CHEMISTRY

THE WIESS SCHOOL OF NATURAL SCIENCES

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DEGREES OFFERED: BA, BS, MA, PHD

The Department of Chemistry offers undergraduate chemistry majors leading to both the bachelor of science degree and the bachelor of arts degree. The BS program rigorously prepares students for advanced work in chemistry or a related discipline, and the degree requirements are consistent with the guidelines for certification by the American Chemical Society. This curriculum provides a broad and comprehensive introduction to core areas of chemistry while promoting depth of understanding in one or more specific fields. BS students complete a series of foundation courses in general chemistry, analytical chemistry, biological chemistry, inorganic chemistry, organic chemistry, and physical chemistry. Students then complete one or more specializations, or "tracks", consisting of in-depth courses both in and out of the specialization. The BA degree is a more flexible program that provides a comprehensive overview of all

areas of chemistry, including laboratory experiences, but can be coupled more easily with other majors or professional career paths. Both degree programs offer students a solid background in the fundamental principles of chemistry, the properties and reactions of chemical compounds, and their uses.

Graduate studies emphasize individual research together with a fundamental understanding of chemistry beyond the students' specific interests. Faculty research interests include the synthesis and biosynthesis of organic natural products; supramolecular chemistry, molecular recognition, and biological catalysis; bioinorganic and organometallic chemistry; main group element and transition metal chemistry; the chemistry of the main group elements; the design of nanophase solids; molecular photochemistry and photophysics; infrared kinetic spectroscopy, laser, and NMR spectroscopy; studies of electron transfer in crossed beams; theoretical and computational chemistry; the study of fullerene molecules, carbon nanotubes, and their derivatives; polymer synthesis and characterization; molecular electronics; molecular machines; and chemical-based nanotechnology.

Degree Requirements for the BS in Chemistry

For general university requirements, see Graduation Requirements (Undergraduate Students section, pages 2–5). The BS in chemistry requires at least 124 credit hours, including 64 credit hours of chemistry requirements (below) and at least 60 additional credit hours that satisfy the distribution requirements (Undergraduate Students section, pages 3–4). The following courses are required for all students pursuing the bachelor of science degree in chemistry:

General Chemistry

CHEM 121 *General Chemistry I*

CHEM 122 *General Chemistry II*

CHEM 123 *General Chemistry Laboratory I*

CHEM 124 *General Chemistry Laboratory II*

Chemistry Foundation Courses

CHEM 211 *Organic Chemistry I* or CHEM 251 *Honors Organic Chemistry I*

CHEM 310 *Physical Chemistry*

CHEM 330 *Analytical Chemistry*

CHEM 360 *Inorganic Chemistry*

BIOS 301 *Biochemistry I*

Introductory Laboratory Modules

CHEM 351 *Introductory Module in Inorganic Chemistry*

CHEM 352 *Introductory Module in Organic Chemistry*

CHEM 353 *Introductory Module in Analytical Methods*

Mathematics*

MATH 101 *Single Variable Calculus I*

MATH 102 *Single Variable Calculus II*

MATH 211 *Ordinary Differential Equations and Linear Algebra*

MATH 212 *Multivariable Calculus*

(MATH 221 & 222 *Honors Calculus III* and *IV* may substitute for MATH 211 and 212)

Physics

PHYS 101 or 111 *Mechanics* (with lab) or PHYS 125 *General Physics* (with lab)

PHYS 102 or 112 *Electricity and Magnetism* (with lab) or PHYS 126 *General Physics II* (with lab)

* The Department of Mathematics may, after consultation with a student concerning his/her previous math preparation, recommend that a student be placed into a higher level math course than for which the student has official credit. The Department of Chemistry will accept this waiver of the math classes upon a written confirmation of the waiver from the Department of Mathematics and upon the student's successful completion of the higher level math course.

In-depth Chemistry Courses
In addition to the above required courses for the bachelor of science in chemistry, each student must complete the requirements for one of the following specializations or tracks. Other departments offer advanced courses with substantial chemistry content, and these may count toward this requirement with approval of a track advisor. A student may, by working with his or her chemistry major advisor and with the approval of the chemistry department, propose a track in another specialization. Such proposed tracks must have course and laboratory experiences comparable to those of the tracks listed below. A double specialization can be earned by completing the requirements for two specialties. For double specialization, only two advanced lecture courses may count towards both specializations. The remaining two advanced courses in each specialization must be unique (i.e., double specialization requires six advanced lecture courses, and triple specialization require eight). A nanochemistry specialization can be added to any of the standard tracks by adding two nanoscience courses.

Specialization in Biological and Medicinal Chemistry
(Track Advisors: Matsuda and Landes)

- CHEM 212 *Organic Chemistry II* or CHEM 252 *Honors Organic Chemistry II*
- BIOS 302 *Biochemistry II*
- Two additional three-credit advanced chemistry courses. Students interested in biological and medicinal chemistry are encouraged to consider CHEM 401 *Advanced Organic Chemistry*, CHEM 411 *Spectral Methods in Organic Chemistry*, CHEM 440 *Enzyme Mechanisms*, CHEM 442 *Medicinal Chemistry I*, CHEM 443 *Medicinal Chemistry II*, CHEM 543 *Secondary Metabolism*, CHEM 537 *Biophysical Chemistry*, CHEM 547 *Supramolecular Chemistry*, BIOS 352 *Physical Chemistry for the Biosciences*.
- CHEM 491 *Research for Undergraduates* (3 credit hours)
- Four advanced lab modules. Students interested in biological and medicinal chemistry are encouraged to consider CHEM 374 *Advanced Module in Organic Synthesis*, CHEM 378 *Advanced Module in Plant Natural Products Biochemistry*, and BIOS 311 *Advanced Experimental Biosciences*

Specialization in Inorganic Chemistry and Inorganic Materials
(Track Advisors: Whitmire, Wilson, and Marti)

- CHEM 475 *Physical Methods in Inorganic Chemistry*
- CHEM 495 *Transition Metal Chemistry*
- Two additional three-credit advanced chemistry courses
- CHEM 491 *Research for Undergraduates* (3 credit hours)
- Four advanced lab modules

Specialization in Organic Chemistry
(Track Advisors: Engel and Ball)

- CHEM 212 *Organic Chemistry II* or CHEM 252 *Honors Organic Chemistry II*
- CHEM 401 *Advanced Organic Chemistry*

- Two additional three-credit advanced chemistry courses. Students interested in organic chemistry are encouraged to consider the following advanced courses: CHEM 411 *Spectral Methods in Organic Chemistry*, CHEM 430 *Quantum Chemistry*, CHEM 440 *Enzyme Mechanisms*, CHEM 442 *Medicinal Chemistry I*, CHEM 443 *Medicinal Chemistry II*, CHEM 445 *Physical Organic Chemistry*, CHEM 495 *Transition Metal Chemistry*, CHEM 543 *Secondary Metabolism*, and CHEM 547 *Supramolecular Chemistry*.
- CHEM 491 *Research for Undergraduates* (3 credit hours)
- Four advanced lab modules. Students interested in organic chemistry are encouraged to consider CHEM 372 *Advanced Module in the Synthesis and Characterization of Fullerene Compounds* and CHEM 374 *Advanced Module in Organic Synthesis*

Specialization in Physical and Theoretical Chemistry
(Track Advisors: Hutchinson and Link)

- CHEM 430 *Quantum Chemistry*
- CHEM 420 *Classical and Statistical Thermodynamics*
- One additional three-credit advanced course in physical chemistry (CHEM 415 *Chemical Kinetics and Dynamics*, CHEM 531 *Advanced Quantum Chemistry*, or CHEM 537 *Biophysical Chemistry*)
- One additional three-credit advanced course in chemistry outside of physical chemistry
- CHEM 491 *Research for Undergraduates* (3 credit hours)
- Four advanced lab modules. Students interested in physical chemistry are encouraged to consider CHEM 381 *Advanced Module in Equilibrium Physical Chemistry* and CHEM 383 *Advanced Module in Quantum Chemistry*

All specializations mandate three credit hours of CHEM 491. A student with substantial research experience (e.g., a summer internship in another university) outside of the formal CHEM 491 course may substitute one additional 3-credit-hour advanced course within the specialization for CHEM 491. This substitution requires approval of the Chemistry Department based on the quality of the research experience, which the student should document with a comprehensive written report. It is advisable to seek feedback on the probable suitability of a summer internship before undertaking that work. An advanced laboratory module can be replaced by either 1) a second three-hour term in CHEM 491; 2) two credits of CHEM 215; 3) two credits of CHEM 700 (*Teaching Practicum*, which can be taken by undergrads who gain the instructor's permission); or four laboratory courses that have substantial chemistry content from disciplines related to chemistry (biochemistry, physics, materials science, environmental engineering, etc.; these must be approved by the track advisor). No more than two advanced modules can be replaced through these substitutions. These substitutions cannot be made for introductory modules. Students interested in health professions need two credit hours of organic laboratory, and should take either CHEM 215, or both CHEM 352 and CHEM 374.

Degree Requirements for the BA in Chemistry

For general university requirements, see Graduation Requirements (Undergraduate Students section, pages 2–3). The BA in chemistry

requires at least 120 credit hours, including 45 credit hours of chemistry requirements (below) and at least 78 additional credit hours that satisfy the distribution requirements (Undergraduate Students section, pages 3–4). Prof. Hutchinson is the BA advisor.

General Chemistry and Foundation Courses

CHEM 121 *General Chemistry I*

CHEM 122 *General Chemistry II*

CHEM 123 *General Chemistry Laboratory I*

CHEM 124 *General Chemistry Laboratory II*

CHEM 211 *Organic Chemistry I* or CHEM 251 *Honors Organic Chemistry I*

CHEM 310 *Physical Chemistry* or BIOS 352 *Physical Chemistry for the Biosciences*

CHEM 330 *Analytical Chemistry*

CHEM 360 *Inorganic Chemistry*

BIOS 301 *Biochemistry I*

Two Additional Upper-level 3-credit Chemistry Lecture Courses (these can include CHEM 212 or CHEM 252). Other departments offer advanced courses with substantial chemistry content, and these may count toward this requirement with approval of the BA advisor.

Introductory Laboratory Modules

CHEM 351 *Introductory Module in Inorganic Chemistry*

CHEM 352 *Introductory Module in Organic Chemistry*

One additional chemistry laboratory course (CHEM 215 or any chemistry lab module)

Mathematics*

MATH 101 *Single Variable Calculus I*

MATH 102 *Single Variable Calculus II*

Physics

PHYS 101 or 111 *Mechanics* or PHYS 125 *General Physics*

PHYS 102 or 112 *Electricity and Magnetism* or PHYS 126 *General Physics II*

Degree Requirements for the BS in Chemical Physics

The chemical physics major leading to a BS degree is offered in conjunction with the Department of Physics and Astronomy. Students take upper-level courses in both chemistry and physics, focusing on the applications of physics to chemical systems. Students majoring in chemical physics must complete the following courses:

Core Courses Required of All Chemical Physics Majors

Chemistry

CHEM 121 *General Chemistry I*

CHEM 122 *General Chemistry II*

CHEM 123 *General Chemistry Laboratory I*

CHEM 124 *General Chemistry Laboratory II*

CHEM 211 *Organic Chemistry I* or CHEM 251 *Honors Organic Chemistry I*

CHEM 310 *Physical Chemistry*

CHEM 360 *Inorganic Chemistry*

Physics

PHYS 101 or 111 *Mechanics*

PHYS 102 or 112 *Electricity and Magnetism*

PHYS 201 *Waves and Optics*

PHYS 202 *Modern Physics*

PHYS 231 *Elementary Physics Lab*

PHYS 301 *Intermediate Mechanics*

PHYS 302 *Intermediate Electrodynamics*

Mathematics

MATH 101/102 *Single Variable Calculus I* and *II*

MATH 211 *Ordinary Differential Equations and Linear Algebra*

MATH 212 *Multivariable Calculus* (MATH 221/222 *Honors Calculus* III and IV may substitute for MATH 211/212)

Additional Courses

One course from PHYS 425 or CHEM 420

Two courses from PHYS 311, PHYS 312, or CHEM 430

Six hours from CHEM 215, CHEM 351, CHEM 352, CHEM 353, CHEM 372–395, PHYS 331, or PHYS 332. Up to two hours of independent research (CHEM 491 or PHYS 491/492 may be counted toward this requirement.)

Six credit hours of mathematics or computational and applied mathematics at the 300 level or above

Degree Requirements for MA and PhD in Chemistry

For general university requirements, see Graduate Degrees (Graduate Students section, page 3–4). Students who have completed course work equivalent to that required for a BA or BS in chemistry may apply for admission to the PhD program. For more information, see Admission to Graduate Study (Graduate Students section, page 2–3). Students are not normally admitted to study for an MA degree.

Requirements for the PhD in Chemistry

Research—The PhD in chemistry is awarded for original research in chemistry. During the first semester of residence, students select a research advisor from among the members of the faculty; the department chair must approve this choice. In some cases, students may choose research advisors outside of the department; however, such arrangements must be approved by the chemistry faculty. The research advisor will guide the student in the choice of an appropriate research topic and in the detailed training required to complete that project. Students must successfully complete CHEM 800 *Graduate Research* and CHEM 600 *Graduate Seminar* every semester of residence. Candidates earn a PhD after successfully completing at least 90 semester hours of advanced study in chemistry and related fields, culminating in a thesis that describes an original and significant investigation in chemistry. The thesis must be satisfactorily defended in a public oral examination. The student must pass the thesis defense before the end of the 16th semester of residency.

Coursework—Within the first two years, the student must complete six 3-semester-hour graduate-level lecture courses at Rice University. In order to satisfy this requirement, each of these courses must satisfy the following criteria:

- They must be approved by the department's graduate advising committee.
- Chemistry courses must be at the 400 level or higher. Certain 300-level courses in other departments may be acceptable with prior approval by the department's graduate advising committee. Courses must be in technical subjects in science or engineering. Courses in teaching, presentation, or management will not be counted toward the six-class requirement.

- Each course must be passed with a grade of B- or higher. It is possible to repeat or replace a course, upon approval of the department's graduate advising committee. A maximum of two courses can be repeated/replaced.
- Students who pursue both the BS and the PhD at Rice need not duplicate course work for the two degrees. However, teaching as an undergraduate does not substitute for the teaching requirements in the PhD program.

Teaching—Each graduate student must participate in teaching (CHEM 700) for the equivalent of three semesters. Assignments are determined by departmental needs. Students also may be requested to fulfill certain service functions for the department.

Qualifying Examination—The qualifying exam has written and oral components, and the expectations for these are available in the department office. The examination committee will be composed of three faculty members, excluding the research advisor. The written document must be submitted to the committee at least one week before the date of the oral examination. The examination must be taken by the last day of class at the end of the student's fourth semester in residency. Any follow-up work required by the committee must be completed by the assigned date, and the exam must be passed by the end of the sixth semester.

Advancement to Candidacy for the PhD—After completing the required coursework, teaching, and qualifying examination, a student must petition to be advanced to candidacy for the PhD degree. Upon advancement to candidacy, a student chooses a thesis committee of at least three faculty members with the guidance and approval of the research advisor and department chair. The thesis committee must include one faculty member whose primary appointment is outside of the chemistry department.

Satisfactory Performance

To remain in good standing, a student must maintain a GPA of 3.00 (B) or higher in all lecture courses, including grades above B- in CHEM 600, CHEM 700, and CHEM 800. Failure to maintain satisfactory grades and sufficient progress in research will result in probation and possible dismissal. The student must be enrolled full time in a departmentally approved research group beginning the second semester, and every semester thereafter. Students must make satisfactory research progress as judged by their research director and thesis committee. The student, advisor, or committee may request a meeting between student and committee at any time to evaluate progress or to determine a course of action. The thesis committee will assess the progress being made in research and may invite the student to present a discussion of his or her work. If progress is unsatisfactory, the committee may recommend a semester of probation, which could result in dismissal from the program if progress remains unsatisfactory in the subsequent semester.

Requirements for the MA in Chemistry

MA Program—Although students are not normally admitted to study for an MA, this degree is sometimes awarded to students who do not complete the PhD program. Candidates for the MA degree must:

- Complete six one-semester courses
- Produce a thesis that presents the results of a program of research approved by the department
- Pass a final thesis defense

Students who are admitted to PhD candidacy may apply for an automatic master's degree.

Appeal

Students may petition the Chemistry Department Graduate Advising Committee for variances on these academic regulations.

See CHEM in the Courses of Instruction section.