



JACOBS
UNIVERSITY



School of Engineering and Science

Chemistry (BSc)

Bachelor's Degree Program

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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 exciting core education of chemistry with the facets nanoscience interwoven. 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. The Chemistry Faculty and students have regular contact and work closely together regarding theoretical questions, research, and the development of written and oral communication skills. The program and faculty members further promote undergraduates, at an early stage, to get involved in a funded research project that allows close interaction with M.Sc. (Nanomolecular Science M.Sc. program) and Ph.D. students. Furthermore, 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), and is supplemented by third year (advanced) courses (e.g. in nanoscience, computational chemistry, or catalysis). In addition, 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 "Nanomolecular Science" graduate program at Jacobs University, and highly motivated 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 Nanomolecular Science within one additional year. Furthermore, the program was 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.

In the above described ways, our B.Sc. Chemistry degree 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 (20 ECTS credits). These credits are composed of Guided Research I/II and Seminar I/II. The basic research project course can be performed in any chemistry research area at JACOBS UNIVERSITY with the chemistry faculty and university lecturers 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.

This course 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. However, the student may transfer to another laboratory in the second semester. This basic, but exploratory, 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 is a springboard that allows you the maximum flexibility in planning your future career objectives. Our theoretically and practically talented 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 fulfilling 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.

Bachelor of Science in Chemistry			
Transdisciplinary Education University Studies Courses (USC) Courses in Humanities and Social Sciences (HSS) Home School Electives	Guided Research Module Chemistry	Guided Research B.Sc. Thesis	400321, 400322
	Computational/Synthesis Module	Advanced Synthesis Organometallic Chemistry	400312 400342
		Computational Chemistry and Biochemistry Structure and Mechanism	400301 400302
	Integrated Chemistry Lab	Advanced Chemistry Lab I, II	400231, 400232
	Inorganic Chemistry Module	Advanced Inorganic Chemistry I, II	400221, 400222
	Physical Chemistry Module	Advanced Physical Chemistry I, II	400211, 400212
	Organic Chemistry Module	Advanced Organic Chemistry I, II	400201, 400202
	General Chemistry Module	General Chemistry I, II NatSciLab Chemistry I, II Analytical Chemistry	400101, 400102 400111, 400112 400121
		ESc Module 1 (physics recommended)	
		ESc Module 2	
	Mathematics ESM for LifeChem	ESM 1C	120121

Figure 1: Chemistry Module Structure ¹

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.

¹General Chemistry I/II have been replaced by 400101 General Inorganic Chemistry and 400102 General Organic Chemistry I. 400201 Advanced Organic Chemistry I has been replaced by 400103 General Organic Chemistry II. 400202 Advanced Organic Chemistry II has been replaced by 400202 Bioorganic Chemistry.

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: 20 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 Chemistry¹
- 400102** General Organic Chemistry¹
- 400111** General Inorganic Chemistry Lab

400112 General Organic Chemistry Lab

400121 Analytical/Environmental Chemistry

400200 – ADVANCED ORGANIC CHEMISTRY MODULE

Short Name: ModOrganicChem

Semester: 3 – 4

Credit Points: 10 ECTS

General Information At the level of chemical life the bonding of carbon is central; with hydrogen, oxygen, nitrogen, sulfur, calcium, iron, magnesium, and phosphorous and a handful of other trace elements playing a supporting role. Organic chemistry is the study of the aforementioned carbon-based chemistry outside the requirements of living systems, while bioorganic chemistry deals with the synthesis, isolation, and derivation of biologically relevant species and the exploitation of enzymatic reactions for synthesis. These fields have provided us with the medicines needed to cure diseases, polymers for lightweight and durable materials, better foods, dyestuffs and textiles. Subjects of study within the module include NMR spectroscopy, aromaticity, radical reactions, conjugated systems, cycloadditions, carbonyl and carboxyl group chemistry with emphasis on functional group interconversion, metal-organic reagents, reductions and oxidations, complex reaction mechanisms, carbon-carbon and carbon-heteroatom bond formation, kinetics, symmetry elements, amino acids, lipids, biopolymers, including saccharides, peptides, proteins, nucleotides, steroids, and hormones. Conceptual chapters deal with solvent properties, structure-reactivity relationships, intra- and intermolecular interactions, importance of acidity and basicity on reactivity, radiolabeling, synthetic strategies, experimental design, activating and protecting groups, solid-phase synthesis, and enzymatic reactions. Special chapters deal with common drugs, artificial sweeteners and other dietary additives, organic chemistry in daily life, name reactions, steric and stereoelectronic effects, as well as polar effects. Themes from physics and biochemistry are interwoven to provide further context. Finally, the student will appreciate how we arrived at our present organic knowledge base and why it is mandatory to continuously challenge our working theories.

Learning Goals

- Mechanistic understanding of organic reactions
- Ability to recognize analogies in organic reactions
- Understanding of the driving force for chemical reactions
- Ability to identify functional and reactive groups in large molecules
- Strategic planning of multi-step organic reactions
- Comprehension of three-dimensional orientation of organic molecules
- Knowledge of fundamental chemical concepts
- Oral presentation skills
- Development of chemical intuition and the ability to think on a molecular level
- Ability to use expert chemical terminology, e.g., to describe stereochemistry, selectivity, and isomerism
- Transferable conceptual skills

¹These courses have been replaced by 400101 General Inorganic Chemistry and 400102 General Organic Chemistry I.

Courses**400201** Advanced Organic Chemistry I²**400202** Advanced Organic Chemistry II (Bioorganic Chemistry)²**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.

²400201 Advanced Organic Chemistry I has been replaced by 400103 General Organic Chemistry II. 400202 Advanced Organic Chemistry II has been replaced by 400202 Bioorganic Chemistry.

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 apparatus, 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 – COMPUTATIONAL/SYNTHESIS MODULE

Short Name: ModCompSynthChem

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 (at least three out of four)**400301** Computational Chemistry and Biochemistry**400302** Structure and Mechanism**400312** Advanced Synthesis**400342** Organometallic Chemistry

If only three courses are taken, a third semi-optional course must be taken.

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
 - 3-5 courses in the School of Humanities and Social Sciences (**HSS**),
 - 3-5 University Study Courses (**USC**).
- 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.

University requirements outside of the school of the major are type-coded “u” in the recommended course plans below.

3.2 Courses Mandatory for the Major

Requirements of the Major

Students choose the following courses (140 ECTS credits) out of the following:

- **Year 1 level courses:**
 - Engineering and Science Mathematics IC (120121, 5 ECTS credits),
 - General Chemistry I/II (400101, 400102, 10 ECTS credits)¹,
 - plus associated Natural Science Lab Units (NatSciLabs) (400111, 400112, 5 ECTS credits).
 - Analytical/Environmental Chemistry, (400121, 5 ECTS credits)
- **Year 2 level courses:**
 - Advanced Organic Chemistry I/II (400201, 400202, 10 ECTS credits)²,
 - 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/Advanced Inorganic Chemistry Lab/Advanced Lab Course Physical Chemistry (400231, 400232, 400262, 15 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),

¹These courses have been replaced by 400101 General Inorganic Chemistry and 400102 General Organic Chemistry I.

²400201 Advanced Organic Chemistry I has been replaced by 400103 General Organic Chemistry II. 400202 Advanced Organic Chemistry II has been replaced by 400202 Bioorganic Chemistry.

3 to 4 out of the following 4 courses:

- 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)
- 2 to 3 Chemistry Semi-Optional Courses, 5 ECTS credits each. The number depends on the number of courses chosen above. Semi-optional courses can be undergraduate courses in chemistry, physics, earth and space science, biotechnology, integrated environmental studies, and mathematics, or graduate courses in nanomolecular sciences and molecular life sciences. The individual choice of the courses must be approved by the advisor and the program coordinator.

3.3 Recommendation

- two first year ESc subjects (10 ECTS credits) plus
- associated NatSciLabs (5 ECTS credits, recommended General Physics I/II plus associated NatSciLab Units).

3.4 Premedical Requirements

Chemistry students fulfill the natural science requirements for US medical school in the regular course sequence within the first 2 years, if they select General Physics and General Biology as ESc subjects in the first year. No additional mandatory courses or changes in the course sequence are required.

3.5 Tutorials

Chemistry faculty at Jacobs is committed to a close interaction with undergraduate students on a subject based and personal university level. Direct personal interactions between faculty and students play a central role in our chemistry education. For this reason, next to formally scheduled tutorials within individual courses, undergraduate students are encouraged to discuss all subject based items with the instructors of record for the individual courses in informal tutorials. These informal tutorials usually take place during Professorial office hours or by prior appointment with the instructor of records. Furthermore dedicated tutorials for individual courses are regularly scheduled for the purpose of examination preparations by the instructors of records one to two weeks before the examinations.

3.6 Home school electives

Within Jacobs transdisciplinary education principle undergraduate students are required to attend a series of home school elective courses. These can comprise any suitable course within the School of Engineering and Science (SES) both at the undergraduate and Master level. For students who wish to attend such courses containing a chemistry related content the chemistry faculty recommends for guidance purposes only the following courses. In exceptional cases (e.g. sickness) semi-optional chemistry courses can after prior agreement with the programme co-ordinator be replaced with any of the courses on this list.

Undergraduate courses

- 500351 Introduction to Biophysical Chemistry
- 560311 High Throughput Screening Technology
- 200352 Principles and Applications of Optical Spectroscopy
- 210320 Geochemistry

Graduate courses

- 420431 Nanomolecular Science I
- 420432 Nanomolecular Science II
- 420441 From Molecules to Matter
- 530461 Techniques for the Analysis and Structure Determination of Biomolecules

4 Recommended Course Plan

Year 1 Courses	Fall	C T	Spring	C T
ESc Mathematics IC ¹	120121	5 m		
General Chemistry I/II ²	400101	5 m	400102	5 m
Chemistry Natural Science Lab Modules I/II	400111	2.5 m	400112	2.5 m
Analytical/Environmental Chemistry	400121	5 m		
First year courses in 1 st ESc subject		5 e		5 e
First year courses in 2 nd ESc subject		5 e		5 e
Language Courses or Home School Electives ³		2.5 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 Organic Chemistry I/II ⁴	400201	5 m	400202	5 m
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 Lab Course Physical Chemistry			400262	3.75 m
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
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
3 out of the following 4 courses:⁵				
Computational Chemistry and Biochemistry Structure and Mechanism	400301	5 m		
Advanced Synthesis	400312	5 m	400302	5 m
Organometallic Chemistry			400342	5 m
Semi-optional elective courses		5 e		5 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, u=university),

Transdisciplinary Courses are School of Humanities and Social Sciences courses and USCs.

¹ Students who are interested in Physical Chemistry should take at least two ESM courses.

² see footnote 1 on page 12

³ Recommended: Introduction to Chemistry Research I and II (400131 and 400132)

⁴ see footnote 2 on page 12

⁵ Not all of the 4 courses will offered very year. If only three of the four courses are taken, a third semi-optional

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> .

5 Courses: Chemistry

5.1 First Year of Study

400101 – General Inorganic Chemistry¹

<i>Short Name:</i>	GenChem I
<i>Type:</i>	Lecture
<i>Semester:</i>	1
<i>Credit Points:</i>	5 ECTS
<i>Prerequisites:</i>	None
<i>Corequisites:</i>	None
<i>Tutorial:</i>	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.

400111 – Natural Science Lab Unit Inorganic Chemistry

<i>Short Name:</i>	NatSciLabChem I
<i>Type:</i>	Lab
<i>Semester:</i>	1
<i>Credit Points:</i>	2.5 ECTS
<i>Prerequisites:</i>	
<i>Corequisites:</i>	400101
<i>Tutorial:</i>	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.

400102 – General Organic Chemistry¹

<i>Short Name:</i>	OrganicChem
<i>Type:</i>	Lecture
<i>Semester:</i>	2
<i>Credit Points:</i>	5 ECTS
<i>Prerequisites:</i>	None
<i>Corequisites:</i>	None
<i>Tutorial:</i>	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.

400112 – Natural Science Lab Unit Organic Chemistry

Short Name: NatSciLabChem II
Type: Lab
Semester: 2
Credit Points: 2.5 ECTS
Prerequisites: None
Corequisites: 400102
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: ExpTheoChem B I
Type: Lecture
Semester: 5
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

¹These courses have been replaced by 400101 General Inorganic Chemistry and 400102 General Organic Chemistry I.

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 or 2
Credit Points: 2.5 ECTS
Prerequisites: None
Corequisites: 400101
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.

5.2 Second Year of Study

400201 – Advanced Organic Chemistry I²

Short Name: AdvChem A I
Type: Lecture
Semester: 3
Credit Points: 5 ECTS
Prerequisites: 400102
Corequisites: None
Tutorial: Yes

Course contents The course deals with advanced organic chemistry 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.

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, semiconductors), Symmetry and Group Theory, Structures of Solids (metals, ionic solids), Acids and Bases (Brønsted, Lewis, hard/soft acids/bases, solvents).

²400201 Advanced Organic Chemistry I has been replaced by 400103 General Organic Chemistry II.

400231 – Advanced Integrated Organic and Analytical Chemistry Lab

Short Name: AdvChem Lab I
Type: Lab
Semester: 3
Credit Points: 7.5 ECTS
Prerequisites: 400112
Corequisites: 400201
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.

400202 – Advanced Organic Chemistry II (Bioorganic Chemistry)³

Short Name: AdvChem A II
Type: Lecture
Semester: 4
Credit Points: 5 ECTS
Prerequisites: 400201
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.

³400202 Advanced Organic Chemistry II has been replaced by 400202 Bioorganic Chemistry.

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 discussed 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 Lab Course Physical Chemistry

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.

400132 – Introduction to Chemistry Research II

Short Name: IntroResearch II
Type: Lab
Semester: 3 or 4
Credit Points: 2.5 ECTS
Prerequisites: 400101, 400102, 400111, 400112, 400131
Corequisites: 400221
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.

5.3 Third Year of Study

400321 – Guided Research Chemistry I

Short Name: GRChem I
Type: Lab
Semester: 5
Credit Points: 7.5 ECTS
Prerequisites: 400231, 400222
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.

400301 – Computational Chemistry and Biochemistry

Short Name: ExpTheoChem A I
Type: Lecture
Semester: 5
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.

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

<i>Short Name:</i>	GRSemChem II
<i>Type:</i>	Seminar
<i>Semester:</i>	6
<i>Credit Points:</i>	2.5 ECTS
<i>Prerequisites:</i>	None
<i>Corequisites:</i>	None
<i>Tutorial:</i>	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 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.

400302 – Structure and Mechanism

<i>Short Name:</i>	ExpTheoChem A II
<i>Type:</i>	Lecture
<i>Semester:</i>	6
<i>Credit Points:</i>	5 ECTS
<i>Prerequisites:</i>	400211 , 400201
<i>Corequisites:</i>	None
<i>Tutorial:</i>	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: ExpTheoChem B II

Type: Lecture

Semester: 6

Credit Points: 5 ECTS

Prerequisites: 400201

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: 6

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, heterogeneous and homogeneous catalysis, industrially important processes (Fischer-Tropsch-Reactions, Wacker Oxidation, Hydroformylation, Reppe-Synthesis).

