allows close interaction with M.Sc. and Ph.D. students. The faculty uses their contacts to place the chemistry students into mandatory summer internships in academic or industrial environments during their second summer at Jacobs University. To ensure international recognition, the Chemistry curriculum at Jacobs University was designed according to the most recent Chemistry Eurobachelor guidelines as well as the recommendations of the American Chemical Society (ACS). Apart from the mandatory courses, students can freely select up to 8 specialization courses of their interest, including biochemistry, biophysical chemistry, geochemistry, and chemical physics. Importantly, our undergraduate major is synergistic with the "Physical Sciences" graduate program at Jacobs University, and students can take up to three graduate courses during their undergraduate education. This optional "Early Track" alternative, which students can decide to participate in at any time during their undergraduate education, can lead to the M.Sc. degree in Physical Sciences within one year after the B.Sc. degree is obtained. The program is designed to accommodate those students who want to take the entrance exams of the Anglo-American Medical Schools

by the end of their second year of study at Jacobs University. B.Sc. in Chemistry offers a challenging learning environment with maximum flexibility. These unique features combine to make our graduates very attractive to employers as well as graduate schools.

1.3 Research Opportunities

Our Chemistry students receive intensive practical laboratory training during the first two years of their undergraduate B.Sc. degree. The third year is devoted to a large and independent research project. The basic research project course can be performed in any chemistry research area at Jacobs University with the chemistry faculty as potential supervisors. This includes research in the following areas offered at Jacobs University: organic chemistry, inorganic chemistry, physical and physical-organic chemistry, computational chemistry and biochemistry, analytical chemistry, environmental chemistry, nanoscience, supramolecular chemistry, catalysis, and biomolecular chemistry. Research is conducted under the mentorship of a Chemistry Faculty member and his/her extended research group, with research times being individually scheduled. It is the responsibility of the student to find a supervisor for his/her research project. Typically, the student fulfills the research requirements by working two full semesters in the same research group. It is also possible to transfer to another laboratory in the second semester. This research activity is concluded with the writing of a B.Sc. thesis, and it is not uncommon that the research work of the student becomes part of a publication in a peer reviewed journal. For curious and eager students, independent laboratory research is encouraged at any time before the third year of study.

1.4 Summer Internships

One mandatory summer internship, in industry or academia, strengthens the student with prospective and practical insight into the actual working environment of other chemists. These opportunities frequently make future graduate school entrance or industrial employment achievable. Stimulating industrial or academic internships are common within Europe and occasionally occur in North America. The internship is strongly encouraged during the summer session following the second year of study at Jacobs University.

1.5 Career Opportunities

At the core of nearly every aspect of our lives is the science of chemistry. It is therefore not surprising to find that career opportunities for chemists are diverse and abundant. A degree in Chemistry allows you the maximum flexibility in planning your future career objectives. Our students have been able to compete for and gain placement into very competitive graduate schools and have been successful in obtaining top industrial positions. With a B.Sc. degree one can enter graduate school (M.Sc. or Ph.D. programs in chemistry, nanoscience, physics, and biochemistry are typical) or begin an industrial career. In industry, research and development in the areas of pharmaceutical drugs, agrochemicals, materials and energy, environmental monitoring, forensic science, medical research, and computer modelling are attractive and popular career options. Chemists are also successful in other positions, such as teaching, production management, textiles, food production, business consulting, dentistry, scientific journalism, medicine, matters of law (patent attorney, civil or industrial lawyer), marketing, and even

careers in politics are open to chemists! The course requirements of the American medical schools (”pre-med”) can be met within the first two years to allow early registrations for both the GRE and MCAT examinations.

2 Modules: Chemistry

For greater transparency of the logics and as guidance for the (prospective) student, we have structured the respective major programs in terms of modules. A module is defined as a combination of courses (lectures, lab units or other types of courses) interconnected by the same learning goals (Lernziel). Before listing the individual courses and describing their contents, these modules are presented and characterized by the skills and abilities that the student is expected to acquire. But irrespective of this overarching modular structure, the learning progress will be documented with credit points and grades attributed to the individual courses or lab units. This facilitates the control of the student's progress through the student as well as the university on a semester basis, while the modules extend over a year. Only the core content of a major program is suited for modularization. The freely eligible Home School electives and transdisciplinary courses fall outside this structure.

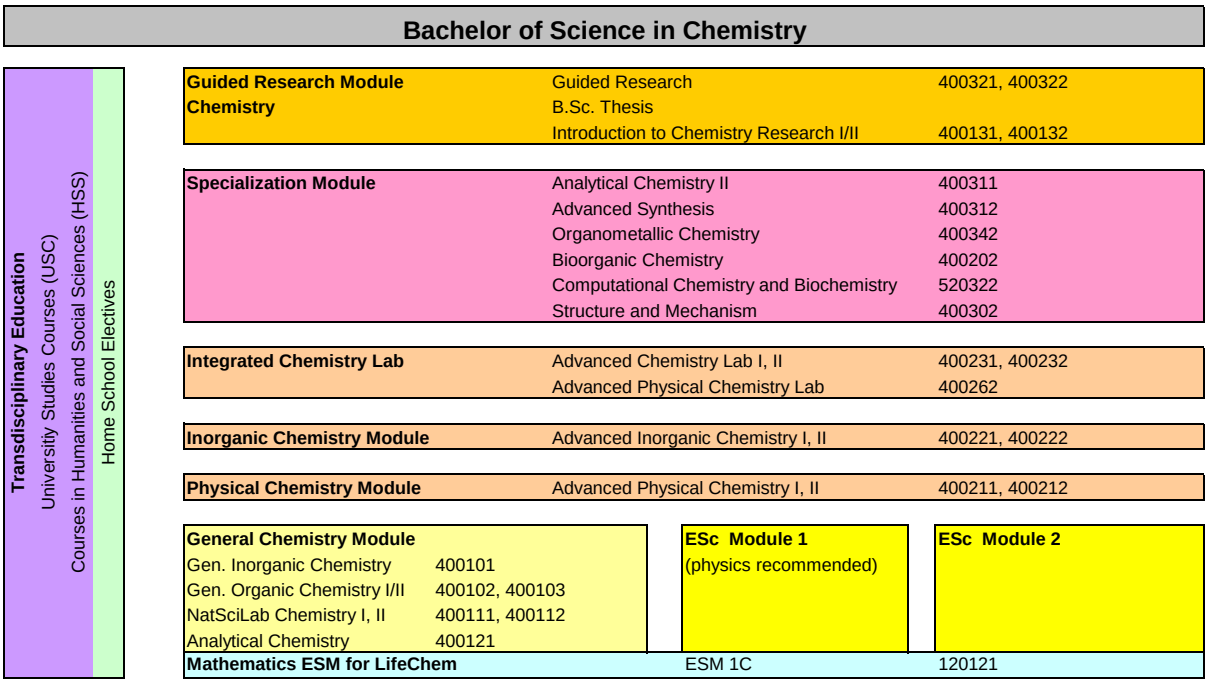

Figure 1: Chemistry Module Structure

Subsequently the individual modules are being defined with respect to learning goals and acquired competencies. The listed course numbers constitute a reference to the individual courses and the descriptions of their contents.

2.1 General Science

Home School Electives and transdisciplinary courses are not listed as modules.

120110 – Mathematics Module

Short Name: ESM for LifeChem
Semester: 1
Credit Points: 5 ECTS

General Information Students of Chemistry are required to take one Engineering and Science Mathematics course: See Engineering and Science Mathematics handbook.

Courses
120121 Engineering and Science Mathematics IC

xxx – Natural Science Modules

Short Name: ModGenSES
Semester: 1 – 2
Credit Points: 30 ECTS

General Information This includes the additional first year general science modules that consist of the general lectures and associated lab units which are required from all students majoring in the School of Engineering and Science. One recommended module for Chemistry students is General Physics.

Learning goals
- This should offer the student an introduction into other sciences offered within the School of Engineering and Science (SES).

Courses
4 general engineering and science lectures (5 ECTS credits each)
4 Natural Science Lab Units associated with the above lectures (2.5 ECTS credits each)
200101 General Physics I (recommended)
200102 General Physics II (recommended)
200111 NatSciLab Physics I (recommended)
200112 NatSciLab Physics II (recommended)

2.2 Chemistry Major

400100 – General Chemistry Module

Short Name: ModGenChem
Semester: 1 – 2
Credit Points: 25 ECTS

General Information This module deals with the most basic concepts of chemistry, for example atomic structure (classical versus quantum-mechanical), stoichiometry, chemical bonding (ionic versus covalent), nomenclature, periodic properties of the elements, different phases, molecular structure, hybridization of organic molecules, organic functional groups, inorganic chemical reactions (precipitation, acid-base, redox), fundamental organic reactions (addition, elimination, substitution), isomerism and chirality, concepts for chemical reactivity (nucleophilicity, electrophilicity, hardness and softness), and reactive species (carbocations, carbanions, radicals). The lecture material is complemented by hands-on practical experience involving lab safety, basic chemical reactions and techniques, including lab equipment and basic chemical reactions in inorganic (pH-related experiments, precipitation, titration, filtration, etc.) and organic chemistry (esterification, bromination, saponification, substitution, natural product isolation). In addition, fundamental analytical experiments are conducted, including gravimetry, titrations (acid-base and redox), infrared spectra, melting and boiling point, refractive index. Practical work (individual as well as in groups) is accompanied by the writing of lab reports, including yield calculations, analysis of experimental results, stoichiometry. These introductory courses and laboratories are complemented by a third course in analytical chemistry. This course provides a global perspective of chemistry through a solid introduction to modern analytical techniques for purification and structure identification, including high-throughput screening and trace detection. In doing so, this course demonstrates the application of analytical chemistry beyond the core areas of chemistry, thus aspects from biotechnology and environmental chemistry are strongly interwoven. The combination of these courses allows an awareness and appreciation for the continued impact of chemistry on society in general.

Learning Goals

- Understanding of life and matter in terms of chemical entities and bonding
- Appreciation of the importance of chemistry and chemical concepts in daily life
- Ability to solve chemistry-related problems on the basis of mass balance, equilibria, yield, and energetics
- Knowledge of conventions, units, and chemical terminology
- Supervised conduction of basic experiments
- Team-working skills
- Strategic problem analysis and solution
- Interpretation of visual observations in terms of chemical changes
- Introduction to the most basic chemical terminology in German language
- Awareness of chemical hazards and lab hygiene, safe handling of chemicals
- Knowledge of the principles of modern analytical techniques
- Appreciation of analytical techniques for environmental purposes
- Consideration of the complex effects of chemicals on the environment
- Assessment of fundamental pathways for biodegradation and/or toxicity
- Understanding of the importance of analytical chemistry in assays, in environmental trace detection, and in forensic science

Courses

400101 General Inorganic Chemistry
400102 General Organic Chemistry I
400103 General Organic Chemistry II

400111 General Inorganic Chemistry Lab
400112 General Organic Chemistry Lab
400121 Analytical/Environmental Chemistry

400210 – Advanced Physical Chemistry Module

Short Name: ModPhysChem
Semester: 3 – 4
Credit Points: 10 ECTS

General Information The module is meant to enable students to apply the quantitative theoretical and experimental techniques of physical chemistry to chemical, biochemical, and materials science problems and to understand chemical systems and processes in terms of their energetics, thermodynamics and kinetics. Fundamental concepts of molecular quantum mechanics and statistical mechanics are introduced to describe phenomena, observations and properties of molecular and condensed-phase systems.

Learning goals

- Calculus-based problems solving
- Application of engineering and science mathematics in chemistry
- Understanding of the physical-chemical principles governing chemical processes
- Appreciation of the fundamental laws of physics as common denominators in chemistry
- Ability to interpret processes in terms of thermodynamics, including real-life phenomena
- Fundamental knowledge of quantum mechanics and statistical thermodynamics

Courses
400211 Advanced Physical Chemistry I
400212 Advanced Physical Chemistry II

400220 – Advanced Inorganic Chemistry Module

Short Name: ModInorganicChem
Semester: 3 – 4
Credit Points: 10 ECTS

General Information This module starts with an introduction to nuclear chemistry, followed by an in-depth study of the periodic trends of the elements, molecular bonding and geometry, Lewis dot structures, molecular orbital theory (including band structures), solid-state structures and bonding (metal and ionic lattices), symmetry and group theory, and vibrational analysis. A special focus lies on transition metals, their typical oxidation states, coordination numbers and geometries, the study of electronic properties of coordination complexes (spectroscopy), and reactivity (ligand exchange, redox). Students acquire soft skills by performing independent surveys of scientific literature, concluding with the preparation of a term paper and in-class presentation of their results.

Learning Goals

- Comprehension of three-dimensional orientation of atoms, orbitals, and molecules
- Understanding the influence of geometric and electronic ligand contributions on overall molecular properties
- Appreciation of the symmetry as a determining factor of spectroscopic and physical properties
- Use of spectroscopy as a tool for structure analysis
- Extension of MO theory from diatomic to bulk structures
- Thermochemical calculations
- Prediction of molecular stability and solid-state properties
- Ability to understand primary literature, extract essential information in a written report, and condense it in an oral in-class presentation

Courses

400221 Advanced Inorganic Chemistry I
400222 Advanced Inorganic Chemistry II (Coordination Chemistry)

400230 – Integrated Laboratory Module

Short Name: ModAdvChemLab
Semester: 3 – 4
Credit Points: 15 ECTS

General Information This laboratory module focuses on advanced laboratory skills with the aim of integrating analytical, physical, organic, and inorganic experiments. Students learn advanced practical techniques, including the assembly of complex glass apparati, inert atmosphere and vacuum techniques, hydrogenation, low-temperature reactions, handling of hazardous materials, multi-step reactions, synthesis of polyfunctional molecules and coordination complexes, purification techniques (chromatographic separations, sublimation, recrystallization), characterization of products by using state-of-the art instrumentation (NMR, IR, AA, UV-Vis, GC, TGA) in both the solid and solution phase. The lab work is complemented by physical-chemistry experiments extending to calorimetric (thermochemical) investigations, spectroscopic principles and effects (EPR, NMR), kinetic measurements (hydrolysis), fractional distillation principles, theoretical plate calculations etc. Practical work is accompanied by the write-up of lab reports, including structure assignments and interpretation of analytical data. Students are expected to prepare their experiments in advance, including synthetic strategy development. Students become familiarized, through literature search assignment, with the computer-assisted searching in chemical data bases, chemical structure drawing programs, simple molecular modeling calculations, retrieval of primary literature, localization of physical data of compounds, and ordering procedures of literature through interlibrary loan. Accompanying seminars provide introductions to NMR and IR spectroscopy and to basic molecular modeling. The interpretation of the physical chemistry experiments includes detailed error-calculations.

Learning goals

- Chemical information retrieval skills

- Ability to implement good measurement science and practice
- Error analysis
- Acquisition of advanced laboratory and instrumental skills
- Ability to plan and conduct multi-step chemical reactions
- Knowledge of instrumental analysis
- Application of advanced theoretical knowledge hands-on
- Recognition of the interplay of different chemistry areas in hands-on practice

Courses
400231 Advanced Integrated Organic Chemistry Lab
400232 Advanced Integrated Inorganic Chemistry Lab
400262 Advanced Physical Chemistry Lab

400300 – Specialization Module

Short Name: SpecializationMod
Semester: 5 – 6
Credit Points: 20 ECTS

General Information The module focuses on the understanding of structure and dynamics of molecular systems, how to synthesize and characterize them quantitatively by using experiment and theory. This includes molecular structure and processes, molecules in an environment, reaction mechanisms and intermediates, linear free energy relationships, as well as photochemical reactions. A specific focus will be on organometallic, natural product, and pharmaceutical drug synthesis and their applications and will be taught from the vantage point of strategy and methodology. It includes estimation of chemical reactivity by using computational and empirical tools for predicting molecular orbitals, steric and stereoelectronic effects, polar effects, deuterium isotope effects, and solvent effects. The students will get acquainted with various spectroscopic (in theory) and computational techniques (quantum chemistry and molecular simulation, hands-on) and advanced synthesis methods

Learning goals
- Fundamental understanding of the different levels of sophistication of computational methods
- Proper choice of computational approaches in dependence on the actual problem
- Familiarization with different software and structure visualization programs
- Computer-assisted problem solving
- Relevance of molecular orbitals on chemical reactivity
- Ability to apply the concepts of aromaticity and the forbiddenness of concerted reactions
- Application of isotope, solvent, and substituent effects to study reaction mechanisms
- Complex synthetic strategies
- Recognition of synthesis in the drug discovery process
- Ability to be well-versed and precise in chemical terminology and scientific English
- Learning to challenge existing theories and developing new hypotheses
- Knowledge of recent synthetic methodologies
- Application of chemical know-how in the life and materials sciences

Courses (4 out of 6 courses are mandatory:)
400202 Bioorganic Chemistry
400301 Computational Chemistry and Biochemistry
400302 Structure and Mechanism
400311 Analytical Chemistry II
400312 Advanced Synthesis
400342 Organometallic Chemistry

400320 – Guided Research Chemistry and Bachelor Thesis

Short Name: ModGRChem
Semester: 5 – 6
Credit Points: 20 ECTS

General Information Students individually pursue research projects within the research labs of the chemical science faculty. Projects generally extend over one full year, in one or two research groups, and work times may include the intercessions. Research projects generally are initiated with a survey of the relevant literature and presentation of the project objectives within a departmental seminar. Experimental approaches are developed and carried out under guidance of the respective faculty member in close coordination of the research group. Typically, the student has a dedicated scientific mentor, but are allowed access to a large range of sophisticated instrumentation. The work culminates in the preparation of the undergraduate research thesis, the results of which are defended in an additional departmental seminar. During their guided research, students are fully immersed within an active research environment, consisting of group meetings, and lectures of visiting scientists.

Learning goals
- Written and oral presentation of research proposals and results
- Ability to adapt to a new environment ” Scientific communication skills
- Experimental design, including economical and safety considerations
- Time management and organizational skills
- Literature survey
- Team working skills
- Critical thinking
- Familiarization with scientific achievements and failures
- Learning from experience
- Project accountability
- Laboratory resource and infrastructure responsibility

Courses
400321 Guided Research I
400322 Guided Research II
400331 Guided Research: Seminar I
400332 Guided Research: Seminar II

3 Requirements for a B.Sc. in Chemistry

3.1 General Requirements

To obtain a B.Sc. degree at Jacobs University a minimum of 180 ECTS credit points must be earned over a period of 6 semesters.

- 140 ECTS credits must be earned in the School of Engineering and Science.
- 30 ECTS credits must be earned through transdisciplinary courses, comprised of courses in the School of Humanities and Social Sciences (**HSS**) and University Study Courses (**USC**). Students can choose how many USCs or SHSS courses they take.
- 10 ECTS credits (4 courses) are accredited either for language courses or additional Home School electives. Students can decide whether they take language courses or not.

3.2 Courses Mandatory for the Major

Requirements of the Major

- **Year 1 level courses:**
  - Engineering and Science Mathematics IC (120121, 5 ECTS credits),
  - General Inorganic Chemistry (400101, 5 ECTS credits),
  - General Organic Chemistry I/II (400102, 400103, 10 ECTS credits),
  - NatSciLab Chemistry I (Inorganic Chemistry) (400111, 2.5 ECTS credits).
  - NatSciLab Chemistry II (Organic Chemistry) (400112, 2.5 ECTS credits).
  - Analytical/Environmental Chemistry, (400121, 5 ECTS credits)

- **Year 2 level courses:**
  - Advanced Physical Chemistry I/II (400211, 400212, 10 ECTS credits),
  - Advanced Inorganic Chemistry I/II (400221, 400222, 10 ECTS credits),
  - Advanced Integrated Organic and Analytical Chemistry Lab (400231, 7.5 ECTS credits)
  - Advanced Inorganic Chemistry Lab (400232, 3.75 ECTS credits)
  - Advanced Physical Chemistry Lab (400262, 3.75 ECTS credits)

- **Year 3 level courses:**
  - Guided Research Chemistry/BSc Thesis (400321, 400322, 15 ECTS credits).
  - Guided Research Chemistry Seminar I/II (400331, 400332, 5 ECTS credits),

- **Year 2 and 3 level chemistry specialization courses:**
  4 out of the following 6 courses (20 ECTS credits):
  - Analytical Chemistry II (400311, 5 ECTS credits)
  - Bioorganic Chemistry (400202, 5 ECTS credits)
  - Computational Chemistry and Biochemistry (400301, 5 ECTS credits)
  - Structure and Mechanism (400302, 5 ECTS credits)
  - Advanced Synthesis (400312, 5 ECTS credits)
  - Organometallic Chemistry (400342, 5 ECTS credits)

Jacobs University Bremen reserves the right to substitute courses by replacements and/or reduce the number of mandatory/mandatory elective courses offered

4 Recommended Course Plan

Year 1 Courses	**Fall**	**C**	**T**	**Spring**	**C**	**T**
ESc Mathematics IC[1]	120121	*5*	m			
General Inorganic Chemistry	400101	*5*	m			
General Organic Chemistry I/II	400102	*5*	m	400103	*5*	m
NatSciLab Chemistry I (Inorganic Chemistry)	400111	*2.5*	m			
NatSciLab Chemistry II (Organic Chemistry)				400112	*2.5*	m
Analytical/Environmental Chemistry				400121	5	m
First year courses in ESc subject		*5*	e		*5*	e
Language Courses or Home School Electives[2]		*7.5*	e		*2.5*	e
Transdisciplinary Courses					*10*	u
Running Total / *Semester Total*	30	*30*		60	*30*	

Year 2 Courses	**Fall**	**C**	**T**	**Spring**	**C**	**T**
Advanced Physical Chemistry I/II	400211	*5*	m	400212	*5*	m
Advanced Inorganic Chemistry I/II	400221	*5*	m	400222	*5*	m
Advanced Integrated Organic and Analytical Chemistry Lab	400231	*7.5*	m			
Advanced Inorganic Chemistry Lab				400232	*3.75*	m
Advanced Physical Chemistry Lab				400262	*3.75*	m
Chemistry Specialization Courses[3]		*5*	me		*5*	me
Language Courses or Home School Electives		*2.5*	e		*2.5*	e
Transdisciplinary Courses		*5*	u		*5*	u
Running Total / *Semester Total*	90	*30*		120	*30*	

Year 3 Courses	**Fall**	**C**	**T**	**Spring**	**C**	**T**
Chemistry Specialization Courses [3]		*5*	me		*5*	me
Guided Research and BSc Thesis	400321	*7.5*	m	400322	*7.5*	m
Guided Research Seminar I / II	400331	*2.5*	m	400332	*2.5*	m
Language Courses or Home School Electives		*10*	e		*10*	e
Transdisciplinary Courses		*5*	u		*5*	u
Running Total / *Semester Total*	150	*30*		180	*30*	

C = ECTS credit points, T=type (m=mandatory, e=elective, me= mandatory elective, u=university), Transdisciplinary Courses are School of Humanities and Social Science and University Studies Courses

[1] Students who are interested in Physical Chemistry should take at least two Mathematics (ESM) courses.
[2] Recommended: Introduction to Chemistry Research I and II (400131 and 400132)
[3] see list on next page

Year 2 and 3 Chemistry Specialization Courses	Fall	C	T	Spring	C	T
4 out of the following 6 courses are mandatory:[4]						
Analytical Chemistry II	400311	*5*	me			
Bioorganic Chemistry				400202	*5*	me
Computational Chemistry and Biochemistry	400301	*5*	me			
Structure and Mechanism				400302	*5*	me
Advanced Synthesis	400312	*5*	me			
Organometallic Chemistry				400342	*5*	me

4.1 Recommendation Professional Skills

The SES highly recommends attending the Professional Skills seminars offered by the Career Services Center. Those seminars include soft skills development seminars and application training which will help you to cope with your studies and master your internship and job search.

All undergraduate students are required to complete an internship, normally to be accomplished between the second and third year of study. Information about the internship will be listed on the transcript. The internship must last at least two consecutive months. No credits are connected to the internship requirement. For more information on internships see http://www.jacobs-university.de/career-services/internship .

[4]The present list of courses is open to adjustments and additions.

5 Courses: Chemistry

5.1 First Year of Study

400101 – General Inorganic Chemistry

Short Name: GenInorgChem
Type: Lecture
Semester: 1
Credit Points: 5 ECTS
Prerequisites: None
Corequisites: None
Tutorial: Yes

Course contents An introduction to chemistry that comprises the following parts: Introduction and definitions: history, elements, compounds, units, Chemical reactions: Chemical equations, energy, reaction rates, equilibrium, acids and bases, thermodynamics Atoms and Atomic structure Spectroscopy, the hydrogen atom, many electron atoms, the periodic properties of the elements The chemical bond Ionic bonds, lattice enthalpy, covalent bonds, hydrogen bonds, the shape of molecules (VSEPR), the elements and their properties, a walk through the periodic table: characteristic properties, natural abundance and chemistry of main group elements and transition metals.

400102 – General Organic Chemistry I

Short Name: GenOrgChemI
Type: Lecture
Semester: 1
Credit Points: 5 ECTS
Prerequisites: None
Corequisites: None
Tutorial: Yes

Course contents The course will give an introduction into the principles of organic chemistry with experimental demonstrations. Organic chemistry is the chemistry of ”living matter” and is therefore essential in the context of life sciences. The material to be covered will include a definition of organic compounds, bonding and hybridization, functional groups, organic acids and bases, conformations, nomenclature, chirality, nucleophilic substitution, elimination reactions, addition reactions, radical reactions, synthesis of alcohols, ethers, and carbonyl compounds. Special chapters will be devoted to some physical aspects in organic chemistry, including infrared spectroscopy and UV spectrophotometry.

400103 – General Organic Chemistry II

Short Name: GenOrgChemII
Type: Lecture
Semester: 2
Credit Points: 5 ECTS
Prerequisites: 400102
Corequisites: None
Tutorial: Yes

Course contents The course is a continuation of 400102 General Organic Chemistry I and is intended for all chemistry-related majors and students wishing to fulfill US medical school requirements. The course will cover the following areas of organic chemistry: nuclear magnetic resonance, aromatic compounds and their reactions, reactions of carbonyl compounds and carboxyl acid derivatives, aldol reactions, enolate chemistry, reactions of amines, and nucleophilic aromatic substitution. An additional section may be devoted to natural product chemistry which will include lipids, saccharides, oligonucleotides, and polypeptides. The emphasis of the course will be on retrosynthetic analysis, synthetic strategies, protecting groups, and in-depth mechanistic understanding.

400111 – Natural Science Lab Chemistry I (Inorganic Chemistry)

Short Name: NatSciLabChem I
Type: Lab
Semester: 1
Credit Points: 2.5 ECTS
Prerequisites: None
Corequisites: 400101
Tutorial: No

Course contents Foundation principles of chemistry, including basic laboratory techniques, stoichiometry, acid-base and solubility equilibria, redox reactions, thermochemistry, chemical kinetics, complex formation, instrumental analysis, simple organic reactions.

400112 – Natural Science Lab Chemistry II (Organic Chemistry)

Short Name: NatSciLabChem II
Type: Lab
Semester: 2
Credit Points: 2.5 ECTS
Prerequisites: 400102
Corequisites: 400103
Tutorial: No

Course contents The laboratory course in organic chemistry will introduce basic techniques of preparative organic chemistry. Simple organic reactions will be conducted, including several single-step and multi-step syntheses. Purification procedures, including recrystallization,

distillation, sublimation, and chromatography will be introduced. Methods of sample identification will include melting point, infrared spectroscopy, UV spectrophotometry, and NMR spectroscopy. Participants must have taken Chemical Safety Instruction to attend (announced separately).

400121 – Analytical / Environmental Chemistry

Short Name: AnaEnvirChem
Type: Lecture
Semester: 2
Credit Points: 5 ECTS
Prerequisites: None
Corequisites: None
Tutorial: Yes

Course contents Analytical chemistry is an important applied area of chemistry. Analytical chemistry deals with the separation, identification and quantification of any chemical compound. It therefore provides an interface between the traditional areas of organic, inorganic and physical chemistry with life sciences and all other areas of science requiring identification and quantification of chemical compounds. Analytical chemistry provides the tools for all areas of experimental chemistry and a good foundation of analytical techniques is not only expected of any chemist but also life scientist. The course will give an introduction into analytical chemistry with selected applications in environmental chemistry. This will include an introduction to analytical terms and definitions, basic statistic treatment of experimental data, qualitative and quantitative analysis and instrumental analysis with emphasis on spectroscopic techniques such as UV/Vis, NMR, mass spectrometry, IR and Raman spectroscopy and fluorimetry. Furthermore separation techniques such as HPLC and GC will be covered.

400131 – Introduction to Chemistry Research I

Short Name: IntroResearch I
Type: Lab
Semester: 1
Credit Points: 2.5 ECTS
Prerequisites: None
Corequisites: 400102
Tutorial: Yes

Course contents Students with an adequate background in any field of chemistry are invited to join a research group of their choice in either organic, inorganic, analytical or computational chemistry. The students will be assigned a short research project in a cutting edge field of chemical research. Within the course students will learn under the direct supervision of graduate students how to plan, carry out and interpret chemical experiments using modern equipment in the research laboratories of Jacobs University. Students are expected to attend research group meetings of the individual research groups to further their knowledge in a specialised field of

chemical research. It is expected that the students work at least one full day a week in the research laboratories. At the end of this course students are expected to summarise their results in a short report and give an oral presentation defending their results in a research group seminar.

400132 – Introduction to Chemistry Research II

Short Name: IntroResearch II
Type: Lab
Semester: 2
Credit Points: 2.5 ECTS
Prerequisites: 400131
Corequisites: None
Tutorial: Yes

Course contents Students with an adequate background in any field of chemistry are invited to join a research group of their choice in either organic, inorganic, analytical or computational chemistry. The students will be assigned a short research project in a cutting edge field of chemical research. Within the course students will learn under the direct supervision of graduate students how to plan, carry out and interpret chemical experiments using modern equipment in the research laboratories of Jacobs University. Students are expected to attend research group meetings of the individual research groups to further their knowledge in a specialized field of chemical research. It is expected that the students work at least one full day a week in the research laboratories. At the end of this course students are expected to summarize their results in a short report and give an oral presentation defending their results in a research group seminar.

5.2 Second Year of Study

400211 – Advanced Physical Chemistry I

Short Name: AdvChem B I
Type: Lecture
Semester: 3
Credit Points: 5 ECTS
Prerequisites: None
Corequisites: None
Tutorial: Yes

Course contents This 2nd-year course covers classical chemical thermodynamics and kinetics. The thermodynamics part includes the laws of thermodynamics, energy, enthalpy, entropy and free energy. They are applied to physical processes as well as chemical reactions. The kinetics part treats basic chemical kinetics laws, reactions of different order and applications to complex reaction sequences with the appropriate approximation. A final part deals with the kinetics of diffusion and ion mobility in fluid mixtures.

400221 – Advanced Inorganic Chemistry I

Short Name: AdvChem C I
Type: Lecture
Semester: 3
Credit Points: 5 ECTS
Prerequisites: 400101
Corequisites: None
Tutorial: Yes

Course contents The course deals with advanced general chemistry and inorganic chemistry. It is intended for majors in Chemistry, Biochemical engineering, Biochemistry and Cell Biology. Topics: Atomic Structure (origin of the elements, hydrogenic atoms, many-electron atoms), Molecular Structure and Bonding (review of Lewis structures, VB theory, MO theory, seminconductors), Symmetry and Group Theory, Structures of Solids (metals, ionic solids), Acids and Bases (Brønsted, Lewis, hard/soft acids/bases, solvents).

400231 – Advanced Integrated Organic and Analytical Chemistry Lab

Short Name: AdvChem Lab I
Type: Lab
Semester: 3
Credit Points: 7.5 ECTS
Prerequisites: 400112,400103
Corequisites: None
Tutorial: No

Course contents This laboratory course is intended for majors in chemistry and students wishing to fulfill requirements for US medical schools. The laboratory course in organic chemistry will introduce advanced techniques of preparative organic chemistry. Multistep organic reactions will be conducted, and additional purification procedures will be introduced, including column chromatography, GC, and HPLC. Methods of sample identification will include melting point, infrared spectroscopy, UV spectrophotometry, fluorimetry, and NMR spectroscopy. One section of the integrated laboratory course will be devoted to experiments in natural product chemistry and biochemistry.

400212 – Advanced Physical Chemistry II

Short Name: AdvChem B II
Type: Lecture
Semester: 4
Credit Points: 5 ECTS
Prerequisites: 400211
Corequisites: None
Tutorial: Yes

Course contents This second-year course deals with statistical mechanics and thermodynamics as well as with basic quantum mechanics and molecular structure. In statistical mechanics, the ensemble is introduced and the laws of thermodynamics are derived from the partition function. Distributions for different ensembles are derived. Illustrative applications are chosen e.g. from liquid theory. The molecular quantum mechanics part introduces the necessary subset of quantum mechanics and the main results for vibrators, rotators and electronic systems. Chemical bonds are duscussed in terms of simple molecular-orbital theory. With the results from quantum mechanics, molecular spectroscopies (e.g. infrared, Raman, microwave and photoelectron) are discussed.

400222 – Advanced Inorganic Chemistry II (Coordination Chemistry)

Short Name: AdvChem C I
Type: Lecture
Semester: 4
Credit Points: 5 ECTS
Prerequisites: 400221
Corequisites: None
Tutorial: Yes

Course contents This course deals with advanced inorganic and coordination chemistry. It is intended for majors in Chemistry, Biochemical Engineering, Biochemistry and Cell Biology. Topics: d-metal complexes (structures and symmetries, bonding and electronic structure, reactions of complexes), The electronic spectra of complexes (electronic spectra of atoms, electronic spectra of complexes, bonding and spectra of M-M bonded compounds), catalysis (general principles, homogeneous catalysis, heterogeneous catalysis), reaction mechanisms of d-metal Complexes (ligand substitution reactions in square-planar and octahedral complexes, redox reactions, photochemical reactions).

400232 – Advanced Inorganic Chemistry Lab

Short Name: AdvChemLab II
Type: Lab
Semester: 4
Credit Points: 3.75 ECTS
Prerequisites: 400111
Corequisites: 400222
Tutorial: No

Course contents Study of properties and reactivity of molecular and ionic solids, coordination complexes and acids/bases. Synthesis, separation, purification and characterization of inorganic main-group and transition metal compounds. Instrumentation used during the lab includes the following: IR, UV-vis, AA, TGA-DSC, GC, HPLC.

400262 – Advanced Physical Chemistry Lab

Short Name: AdvPhysChemLab
Type: Lab
Semester: 4
Credit Points: 3.75 ECTS
Prerequisites: 400211
Corequisites: 400212
Tutorial: No

Course contents In Advanced Laboratory Course Physical Chemistry, participants gain hands-on experience in three important fields of Physical Chemistry: thermodynamics, kinetics, and electrochemistry. The experiments selected exemplify topics discussed in Physical Chemistry lecture (400211) taught as a part of the Advanced Chemistry lectures. Participants will investigate fundamental aspects and modern developments of Physical Chemistry to improve their skills in quantitative analysis of experimental data. An important part is the recognition of error sources and assessment of the quality of the result.

5.3 Third Year of Study

400321 – Guided Research Chemistry I

Short Name: GRChem I
Type: Lab
Semester: 5
Credit Points: 7.5 ECTS
Prerequisites: None
Corequisites: 400331
Tutorial: No

Course contents The lab/research project course can be performed in any chemical science at Jacobs University and must be approved by the instructor of record. This includes research in the following areas offered at Jacobs University: chemistry, organic chemistry, inorganic chemistry, physical chemistry, computational chemistry and biochemistry, analytical chemistry, environmental chemistry, polymer chemistry, nanoscience, chemical physics, biochemistry, geochemistry, biochemical engineering, and biophysical chemistry. This course can be carried out by attending an advanced laboratory course in the respective areas (note prerequisites) or by working in a research group at Jacobs University with work times being individually scheduled. In the latter case, it is the responsibility of the student to find a supervisor for his/her research project. Typically, the student fulfills the requirements by working for one semester in the same research group.

400331 – Guided Research Chemistry Seminar I

Short Name: GRSemChem I
Type: Seminar
Semester: 5
Credit Points: 2.5 ECTS
Prerequisites: None
Corequisites: 400321
Tutorial: No

Course contents The chemistry seminar series will include presentations by guest speakers, Jacobs University chemistry faculty, Jacobs University graduate and undergraduate students on research topics or literature review. Scheduling of the seminar slots is flexible, with typically one weekly session. Participating students and faculty will be informed through an e-mail list about upcoming seminars. This seminar counts 3 credits for graduate students and 1.5 credits for undergraduate students in relation to the student work load required.

400322 – Guided Research Chemistry II and Bachelor Thesis

Short Name: GRChem II
Type: Lab
Semester: 6
Credit Points: 7.5 ECTS
Prerequisites: 400321
Corequisites: 400332
Tutorial: No

Course contents The lab/research project course can be performed in any chemistry research area at Jacobs University with the chemistry faculty and research instructors as potential supervisors. This includes research in the following areas offered at Jacobs University: organic chemistry, inorganic chemistry, physical and physical-organic chemistry, computational chemistry and biochemistry, analytical chemistry, environmental chemistry, nanoscience, supramolecular chemistry, biomolecular chemistry. This course is carried out by working in a chemistry research group at Jacobs University with work times being individually scheduled. It is the responsibility of the student to find a supervisor for his/her research project. Typically, the student fulfills the requirements by working for one full semester in the same research group. Eligible courses are approved by the instructor of record.

400332 – Guided Research Chemistry Seminar II

Short Name: GRSemChem II
Type: Seminar
Semester: 6
Credit Points: 2.5 ECTS
Prerequisites: None
Corequisites: 400322
Tutorial: No

Course contents The chemistry seminar series will include presentations by guest speakers, Jacobs University chemistry faculty, Jacobs University graduate and undergraduate students on research topics or literature review. Scheduling of the seminar slots is flexible, with typically one weekly session. Participating students and faculty will be informed through an e-mail list about upcoming seminars. This seminar counts 3 credits for graduate students and 1.5 credits for undergraduate students in relation to the student work load required. The course will deal with the area of physical-organic chemistry and requires the fundamental knowledge from the preceding organic and physical chemistry courses, in particular Advanced Chemistry AI and BI. The course will cover the following areas: Conformational analysis and molecular mechanics, applications of molecular orbital theory and valence bon, reactive intermediates, spectroscopic methods of studying chemical reactions and reaction mechanisms, and applications to various reaction types. Two special chapters will be dedicated to mechanistic photochemistry and supramolecular chemistry.

5.4 Second and Third Year of Study Chemistry Specialization Courses

400311 – Analytical Chemistry II

Short Name: AnaChemII
Type: Lecture
Semester:
Credit Points: 5 ECTS
Prerequisites: 400121
Corequisites: None
Tutorial: None

Course contents The course builds on Analytical and Environmental chemistry. It gives an overview on advanced techniques for chemical structure elucidation, separation, identification and quantification for organic, biological and inorganic molecules. The course will cover advances NMR techniques (multidimensional NMR) for structure elucidation, advanced mass spectrometry (soft ionization techniques, tandem MS, high resolution MS) and their applications to the analysis of biological mixtures, advanced chromatography, hyphenated chromatographic techniques, chirooptical methods, electrochemistry and modern bioanalytical methods. Additionally topics such as validation, quality assurance and good laboratory practice are covered.

400202 – Bioorganic Chemistry

Short Name: BioorgChem
Type: Lecture
Semester:
Credit Points: 5 ECTS
Prerequisites: 400103
Corequisites: None
Tutorial: Yes

Course contents The course deals with the properties, origins, applications, biosynthesis and importance of biological molecules. It provides insight in the chemical basis of life providing a thorough understanding of living organisms on a molecular level. The biological molecules to be discussed include: I. carbohydrates; II. Lipids; III Amino acids and proteins; IV. Nucleic acids; V. Terpenes; VI. Polyphenolics; VII. Polyketides; VIII. Alkaloids. Furthermore the course will give an introduction to medicinal chemistry illustrating how natural products or synthetic modifications of biological molecules can interact with biological systems in order to be exploited as drug molecules. Selected examples include antibiotics, protease inhibitors, non-steroidal anti-inflammatory drugs and proton pump inhibitors.

400301 – Computational Chemistry and Biochemistry

Short Name: CompChemBiochem
Type: Lecture
Semester:
Credit Points: 5 ECTS
Prerequisites: 400212
Corequisites: None
Tutorial: Yes

Course contents This is an advanced third-year course. It provides the an introduction to modern methods of computational chemistry, quantum chemistry and molecular simulation, as the most widely used techniques. The quantum chemistry part covers basis sets, the variational principle, Slater determinants, the Hartree-Fock method, an overview of post-Hartree-Fock methods and density-functional theory. The molecular simulation part deals with force fields, molecular dynamics, Monte Carlo and analysis methods. In both areas, applications and examples are chosen from chemistry and biochemistry.

400302 – Structure and Mechanism

Short Name: ExpTheoChem A II
Type: Lecture
Semester:
Credit Points: 5 ECTS
Prerequisites: 400211
Corequisites: 400103
Tutorial: Yes

Course contents The course will deal with the area of physical-organic chemistry and requires the fundamental knowledge from the preceding organic and physical chemistry courses, in particular Advanced Chemistry AI and BI. The course will cover the following areas: Conformational analysis and molecular mechanics, applications of molecular orbital theory and valence bond, reactive intermediates, spectroscopic methods of studying chemical reactions and reaction mechanisms, and applications to various reaction types. Two special chapters will be dedicated to mechanistic photochemistry and supramolecular chemistry.

400312 – Advanced Synthesis

Short Name: AdvSynthesis
Type: Lecture
Semester:
Credit Points: 5 ECTS
Prerequisites: 400103
Corequisites: None
Tutorial: Yes

Course contents Building on your basic knowledge of functional group transformations and stereochemistry, strategies for the synthesis of complex organic molecules (natural products and pharmaceutical drugs) will be discussed. In this context, you will learn the importance of the order and type of transformation (retrosynthetic analysis) required for brevity in synthesis. To do so, we will cover functional group compatibility, the use of modern reagents, and the control of stereochemistry (chirality) through the use of chiral auxiliaries vs enantioselective synthesis. Finally, all of these aspects will be assessed, learned and applied through the use of reaction mechanisms (arrow pushing).

400342 – Organometallic Chemistry

Short Name: OrgmetChem
Type: Lecture
Semester:
Credit Points: 5 ECTS
Prerequisites: 400221
Corequisites: None
Tutorial: No

Course contents This course deals with organometallic chemistry. It is intended in particular for Chemistry and Nanomolecular Science students. Topics: Main Group Metal and Transition Metal Organyls (synthesis, bonding and structures, stability, reactions and use), electron deficient systems, sigma- and pi-bonding, sandwich complexes, environmental aspects, heterogenous and homogeneous catalysis, industrially important processes (Fischer-Tropsch-Reactions, Wacker Oxidation, Hydroformylation, Reppe-Synthesis).