

# DEPARTMENT OF CHEMISTRY UNDERGRADUATE HANDBOOK 2019-2020



The goal of this handbook is to introduce undergraduate students to the Chemistry Department and provide them with detailed information about the Chemistry Major at Yale.

This handbook should be used alongside other resources such as:

- i) The Yale College Program of Study (YCPS) for the Academic Year 2019-2020, which contains brief descriptions of all Undergraduate Chemistry Courses.  
(<http://catalog.yale.edu/ycps/subjects-of-instruction/chemistry/>)
- ii) The Yale Chemistry Department Website  
(<https://chem.yale.edu/academics/undergraduate-studies>).

The Chemistry (CHEM) Major is offered by the Department of Chemistry.

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## I. Introduction

Chemistry has been responsible for some of the most significant improvements in our quality of life over the last century. The discovery of antibiotics and other pharmaceuticals, the advent of computers, and the development of industrial methods such as the Haber-Bosch process to produce fertilizer, all have required fundamental advances in chemistry and have had profound impacts on society. In the next century, it is likely that chemistry will play a central role in the development of alternative-energy vectors to replace fossil fuels, the realization of practical quantum computers, the discovery of new methods to treat and prevent diseases, and the adoption of more sustainable industrial processes. The Chemistry Major at Yale provides students with the technical foundation to both appreciate the scientific basis for previous discoveries and develop the fundamental skills required to make future breakthroughs.

Under the tutelage of world-leading researchers, students are exposed to a broad range of topics in chemistry. After completion of the prerequisites, core classes in Organic, Inorganic, and Physical Chemistry are supplemented by advanced elective classes in more specialized areas such as Chemical Biology, Quantum Chemistry, and Organometallic Chemistry. The development of technical skills through lecture classes is complemented with hands-on experience in state-of-the-art chemistry laboratories. Many students also perform independent laboratory research under the guidance of a faculty mentor. This rigorous training prepares students for professional careers in a diverse array of fields by teaching them how to apply the scientific method, providing them with skills in quantitative reasoning, and exposing them to scientific research. After completing their degree, Chemistry Majors often pursue graduate work in chemistry, biochemistry, or health-related disciplines, but also find their broad scientific training beneficial in fields such as technology policy, business management, and law. Chemistry is an especially appropriate major for students interested in energy research or policy and the environment.

The teaching and research facilities in Chemistry include the iconic Sterling Chemistry Laboratory (built in 1921) which encompasses a new state-of-the-art undergraduate teaching center, the completely reworked Kline Chemistry Laboratory, and the cutting-edge Class of 1954 Chemistry Research Building, in addition to interdisciplinary research laboratories on Yale's West Campus. The Chemistry Department consists of approximately 25 research-active faculty, 6 full-time lecturers whose primary focus is undergraduate teaching, 30 postdoctoral fellows, 200 graduate students, and roughly 65 Chemistry Majors, all of whom work and study in these buildings. The quality and breadth of expertise in the Yale Chemistry community, which also includes faculty having joint appointments in Cell Biology, Molecular, Cellular, and Developmental Biology (MCDB), Molecular Biophysics and Biochemistry (MB&B), and Physics (PHYS), has made Yale a premier center in Chemistry for both students and faculty.

## II. What Can Being a Chemistry Major Do For Me?

The successful completion of a Chemistry Major at Yale prepares students for a future career in a wide range of professions, including medicine, the pharmaceutical industry, and chemical research, as well as various aspects of science-oriented writing, policy, teaching, and consulting. Central themes that students are exposed to throughout the Major are designed to develop expertise in quantitative reasoning, expand knowledge of basic chemical concepts, hone laboratory skills, and foster an appreciation for the important role of science in society. Advanced electives allow students to specialize in specific areas of chemistry, such as Physical, Theoretical, Inorganic, or Organic Chemistry, or Chemical Biology. The rigorous training prepares students for the next stage of their careers, and Chemistry Majors have a high rate of acceptance at medical and graduate schools.

Undergraduate Chemistry Majors at Yale are a valued part of the Yale Chemistry Community. Along with events organized exclusively for Majors, they are invited to various Departmental activities such as the annual Holiday Party and Yale Chemistry Symposium<sup>1</sup>. This allows Chemistry Majors to build camaraderie and interact actively with other members of the Department. In addition, Chemistry Majors engaged in independent research often develop close relationships with other group members. The connections that are facilitated in the Chemistry Department can be both academically and personally valuable for Chemistry Majors for many years into the future.

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<sup>1</sup>The Yale Chemistry Symposium is a one day symposium where graduate students give talks describing their research. There is also a keynote address from a member of the Yale Chemistry Faculty. Lunch and dinner (a BBQ) are provided on the day of the Symposium. This year the Symposium will be held on Friday August the 23<sup>rd</sup> in SCL 110. Events start at 11:00 am and more information will be available on the Yale Chemistry website.

### III. Chemistry Degrees and Courses

Yale undergraduates can select from four different degrees in Chemistry: B.A., B.S., B.S. (Intensive), and B.S./M.S. These differ in the number of required courses and also in the manner in which the senior requirement is completed. The B.A. requires the fewest number of classes, while the B.S./M.S. requires the most. All four degrees require students to complete the appropriate number of courses (see Section IV for detailed information about the exact requirements for each degree) from the following categories:

- (i) *Prerequisites to the Major.* These courses provide students with the necessary background for studying chemistry. For all degrees, this includes courses in Physics and Mathematics, as well as two semesters of General Chemistry Lecture and Laboratory. If a student has a suitable background, in some cases the DUS will waive a prerequisite course. For example, students who start in Organic Chemistry for First Year Students, do not have to take the General Chemistry Lecture or Laboratory sequences at Yale.
- (ii) *Core Courses.* Courses in Organic, Inorganic, and Physical Chemistry are required courses for the Chemistry Major.
- (iii) *Advanced Lecture Courses.* These lecture courses cover material beyond the standard Organic, Inorganic, and Physical Chemistry curriculum. They allow students to specialize in specific areas, for example Organic or Inorganic Chemistry, and learn about more advanced topics in Chemistry such as Quantum Chemistry or Chemical Biology. For Chemistry courses, advanced lecture courses typically are numbered 410 or above. In some cases courses offered outside the Chemistry Department, such as MB&B 300 (Principles of Biochemistry I) or PHYS 448 (Solid State Physics I) will be counted as advanced lecture courses towards the Chemistry Major. Each semester, the DUS provides students with a list of courses in the Chemistry Department that count as advanced lecture courses. Students who wish to complete an advanced lecture course outside the Chemistry Department should contact the DUS for permission prior to formally enrolling in the course.
- (iv) *Advanced Laboratory Courses.* These are laboratory courses which teach students specialized skills beyond the core curriculum. At least one advanced laboratory course is required for all degrees.
- (v) *Senior Requirement.* All degrees require a senior essay. The pathway for completing the senior essay varies depending on the degree type. Specific information about the senior requirement can be found in Section VI.

In some cases, courses that count as a core course for one degree will count as an advanced lecture or laboratory course for another degree. For example, CHEM 333 (Physical Chemistry with Applications in the Physical Sciences II) is a core course for the B.S., B.S. (Intensive), and B.S./M.S. degrees but is considered an advanced lecture course for the B.A. degree.

Students should choose among the four degree tracks according to their career objectives. A brief description of the type of student for which each degree is designed is provided below.

- (i) **B.A.:** The B.A. is typically for students who have an interest in chemistry, but intend to pursue a major or career in another discipline. In these cases, a solid chemical training would be an asset to the student's other major or career. For example, training in chemistry could be beneficial to students who wish to pursue a major or career in areas such as technology policy, economics, or the environment. The B.A. degree is not appropriate for

students who wish to pursue a Ph.D. in chemistry, and typically is completed by students who are also majoring in another discipline.

- (ii) **B.S.:** The B.S. is intended to prepare students for graduate study, in chemistry or a related field, while permitting extensive exploration of other disciplines. Research is not required as part of the B.S. degree.
- (iii) **B.S. (Intensive):** The B.S. (Intensive) prepares students for further careers in the sciences in a similar fashion to a B.S.; however, it offers a more rigorous program of study that requires an extra class in Physics, an extra advanced lecture or laboratory course, and, most importantly, a compulsory research component. Most students decide between the B.S. and B.S. (Intensive) degree based on how many classes they wish to pursue outside of the Chemistry Major, as the choice does not affect prospects after graduation strongly.
- (iv) **B.S./M.S.:** The B.S./M.S. is designed for students whose advanced preparation qualifies them for graduate-level work in the third and fourth years of their undergraduate degree. It requires the completion of eight graduate-level courses in Chemistry. Most years there are only one or two Chemistry Majors for which this degree is suitable and in some years it is not suitable for any Chemistry Major. A B.S./M.S. degree is of little value to students who intend to pursue a Ph.D. in Chemistry, as an M.S. is awarded as part of a doctoral program at most institutions. There is also an opportunity cost associated with taking the large number of advanced chemistry classes required for the B.S./M.S. degree, as students can take fewer classes in other areas. Typically, the B.S./M.S. degree is most suitable for students who wish to pursue a career in policy or consulting and are not intending to complete any additional formal training in Chemistry. The B.S./M.S. degree includes a large research component. For more information on the B.S./M.S. degree see Section VII.

## IV. Chemistry Roadmaps

<b>Chemistry</b>				
<b>Degrees Offered</b>	BA Chemistry	BS Chemistry	BS Chemistry (Intensive Major)	BS/MS Chemistry
<b>Prerequisites for entering the major</b>	General Chemistry I and II (CHEM 161 and 165 or CHEM 163 and 167 CHEM 134L and 136L)			
	Calculus of Functions of One Variable II (MATH 115) (MATH 120 recommended but not required)			
	Introductory Physics (PHYS 170, 180, 200, or 260) (For BS/MS PHYS 200 or above required)			
<b>Requirements for each degree</b>	10 credits 11 courses	13 credits 14 Courses	15 credits 16 Courses	Intensive + 4 grad courses
	2 Semesters Organic Chemistry (with 2 Labs) CHEM 174 or 220 and CHEM 175, 221, or 230. CHEM 222L and 223L			Application by end of 5th term
	Physical Chemistry (CHEM 332 or 328)	2 Semesters Physical Chemistry (with 1 Lab) (CHEM 332, 333 and 330L)		Physics courses must be 200/201 or 260/261
	Inorganic Chemistry CHEM 252			CHEM 490 in 5th and 6th terms
	N/A		PHYS 171, 181, 201, or 261	Research between Jr/Sr year
	4 Advanced electives At least 1 CHEM lecture and lab	4 Advanced electives At least 1 CHEM lecture and 1 lab	5 Advanced electives At least 2 CHEM lectures and 1 lab	N/A
	Senior Seminar CHEM 400			
<b>Senior Requirements</b>	Senior Seminar CHEM 400	2 Semesters Research CHEM 490 or CHEM 400 + advanced additional course	2 Semesters Research CHEM 490	4 Semesters Research comprising CHEM 490 in 5th and 6th terms and CHEM 990 in 7th and 8th terms
<b>Substitutions</b>	Up to 2 relevant advanced science courses in other departments for advanced chem electives			N/A



Four possible paths through the Chemistry Major

Possible BA Sequence		
	Fall	Spring
Year 1	CHEM 161, 134L, & MATH pre-req	CHEM 165, 136L, & MATH pre-req
Year 2	CHEM 220, 222L, & PHYS pre-req	CHEM 221, 223L, & 252
Year 3	CHEM 332	Advanced Lab & 1 Elective
Year 4	CHEM 400 & 1 Elective	1 Elective

Possible BS Sequence		
	Fall	Spring
Year 1	CHEM 161, 134L, & MATH pre-req	CHEM 165, 136L, & MATH pre-req
Year 2	CHEM 220, 222L, & Phys pre-req	CHEM 221 & 223L
Year 3	CHEM 332 & 330L	CHEM 333, 252, & Advanced Lab
Year 4	CHEM 490 & 2 Electives	CHEM 490 & 1 Elective

Possible BS Intensive Sequence		
	Fall	Spring
Year 1	CHEM 163, 134L, & MATH pre-req	CHEM 167, 136L, & MATH pre-req
Year 2	CHEM 220, 222L, & PHYS pre-req	CHEM 221, 223L, 252, & PHYS pre-req
Year 3	CHEM 332 & 330L	CHEM 333, Advanced Lab, & 1 Elective
Year 4	CHEM 490 & 2 Electives	CHEM 490 & 1 Elective

Possible BS/MS Sequence		
	Fall	Spring
Year 1	CHEM 174, 222L, MATH & PHYS pre-req	CHEM 175, 223L, MATH & PHYS pre-req
Year 2	CHEM 330L & 332	CHEM 333, 252, & Advanced Lab
Year 3	CHEM 490 & 2 Electives	CHEM 490 & 2 Electives
Year 4	CHEM 990 & 2 Electives	CHEM 990 & 2 Electives



## V. First Year Chemistry

First Year (General) Chemistry is a prerequisite to complete a Chemistry Major. The majority of students begin their studies in Chemistry at Yale by completing the General Chemistry sequence: either CHEM 161 and 165, General Chemistry I and II, or CHEM 163 and 167, Comprehensive University Chemistry I and II. Through the placement process (described below) the Chemistry Department provides advice to students on which flavor of General Chemistry is most suitable. Typically, students completing CHEM 161 may be taking chemistry for the first time or perhaps took chemistry as a high-school sophomore. Students in CHEM 163 will have more recently completed a year or two of chemistry in high school or may even have taken AP chemistry but not fully mastered the subject at that level, although motivated students may have last taken chemistry as a high-school sophomore if they have a strong math and physics background. Regardless of whether a student completes the CHEM 161/165 or CHEM 163/167 sequence, they are required to take the same General Chemistry Laboratories, CHEM 134L, General Chemistry Laboratory I, and CHEM 136L, General Chemistry Laboratory II. In some cases, students are given permission to place out of the first semester of General Chemistry Lecture and Laboratory (see below) and can start their studies in CHEM 167 and CHEM 136L. If a student wants to start in the second semester of General Chemistry, they only can enroll in CHEM 167, and not CHEM 165. Prospective majors who plan to start in General Chemistry are encouraged to begin their studies in chemistry in their first year at Yale to ensure they can complete all of the requirements for the Chemistry Major, especially if they intend to complete a B.S. It is possible, however, to complete the B.S. in as little as six terms if a student has advanced placement (see below).

Students with a sufficiently strong background in chemistry may initiate their studies with courses in Organic or Physical Chemistry after demonstrating proficiency on the Department's placement examination. Students who have obtained a score of 5 on the AP chemistry exam are especially encouraged to take the placement exam and start in CHEM 174, Organic Chemistry for First-Year Students, CHEM 220, Organic Chemistry I, or CHEM 332, Physical Chemistry I. In particular, CHEM 174 is offered exclusively for first-year students and provides students with an opportunity to build lasting connections with their peers, while learning organic chemistry with a smaller group of students. In some cases students elect to complete CHEM 220 rather than CHEM 174 because of scheduling issues, but the Department strongly recommends CHEM 174. CHEM 332 is recommended for students with a strong background in math. Students who complete CHEM 174, CHEM 220, or CHEM 332 in their first year do not have to complete any General Chemistry Lecture or Laboratory courses (these prerequisites are assumed to have been fulfilled as gauged by performance on the placement examination).

### *Placement Procedures*

#### 1. Placement Procedures for General Chemistry Courses

The Chemistry Department reviews the preparation of all first-year students prior to the beginning of the fall term, using test scores, admission records, and information supplied by students through the High-School Math and Science Survey. Incoming students should complete this survey during the summer before matriculation. The Department determines the appropriate General Chemistry course for every entering first-year student, either CHEM 161, 163, or 167. Students will be able to view their initial placement in late August at the "Course Placement" site on Canvas@Yale. Students who wish to take a more advanced course than their initial placement recommends should plan to take the on-campus placement exam.

## 2. On-Campus Placement Exam for Higher-Level Courses

First-year students wishing to take Organic or Physical Chemistry (CHEM 174, 220, or 332), or those wishing to take a higher-level course than initially assigned by means of the High-School Math and Science Survey, are required to take an in-person placement examination. Details about the time and location of the placement exam are on the Chemistry Department website.

## VI. The Senior Requirement

All Chemistry Majors must complete the senior requirement, which takes the form of a capstone essay. However, the path for writing the senior essay varies depending on the type of degree a Chemistry Major is pursuing. A summary of the different ways to complete the senior requirement for each type of degree is provided below.

### *B.A. Degree*

The only way to fulfil the senior requirement is through completion of CHEM 400, Current Chemistry Seminar, which is a seminar course offered in the Fall semester of each academic year. It is designed to engage students in the Chemistry research-seminar program by providing requisite scientific guidance and a forum for directed discussion. Students write a final paper as part of this course, which counts as their senior essay. Only students in their Senior year can complete CHEM 400.

### *B.S. Degree*

The senior requirement can be fulfilled in two ways, depending on student preferences:

- (i) Through the completion of two semesters (Fall & Spring) of the course CHEM 490, Independent Research in Chemistry, in the Senior year<sup>2</sup>. In this course students perform research with an individual faculty member. At the conclusion of their second semester of CHEM 490, students must write a report (their senior essay) describing their research and must discuss their work publicly in the form of a poster presentation. Both of these activities are coordinated by the Instructor of CHEM 490. More information about independent research and CHEM 490 can be found in Section VIII.
- (ii) Through the completion of the course CHEM 400, Current Chemistry Seminar, and one additional course credit of advanced chemistry lecture or laboratory courses. The final paper written as part of CHEM 400 is considered to be the senior essay.

### *B.S. (Intensive) Degree*

The only way for students to fulfill the senior requirement is through the completion of two semesters (Fall & Spring) of the course CHEM 490, Independent Research in Chemistry, in the Senior year<sup>1</sup>. In this course students perform research with an individual faculty member. At the conclusion of their second semester of CHEM 490, students must write a report (their senior essay) describing their research and must discuss their work publicly in the form of a poster presentation. Both of these activities are coordinated by the Instructor of CHEM 490. More information about research and CHEM 490 can be found in Section VIII.

### *B.S./M.S.*

The senior requirement is fulfilled in the same manner as for the B.S. (Intensive) Degree but students must complete their written essay and poster presentation in the Junior year. To do this, permission is required from the Chemistry DUS.

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<sup>2</sup>In rare circumstances, which must be approved by the Chemistry DUS, students may be able to complete one semester of CHEM 490 in their Junior year and one in their Senior year.

## VII. The Combined B.S./M.S. Degree

Exceptionally well-prepared students may complete a course of study leading to the simultaneous award of the B.S. and M.S. degrees after eight terms of enrollment. Formal application for admission to this program must be made no later than the last day of classes in the fifth term of enrollment. The formal application process involves providing:

- (i) Evidence of eligibility for the B.S./M.S. degree through the submission of an academic transcript. To be eligible for enrollment applicants must have achieved at least two-thirds A or A<sup>-</sup> grades in all of their course credits as well as in all of the course credits directly relating to the major, including prerequisites, by the end of their fifth term.
- (ii) A letter outlining the reasons why a simultaneous degree is being pursued.
- (iii) A detailed plan for completing the program requirements (see below).

The application should be submitted to the Chemistry DUS for approval by the Chemistry Department. If the Department acts favorably on the student's application, it is forwarded with the formal approval of the Chemistry DUS and DGS to the Director of Academic and Educational Affairs in the Yale College Dean's Office, where a joint committee of Yale College and the Yale Graduate School considers the nomination and notifies the student of acceptance into the program.

Even though the formal application is not due until the last day of classes in the fifth term of enrollment, in practice students interested in the B.S./M.S. degree should consult with the Chemistry DUS in their fourth term (or earlier) of enrollment.

The basic requirements for a B.S./M.S. degree are as follows:

- (i) The completion of all of requirements for the B.S. (Intensive) degree, including the senior requirement, which typically is accomplished in the fifth and sixth terms of enrollment. The introductory physics requirement must be fulfilled with PHYS 200 and 201 or 260 and 261; a term course in physics numbered 400 or higher and approved by the Chemistry DUS may be substituted for the introductory sequence.
- (ii) The completion of eight (8) graduate courses in chemistry, four (4) of which can also be counted toward the B.S. (Intensive) degree. Students must earn grades of A in at least two of their graduate-level term courses (or in one yearlong course) and have at least a B average in other graduate-level courses.
- (iii) Four (4) terms of independent research in chemistry supervised by a faculty member are required. Typically, a student completes two terms in their Junior year through CHEM 490, Independent Research in Chemistry, and two terms in their Senior year through CHEM 990, Graduate Chemistry Research. Additionally, students are required to perform independent research with the same faculty member with whom they are completing CHEM 490 and CHEM 990 in the summer between their Junior and Senior years. Normally, the faculty member is part of the Chemistry Department, and approval from the Chemistry DUS is required to perform research with a faculty member outside the Department.
- (iv) At the end of their eighth semester, students are required to write a thesis summarizing their research activities. The thesis must be written under the guidance of the faculty member supervising the research and it must be submitted on the final day of classes (of the student's eighth semester) to their research adviser. The thesis should be no shorter than

twenty-five pages (double-spaced, twelve-point font, excluding figures, tables, and bibliography) and normally should contain the following sections: Introduction, Results and Discussion, Summary and Conclusions, Research Methods, and Bibliography. Students in the B.S./M.S. program must discuss their work in the form of a poster presentation at the end of their sixth semester (to fulfill requirements of the intensive B.S. degree) and an oral presentation at the end of their eighth semester (to fulfill requirements of the M.S. degree). Both the poster (for CHEM 490) and oral (for CHEM 990) presentations are coordinated by the instructor of CHEM 490.

## VIII. Independent Research

Research is required for several Chemistry Degrees and is essential for those undergraduates wishing to obtain a Ph.D. in Chemistry after graduation. The Chemistry Department provides extensive opportunities for Chemistry Majors to perform independent research under the supervision of a faculty member. Research activities span all areas of chemistry, as well as related fields such as Biochemistry and Chemical Physics. All interested students are encouraged to participate in research by working in laboratories for academic credit and/or experience. Financial support may be available in some cases, but students being paid will not receive course credit. A list of faculty associated with the Chemistry Department is provided in Section XII.

Interested students are encouraged to contact faculty members directly regarding possible research opportunities in a particular group. The standard protocol is to request a meeting via e-mail, with an updated CV or resume being attached to provide the faculty member with relevant background information (courses taken, prior research experiences, *etc.*). It is recommended that students discuss research opportunities with several faculty members before choosing a group to join. Prior to making this decision, students should gather information on faculty members' philosophies about undergraduate research and on their expectations for undergraduate researchers, either by talking to the faculty member directly or to members of the group. Senior undergraduates may also be able to provide advice about research in the Chemistry Department. Typically, a student should contact supervisors approximately three months before they intend to commence research.

There is no set time when Chemistry Majors should begin independent research. Some start in the summer after their first year (see Section below on Summer research), whereas others wait until their Junior year. However, in general students who intend to complete CHEM 490 should have some research experience prior to their Senior year.

All students engaging in research activities are required to complete safety training as instructed by their faculty mentor prior to initiating any laboratory work. Additionally, undergraduate researchers must fill out the appropriate form notifying the Chemistry Department that they are conducting research (see Section XIII).

### *Research Courses*

The Chemistry Department offers two different courses focused on research:

#### CHEM 480 (*Introduction to Independent Research in Chemistry*)

Declared Sophomore and Junior Chemistry Majors may elect to complete CHEM 480. Here, students perform at least ten hours of independent research per week with an individual faculty member and write a report about their work at the conclusion of the term. CHEM 480 can be taken multiple times for credit and is a Pass/Fail course governed by Yale College's "P/F with report" policy. A student who passes CHEM 480 will have the mark of "P" entered on their transcript once the course instructor submits an independent-study form with an evaluation of their performance (this report can be viewed by the student). Failure in the course will result in a recorded grade of "F". The completion of CHEM 480 does not satisfy any course requirements for the Chemistry Major.

#### CHEM 490 (*Independent Research in Chemistry*)

Two semesters of CHEM 490 are needed to satisfy the senior requirement for the B.S. (Intensive) degree. Students engaging the B.S. degree also may elect to fulfill the senior requirement by



completing two semesters of CHEM 490 in conjunction with the senior essay. CHEM 490 students conduct independent research with an individual faculty member for at least ten hours per week, with additional mandatory class meetings (typically one hour per week) addressing issues of essential laboratory safety, ethics in science, online literature searching, oral presentation skills, and effective scientific writing. If a Chemistry Major wishes to perform research with a faculty member who does not have an appointment in the Chemistry Department, their proposed research plan needs to be evaluated by the Chemistry DUS (prior to the start of research) to ensure that it is suitable for CHEM 490. At the end of the second semester of CHEM 490, students are expected to submit a report describing their research and to discuss their research publicly in the form of a poster presentation. Each semester students will receive a letter grade (A-F) from the instructor of CHEM 490 that takes into account the grade recommendation forwarded by their research mentor. Chemistry Majors in the B.S./M.S. degree program complete CHEM 490 in their Junior year, whereas all other students only can enroll in their Senior year, unless there are exceptional circumstances (see above).

### Summer Research

Chemistry Majors also can perform research with a faculty member during the summer months, which allows them to work full-time on a specific project. Summer research enables students to continue activities that were initiated during the previous academic year or to begin projects that will be continued during the following academic year. Sometimes the faculty member has grant funds that can support students during the summer. More commonly financial support is provided by the Yale College Deans Office, with further information about such summer-fellowship programs found at the following website: <https://science.yalecollege.yale.edu/yale-undergraduate-research/fellowship-grants/yale-college-deans-research-fellowship>.

Applications for Summer research funding normally are due at the end of February, and interested students should contact a member of the Yale Chemistry Department Faculty in January about summer research. Academic credit is not granted for summer research.

Summer research at other institutions (including those outside the United States) is possible through several programs. More information can be found at the following websites:

<http://yalecollege.yale.edu/student-services/funding-opportunities>

<http://science.yalecollege.yale.edu/yale-science-engineering-research/fellowship-grants>

## IX. Advising for Chemistry Majors

The Chemistry Department is committed to providing advice for students about which classes are appropriate for them and how to achieve their goals after graduation. Once a student has declared themselves to be a Chemistry Major, they are assigned a faculty advisor. Students retain the same faculty advisor until they graduate, thus enabling them to develop an ongoing rapport. Students typically meet with their advisor during the first week of each semester to receive general career advice. More informal meetings can be scheduled as required throughout the semester. Advisors typically do not sign schedules but provide more holistic guidance about courses and careers. Chemistry Majors should contact the Chemistry Undergraduate Registrar, Erin Wynne, to be assigned an advisor if this is not done automatically.

At the start of each semester Chemistry Majors are required to have their course schedule signed by the Chemistry DUS. For Junior and Senior Chemistry Majors the DUS will have provided advice about required courses prior to the start of semester. Students following this advice can submit their schedule to the Chemistry Undergraduate Registrar for the DUS to review and approve. If there is a problem with the schedule or further advice is required, a meeting will be organized with the Chemistry DUS. Throughout the academic year, the Chemistry DUS is available (in addition to assigned faculty advisors) to provide students with advice about appropriate courses and future career plans. The Chemistry DUS normally will host at least one lunchtime meeting or similar event each semester for Chemistry Majors to provide feedback about the major and to give input about any changes planned for the major.

Every year the Chemistry Department selects a number of peer mentors. Peer mentors are senior undergraduate students majoring in Chemistry who can provide sage advice to younger students about which courses to complete, how to choose a research group, and good study habits for being successful in chemistry classes. Peer mentors are not able sign student schedules. For the 2019-2020 academic year, the following individuals serve as peer mentors for Chemistry:

- Alison Ho ([alison.ho@yale.edu](mailto:alison.ho@yale.edu))
- Joe Kim ([hyunjo.kim@yale.edu](mailto:hyunjo.kim@yale.edu))
- Hannah Steffke ([hannah.steffke@yale.edu](mailto:hannah.steffke@yale.edu))
- Isaac Wendler ([isaac.wendler@yale.edu](mailto:isaac.wendler@yale.edu))

If you are interested in becoming a peer mentor, the DUS typically sends an e-mail to all Chemistry Majors prior to the start of each academic year asking for students to apply (with preference usually being given to members of the Senior class).

The Chemistry Department also hosts a Facebook page (Yale Chemistry Majors) designed to connect Chemistry Majors with recently graduated alumni. This page provides information about what Chemistry alumni are doing after graduation and allows current students to contact them. For example, a Chemistry Major considering a specific graduate school might use the Facebook page to contact an alumnus who currently is enrolled in the program/institution of interest. The Facebook page also is a place where photos of events in the Chemistry Department are shared.

A group of undergraduate students also coordinates the Yale Women in Chemistry Club, which provides a supportive community for women and minorities pursuing the Chemistry Major. Events are held throughout the academic year and are open to all to attend. Information about the Club can be found at their Facebook page (Yale Women in Chemistry).

## X. Advising for Students Interested in Health-Care Professions

A Chemistry Major provides students with skills and knowledge that are valuable for a career in health care and, as a consequence, every year a significant number of Chemistry Majors are successfully admitted into medical and related professional schools around the country. Many of the requirements for a B.S. Degree in Chemistry also are necessary for entry into medical school. Premedical students normally complete MB&B 300 (Principles of Biochemistry I) and MB&B 301 (Principles of Biochemistry II), as these classes often are required for entry into medical schools and traditionally are counted as advanced electives towards the Chemistry Major. MCDB 300 (Biochemistry) is an alternative to the MB&B 300/301 sequence, which is also counted as an advanced elective towards the Chemistry Major; however, the Department recommends that Chemistry Majors complete MB&B 300 and MB&B 301, as this provides a more rigorous education in chemical aspects of biochemistry.

The Yale Health Professions Advisory Program (HPAP), which is run by the Office of Career Strategy (<http://ocs.yale.edu/yale-college/health-professions>), is a valuable resource for those interested in completing postgraduate education in the medical/health sciences. The Chemistry Department encourages all students interested in such studies to consult with HPAP staff (located at 55 Whitney Avenue, phone: (203) 432-0818) as early in their Yale career as possible. The HPAP office will be able to provide current information about the course requirements for different medical schools and general advice on preparing medical school applications.

Each year the HPAP office, through the Health Professions Advisory Board (HPAB), publishes two bulletins entitled *Preparing to Become a Health Care Professional* and *Applying to Medical School*. The first document contains general information, while the second includes specific details for those about to apply for admission to medical schools (primarily juniors and seniors).

Students who are interested in applying to M.D./Ph.D. programs should consult the online information published by the Association of American Medical Colleges (AAMC) at <https://students-residents.aamc.org/applying-medical-school/applying-medical-research-programs/applying-mdphd-programs/tools-mdphd-applicants/>

## **XI. Undergraduate Prizes**

The Department gives three prizes to graduating seniors:

- i) The Werner Bergmann Prize: Given to the outstanding senior in the Chemistry Department.
- ii) The Howard Douglass Moore Prize: For excellence in the field of chemistry.
- iii) The Arthur Fleischer Award: For outstanding performance in chemistry.

For all prizes, nominations are sought from faculty members in the Chemistry Department and then a faculty committee selects the winners. Typically, one Bergmann and one Moore Prize are awarded each year, while up to four Fleischer Awards are given. Students receive the Awards at their College Graduation and are not notified prior to this occasion.

## XII. Chemistry Faculty

### *Research Faculty*

**Victor Batista** (Theoretical chemistry) ([victor.batista@yale.edu](mailto:victor.batista@yale.edu))

The Batista group uses computational approaches to provide fundamental understanding of molecular processes and rigorous interpretations of experiments from first principles. They collaborate with a number of experimental groups in the Chemistry Department.



**Gary Brudvig** (Biophysical & inorganic chemistry) ([gary.brudvig@yale.edu](mailto:gary.brudvig@yale.edu))

Research in the Brudvig group aims to define how nature has solved the difficult problem of efficient light-driven, four-electron oxidation of water to oxygen and to use this understanding to develop new artificial processes for solar energy conversion.



**Robert Crabtree** (Inorganic chemistry) ([robert.crabtree@yale.edu](mailto:robert.crabtree@yale.edu))

The Crabtree group focuses on the design and synthesis of inorganic, coordination or organometallic molecules with unusual structures and properties. These are typically catalytic properties for atom economic (green) transformations or utility in alternative energy strategies, such as solar energy and hydrogen storage. The Crabtree group is no longer taking students for undergraduate research.



**Jason Crawford** (Chemical biology) ([jason.crawford@yale.edu](mailto:jason.crawford@yale.edu))

The Crawford laboratory is developing and systematically applying genome sequence-guided methods for the discovery of genetically encoded small molecules from mutualistic and pathogenic microorganisms.



**Craig Crews\*** (Chemical biology) ([craig.crews@yale.edu](mailto:craig.crews@yale.edu))

Through natural product total synthesis, affinity reagent generation, and biochemical methodologies, the Crews lab identifies natural product target proteins, which serve as the starting point for the rapid development of compounds for the treatment of diseases.



**Caitlin Davis** (Biophysical chemistry) ([caitlin.davis@yale.edu](mailto:caitlin.davis@yale.edu))

The Davis laboratory uses experiments at multiple scales, from in vitro to single cell to whole organism, to study fundamental and applied problems at the intersection of chemistry, physics, and biology. A common theme of their research is the development of quantitative spectroscopic imaging techniques to investigate the relationship between function and dynamics in biological systems. The Davis group will be based at Yale from January 2020.



**Jonathan Ellman** (Organic chemistry & chemical biology)

([jonathan.ellman@yale.edu](mailto:jonathan.ellman@yale.edu))

The Ellman group's research emphasizes the development of practical and general synthetic methods and their application to the preparation of pharmaceutical agents and bioactive natural products. His laboratory is also actively engaged in the development and application of chemical tools to study different classes of enzymes.



**Ziad Ganim** (Physical & biophysical chemistry) ([ziad.ganim@yale.edu](mailto:ziad.ganim@yale.edu))

The Ganim group is interested in mechanistic studies of chemical reactions at the single molecule level. They apply an array of single molecule techniques to study how metalloproteins facilitate redox chemistry in their active sites and to study mechanistic heterogeneity during carbon-carbon bond formation in organometallic catalysts.



**Sharon Hammes-Schiffer** (Theoretical chemistry) ([sharon.hammes-schiffer@yale.edu](mailto:sharon.hammes-schiffer@yale.edu))

Research in the Hammes-Schiffer group focusses on the development and application of theoretical and computational methods for describing chemical reactions in condensed phases and at interfaces. Their overall objectives are to elucidate the fundamental physical principles underlying charge transfer processes and catalysis, as well as to assist in the interpretation of experimental data.



**Stavroula Hatzios\*** (Chemical biology) ([stavroula.hatzios@yale.edu](mailto:stavroula.hatzios@yale.edu))

The Hatzios laboratory uses chemical and biological tools to identify proteins that are active during gastrointestinal infections, determine how they respond to environmental cues, and characterize their molecular contributions to disease.



**Nilay Hazari** (Inorganic chemistry) ([nilay.hazari@yale.edu](mailto:nilay.hazari@yale.edu))

The Hazari group works in the area of organometallic chemistry. Their goal is rationally design new catalysts for a range of processes based on detailed studies of reaction mechanisms.



**Seth Herzon** (Organic chemistry & chemical biology) ([seth.herzon@yale.edu](mailto:seth.herzon@yale.edu))

Research in the Herzon group centers on natural products chemistry with an emphasis on the synthesis and study of DNA-damaging natural products, human microbiota metabolites, and antibiotics. They also have projects in synthetic methods typically motivated by challenges encountered in synthesis.



**Patrick Holland** (Inorganic chemistry) ([patrick.holland@yale.edu](mailto:patrick.holland@yale.edu))

The Holland group focuses on developing new transformations of bonds in small molecules such as N<sub>2</sub>, H<sub>2</sub>, and CO<sub>2</sub>. They accomplish this using compounds containing metals, particularly iron.



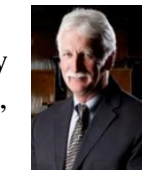
**Mark Johnson** (Physical chemistry) ([mark.johnson@yale.edu](mailto:mark.johnson@yale.edu))

The Johnson laboratory specializes in identifying the factors that control macroscopic behavior at the molecular level. They accomplish this by *designing and building* new types of hybrid instrumentation that integrate laser spectroscopy with cryogenic mass spectrometry.



**William Jorgensen** (Organic chemistry) ([william.jorgensen@yale.edu](mailto:william.jorgensen@yale.edu))

The Jorgensen laboratory specializes in organic, computational, and biochemistry applied to drug discovery, including computer-aided design, organic synthesis, biological assaying, and protein crystallography.





**Patrick Loria** (Biophysical chemistry) ([patrick.loria@yale.edu](mailto:patrick.loria@yale.edu))

The focus of research in the Loria group is to understand how the dynamic and structural properties of proteins correlate with their function with particular emphasis on enzymes and allostery. Their primary experimental tool for addressing these questions is solution nuclear magnetic resonance (NMR) spectroscopy, which allows quantitative, atomic-resolution insight into the kinetics, thermodynamics, and mechanism these important enzyme motions.



**James Mayer** (Inorganic & materials chemistry) ([james.mayer@yale.edu](mailto:james.mayer@yale.edu))

The Mayer laboratory studies the fundamental chemical reactions of molecules and materials, including synthesis, spectroscopy, kinetics and electrochemistry.



**Scott Miller** (Organic chemistry) ([scott.miller@yale.edu](mailto:scott.miller@yale.edu))

The Miller laboratory is interested in all aspects of chemical and biological catalysis, including reaction mechanisms and application in organic synthesis.



**Tim Newhouse** (Organic chemistry) ([timothy.newhouse@yale.edu](mailto:timothy.newhouse@yale.edu))

The Newhouse group synthesizes complex natural products and develops new synthetic methods to prepare these complex small molecules. The properties of newly prepared natural products are exploited for a variety of purposes by collaborating with neuroscientists.



**Anna Pyle\*** (Chemical biology) ([anna.pyle@yale.edu](mailto:anna.pyle@yale.edu))

The Pyle group studies RNA structure and RNA recognition by protein enzymes. They use a combination of experimental biochemistry, crystallography, and computation to study the architectural features of large RNA molecules, such as self-splicing introns and other noncoding RNAs



**James Rothman\*** (Cell biology) ([james.rothman@yale.edu](mailto:james.rothman@yale.edu))

The Rothman laboratory is interested in elucidating the underlying mechanisms of vesicular transport within cells and the secretion of proteins. They take an interdisciplinary approach which includes cell-free biochemistry, single-molecule biophysics, high-resolution optical imaging of single events/single molecules in the cell and in cell-free formats.



**Martin Saunders** (Organic chemistry) ([martin.saunders@yale.edu](mailto:martin.saunders@yale.edu))

The Saunders laboratory is interested in physical organic chemistry. They have extensively studied fullerenes, carbocations, and conformation of organic molecules. The Saunders group is no longer taking students for undergraduate research.



**Charles Schmuttenmaer** (Physical chemistry) ([charles.schmuttenmaer@yale.edu](mailto:charles.schmuttenmaer@yale.edu))

The Schmuttenmaer group investigates systems that require an understanding of both bulk material and molecular properties. Terahertz (THz) spectroscopy is utilized to study all of these systems.



**Sarah Slavoff** (Chemical biology) ([sarah.slavoff@yale.edu](mailto:sarah.slavoff@yale.edu))

The Slavoff group is interested in developing new tools to elucidate novel functions of RNA in cells, including non-canonical translation and RNA degradation in cytoplasmic granules. They utilize a broad range of interdisciplinary methods, including mass-spectrometry-based proteomics, microscopy, structural biology, and small molecule-mediated control of biomolecular function.



**David Spiegel** (Chemical biology) ([david.spiegel@yale.edu](mailto:david.spiegel@yale.edu))

The Spiegel laboratory develops novel chemical methods to enable the synthesis of a variety of complex molecular targets, including natural products. These synthetic materials are used to study the molecular mechanisms that underlie human disease processes (e.g., cancer, Alzheimer's disease, and diabetes) as well as to develop novel therapeutic approaches to these conditions.



**Dieter Söll\*** (Chemical biology) ([dieter.soll@yale.edu](mailto:dieter.soll@yale.edu))

Research in the Söll laboratory covers a broad range of topics unified by a single problem – evolution of the genetic code. Through genetics, biochemistry, structural analysis, and molecular biology, they study bacterial, archaeal and eukaryotic systems to uncover new strategies of genetic code expression.



**Scott Strobel\*** (Chemical biology) ([scott.strobel@yale.edu](mailto:scott.strobel@yale.edu))

Research in the Strobel laboratory is divided between work on RNA biochemistry and the investigation of novel endophytic fungi associated with rainforest plants. The goal is to understand how RNA promotes chemical reactions and to define the basis of RNA-small molecule interactions.



**Patrick Vaccaro** (Physical chemistry) ([patrick.vaccaro@yale.edu](mailto:patrick.vaccaro@yale.edu))

Research in the Vaccaro group strives to elucidate the origins of molecular behavior by probing fundamental physical properties and chemical propensities through synergistic application of modern laser-spectroscopic and quantum-chemical tools. Information gleaned from such studies affords a trenchant glimpse of structural paradigms and dynamical processes that permeate the entire fabric of chemistry, including molecular chirality, non-covalent interactions, and proton-transfer reactions.



**Hailiang Wang** (Materials chemistry) ([hailiang.wang@yale.edu](mailto:hailiang.wang@yale.edu))

The Wang group focuses on materials and surface chemistry for electrochemical energy storage and conversion.



**Elsa Yan** (Biophysical & physical chemistry) ([elsa.yan@yale.edu](mailto:elsa.yan@yale.edu))

The Yan group focusses on protein folding at membrane surfaces and signal transduction across biomembranes through G protein-coupled receptors (GPCRs). They apply second-order laser spectroscopy and biophysical methods to obtain thermodynamic and kinetic information to investigate structure and functions of the proteins.





**Kurt Zilm** (Physical chemistry) ([kurt.zilm@yale.edu](mailto:kurt.zilm@yale.edu))

Research in the Zilm laboratory involves development of new NMR methods and their application to important problems in chemistry and materials science. Recent interests include the use of site specific solid state NMR relaxation measurements to characterize protein backbone motions and to measure difficult to access long range distance constraints.



\*These faculty members have primary appointments in Departments other than Chemistry. It is still possible for undergraduate students to perform research as part of CHEM 480 or CHEM 490 in these groups, but the DUS should be consulted prior to the commencement of research.

*Teaching Faculty\**

**Paul Cooper** ([paul.d.cooper@yale.edu](mailto:paul.d.cooper@yale.edu))

Dr. Cooper has a background in physical chemistry. He typically teaches General Chemistry and Physical Chemistry Laboratory.



**Christine DiMeglio** ([christine.dimeglio@yale.edu](mailto:christine.dimeglio@yale.edu))

Dr. DiMeglio has a background in organic chemistry. She typically teaches Organic Chemistry Laboratory and the Advanced Laboratory.



**Narasimhan Ganapathisubramanian** ([narasimhan.ganapathi@yale.edu](mailto:narasimhan.ganapathi@yale.edu))

Dr. G has a background in physical chemistry. He typically teaches General Chemistry Laboratory and chemistry courses for non-majors.



**Jonathan Parr** ([jonathan.parr@yale.edu](mailto:jonathan.parr@yale.edu))

Dr. Parr has a background in inorganic chemistry. He typically teaches General Chemistry, Inorganic Laboratory, and the Advanced Laboratory, and is normally in charge of CHEM 400 and CHEM 490.



\*Students do not normally perform research with teaching faculty.

### **XIII. Chemistry Forms**

# Department of Chemistry – Yale University

## BA/BS Course of Study Form

Name: \_\_\_\_\_ SID: \_\_\_\_\_ Class: \_\_\_\_\_ Date: \_\_\_\_\_

E-Mail Address: \_\_\_\_\_ Degree: BA  BS  BS-INT

Fall Term	<i>First Year</i>	Spring Term

Fall Term	<i>Sophomore Year</i>	Spring Term

Fall Term	<i>Junior Year</i>	Spring Term

Fall Term	<i>Senior Year</i>	Spring Term

Summer Courses: \_\_\_\_\_

QR Prerequisites: MATH \_\_\_\_\_ PHYS \_\_\_\_\_

General Chem: Lecture \_\_\_\_\_ Laboratory \_\_\_\_\_

Organic Chem: Lecture \_\_\_\_\_ Laboratory \_\_\_\_\_

Inorganic Lecture: \_\_\_\_\_ Physical Lecture: \_\_\_\_\_ Physical Lab: \_\_\_\_\_ (BS/BS-INT)

Advanced Courses: *Adv Chemistry Laboratory* \_\_\_\_\_ *Adv Chemistry Lecture* \_\_\_\_\_ (BA/BS) \_\_\_\_\_ (BS-INT)

Senior Requirement: \_\_\_\_\_ (CHEM 400 or CHEM 490)

Approved Substitutions: \_\_\_\_\_

DUS Approval Signature: \_\_\_\_\_ Name: \_\_\_\_\_ Date: \_\_\_\_\_

**Department of Chemistry – Yale University**  
**Combined BS/MS Course of Study Form**

Name: \_\_\_\_\_ SID: \_\_\_\_\_ Class: \_\_\_\_\_ Date: \_\_\_\_\_

**I. BS-Intensive Core Requirements (course number & term of completion)**

*Lecture Courses*

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*Laboratory Courses*

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**II. Independent Research Requirements**

Research Advisor for CHEM 490/990: \_\_\_\_\_

Title of Research Project: \_\_\_\_\_

\_\_\_\_\_

**III. Advanced Course Requirements (course number & term of completion)**

*BS-Intensive Courses*

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*MS Courses*

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Overlapping Courses (no more than 4): \_\_\_\_\_

**DUS Approval** Signature: \_\_\_\_\_ Name: \_\_\_\_\_ Date: \_\_\_\_\_

**DGS Approval** Signature: \_\_\_\_\_ Name: \_\_\_\_\_ Date: \_\_\_\_\_

## Department of Chemistry – Yale University

### CHEM 490 Registration Form (Standard Yale College Letter Grading)

#### CHEM 490 Student Responsibilities:

A student conducting independent research in CHEM 490 must agree to the following:

- To have a basic proficiency in aspects of chemistry required for my planned activities.
- To devote at least 10hrs per week to research efforts in the laboratory of my mentor.
- To attend mandatory class meetings relating to safety, ethics and research skills.
- To fulfill basic safety requirements, including completion of all pertinent training.

By signing below, the student affirms they have read the extended description of CHEM 490 (attached document), and will abide by all stipulations and requirements listed therein:

Student Name: \_\_\_\_\_ SID: \_\_\_\_\_ College/Class: \_\_\_\_\_

Student Signature: \_\_\_\_\_ Date: \_\_\_\_\_

E-Mail Address: \_\_\_\_\_ Major/Degree: \_\_\_\_\_

Phone Number (optional): \_\_\_\_\_

Emergency Contact (name/phone): \_\_\_\_\_

Faculty Research Mentor: \_\_\_\_\_

Title of Proposed Research: \_\_\_\_\_

#### CHEM 490 Research Mentor Responsibilities:

A mentor supervising independent research in CHEM 490 must agree to the following:

- To affirm by midterm that the student is devoting at least 10hrs per week to research.
- To ensure student meets basic safety requirements before starting laboratory work.
- To administer to student any specialized training required for planned research activities.

Faculty Mentor Name: \_\_\_\_\_

Faculty Mentor Signature: \_\_\_\_\_ Date: \_\_\_\_\_

E-Mail Address: \_\_\_\_\_ Department: \_\_\_\_\_

Please list any rooms for which student needs key or card access (Chemistry only): \_\_\_\_\_

#### CHEM 490 Safety Certification:

Cognizant staff from Yale's Office of Environmental Health and Safety (EHS) or the DUS of Chemistry (upon consultation with EHS personnel) must affirm that the student has fulfilled basic safety requirements *prior to them engaging in any research activities*. This includes completion of online courses on laboratory chemical handling and hazardous waste disposal, as well as any other specialized training deemed necessary.

EHS Staff/DUS Name: \_\_\_\_\_

EHS Staff/DUS Signature: \_\_\_\_\_ Date: \_\_\_\_\_

#### Chem 490 Final Approval:

DUS Name: \_\_\_\_\_

DUS Signature: \_\_\_\_\_ Date: \_\_\_\_\_

## CHEM 490: Independent Research in Chemistry

The following information affords a more detailed description of CHEM 490, enumerating the basic criteria imposed for student enrollment and the formal requirements that must be met for participants to complete the course successfully.

### **Brief Description:**

After consulting with the Director of Undergraduate Studies (DUS) in Chemistry *no later than the last week of the preceding academic term*, Senior Chemistry Majors in B.S.-level degree programs engage individual experimental and/or theoretical problems in the laboratories of a selected faculty member. At least 10hrs per week of research is required (including initial time spent on requisite safety training), with the faculty mentor affirming this level of student commitment by midterm. Additionally, mandatory class meetings (one hour per week) address issues relating to essential laboratory safety and ethics in science, online literary research, oral presentation skills, and effective scientific writing. At the completion of the final semester of CHEM 490 students are expected to submit a capstone report describing their research and to give a poster presentation of said research as coordinated by the instructor of CHEM 490.

Individuals wishing to enroll must have demonstrated proficiency in the aspects of chemistry required for planned activities, as ascertained and certified by the supervising faculty member. For each term of enrollment, students must complete a CHEM 490 registration form, have it signed by their faculty research mentor, and submit it to Chemistry DUS for final approval *no later than the last week of classes in the immediately preceding academic term*. CHEM 490 is restricted to Senior Chemistry Majors pursuing B.S. or B.S.-Intensive degrees, however, in special cases and with DUS approval, juniors may take this course (*e.g.*, individuals engaged in the B.S./M.S. Chemistry program). Only two semesters of CHEM 490 may be taken with assigned letter grades, subject to restrictions imposed by Yale College. Students are able to complete CHEM 490 by working with a faculty member who does not have a primary appointment in the Chemistry Department, but in this case the DUS must approve that the project involves chemical techniques and is related to chemistry.

### **Course Overview:**

The primary purpose of CHEM 490 is to provide undergraduate students with a hands-on exposure to research in the chemical sciences. The course entails one semester of experimental or theoretical work in chemistry with a *minimum* of 10hrs per week being spent in the laboratories of a faculty member, as well as a weekly 1hr class meeting where topics related to research will be discussed. Building on concepts and techniques honed during formal coursework, participants are expected to direct their efforts towards the generation of chemically relevant data designed to engage and address a specific research problem, as coordinated and supervised by their selected faculty mentor. Students are required to submit a capstone report describing their research at the conclusion of their final semester of CHEM 490 and give a poster presentation describing their research.

### **Time Commitment:**

Each student enrolled in CHEM 490 must fulfill a *minimum* of 10hrs per week of research, with the faculty mentor required to certify this level of participation by midterm, and attend the mandatory 1hr weekly meeting. If for any reason an individual is unable to meet this commitment, they will be required to withdraw from the course immediately.

Students traveling to interview for summer/post-graduate positions or to engage in extracurricular activities must account for lost research time by undertaking additional laboratory work as agreed with and coordinated by their faculty mentor.

### **Safety Requirements:**

Participants in CHEM 490 must fulfill basic safety requirements, including *at least* the online courses entitled “Laboratory Chemical Training” and “Hazardous Chemical Waste Training” as administered by the Yale Office of Environmental Health and Safety (EHS) at <http://ehs.yale.edu/training>. Enrolled individuals must complete these courses successfully and receive formal certification from EHS *prior to beginning any laboratory activities*. Depending on the nature of specific efforts undertaken by the student, additional safety courses or other training requirements might be imposed by the faculty mentor and/or EHS personnel. The time expended to comply with such safety/training prerequisites can offset the mandated 10hrs per week of research.

### **Ethical Conduct:**

Plagiarism and other forms of academic/professional dishonesty are antithetical to science, which critically depends on the integrity and ethical conduct of its participants to ensure the successful advancement of scientific knowledge and understanding. Students wishing to enroll in CHEM 490 should review Yale College policies regarding undergraduate plagiarism and cheating carefully (<http://yalecollege.yale.edu/campus-life/undergraduate-regulations>), as well as science-specific regulations composed by Yale’s Office of Research Administration to govern the responsible conduct of research (<http://researchadministration.yale.edu/responsible-conduct-research>).

### **Grading:**

Students enrolled in CHEM 490 earn one (1) graduation credit upon successful completion of the semester and are assigned letter grades, subject to restrictions imposed by Yale College. CHEM 490 may be taken twice, subject to restrictions imposed by Yale College.

### **Enrollment Procedures and Formal Requirements:**

It is expected that individuals wishing to perform independent research will have demonstrated proficiency in the basic aspects of chemistry required for their planned activities, as ascertained and certified by the supervising faculty member. For each term of enrollment, students must complete a CHEM 490 registration form, have it signed by their faculty research mentor, and submit it to Chemistry DUS for final approval *no later than the last week of classes in the immediately preceding academic term*.

### **Capstone Report:**

CHEM 490 is used to satisfy the senior requirement for the Chemistry Major in Yale College and students must produce a capstone report at the conclusion of their final semester of CHEM 490. The capstone report is expected to be fifteen to twenty-five pages in length (double-spaced, twelve-point font, exclusive of figures, tables, and bibliography). All students performing research also must present their work in the form of a poster presentation as coordinated by the instructor of CHEM 490.

# Department of Chemistry – Yale University

## CHEM 480 Registration Form (Pass/Fail Grading)

### CHEM 480 Student Responsibilities:

A student conducting independent research in CHEM 480 must agree to the following:

- To devote at least 10hrs per week to research efforts in the laboratory of my mentor.
- To have a basic proficiency in aspects of chemistry required for my planned activities.
- To fulfill basic safety requirements, including completion of all pertinent training.
- To submit (by end of classes) a final report describing research goals & accomplishments.

By signing below, the student affirms they have read the extended description of CHEM 480 (attached document), and will abide by all stipulations and requirements listed therein:

Student Name: \_\_\_\_\_ SID: \_\_\_\_\_ College/Class: \_\_\_\_\_

Student Signature: \_\_\_\_\_ Date: \_\_\_\_\_

E-Mail Address: \_\_\_\_\_ Major/Degree: \_\_\_\_\_

Phone Number (optional): \_\_\_\_\_

Emergency Contact (name/phone): \_\_\_\_\_

Faculty Research Mentor (in Chemistry): \_\_\_\_\_

Title of Proposed Research: \_\_\_\_\_

### CHEM 480 Faculty Research Mentor Responsibilities:

A mentor supervising independent research in CHEM 480 must agree to the following:

- To affirm by midterm that the student is devoting at least 10hrs per week to research.
- To ensure student meets basic safety requirements before starting laboratory work.
- To administer to student any specialized training required for planned research activities.
- To prepare a substantive report describing the nature of research undertaken by the student and evaluating their overall performance (required for all Yale Pass/Fail courses).

Faculty Mentor Name: \_\_\_\_\_

Faculty Mentor Signature: \_\_\_\_\_ Date: \_\_\_\_\_

Please list any rooms that the student needs key or card access to: \_\_\_\_\_

### CHEM 480 Safety Certification:

Cognizant staff from Yale's Office of Environmental Health and Safety (EHS) or the DUS of Chemistry (upon consultation with EHS personnel) must affirm that the student has fulfilled basic safety requirements *prior to them engaging in any research activities*. This includes completion of online courses on laboratory chemical handling and hazardous waste disposal, as well as any other specialized training deemed necessary.

EHS Staff/DUS Name: \_\_\_\_\_

EHS Staff/DUS Signature: \_\_\_\_\_ Date: \_\_\_\_\_

### Chem 480 Final Approval:

DUS Name: \_\_\_\_\_

DUS Signature: \_\_\_\_\_ Date: \_\_\_\_\_



# CHEM 480: Introduction to Independent Research in Chemistry

The following information affords a more detailed description of CHEM 480, enumerating the basic criteria imposed for student enrollment and the formal requirements that must be met for participants to complete the course successfully.

## **Brief Description:**

After consulting with the Director of Undergraduate Studies (DUS) in Chemistry *no later than the last week of the preceding academic term*, students engage individual experimental and/or theoretical problems in the laboratories of a selected faculty member in Chemistry. At least 10hrs per week of research is required (including initial time spent on requisite safety training), with the faculty mentor affirming this level of student commitment by midterm. A brief report summarizing goals, methods, and accomplishments must be submitted at the end of the term.

Individuals wishing to enroll must have demonstrated proficiency in the aspects of chemistry required for planned activities, as ascertained and certified by the supervising faculty member. For each term of enrollment, students must complete a CHEM 480 registration form, have it signed by their faculty research mentor, and submit it to Chemistry DUS for final approval *no later than the last week of classes in the immediately preceding academic term*. May be taken multiple times for Pass/Fail credit, subject to restrictions imposed by Yale College.

## **Course Overview:**

The primary purpose of CHEM 480 is to provide undergraduate students with a hands-on exposure to basic research in the chemical sciences and a practical introduction to the modern research environment. The course entails one semester of experimental or theoretical work with a *minimum* of 10hrs per week being spent in the laboratories of a faculty member in Chemistry. Building on concepts and techniques honed during formal coursework, participants are expected to direct their efforts towards the generation of chemically relevant data designed to engage and address a specific research problem, as coordinated and supervised by their selected faculty mentor. A brief report summarizing accomplishments must be submitted at the end of the term.

## **Time Commitment:**

Each student enrolled in CHEM 480 must fulfill a *minimum* of 10hrs per week of research, with the faculty mentor required to certify this level of participation by midterm. If for any reason an individual is unable to meet this commitment, they will be required to withdraw from the course immediately.

Students traveling to interview for summer/post-graduate positions or to engage in extracurricular activities must account for lost research time by undertaking additional laboratory work as agreed with and coordinated by their faculty mentor.

## **Safety Requirements:**

Participants in CHEM 480 must fulfill basic safety requirements, including *at least* the online courses entitled “Laboratory Chemical Training” and “Hazardous Chemical Waste Training” as administered by the Yale Office of Environmental Health and Safety (EHS) at <http://ehs.yale.edu/training>. Enrolled individuals must complete these courses successfully and receive formal certification from EHS *prior to beginning any laboratory activities*. Depending on the nature of specific efforts undertaken by the

student, additional safety courses or other training requirements might be imposed by the faculty mentor and/or EHS personnel. The time expended to comply with such safety/training prerequisites can offset the mandated 10hrs per week of research.

### **Ethical Conduct:**

Plagiarism and other forms of academic/professional dishonesty are antithetical to science, which critically depends on the integrity and ethical conduct of its participants to ensure the successful advancement of scientific knowledge and understanding. Students wishing to enroll in CHEM 480 should review Yale College policies regarding undergraduate plagiarism and cheating carefully (<http://yalecollege.yale.edu/campus-life/undergraduate-regulations>), as well as science-specific regulations composed by Yale's Office of Research Administration to govern the responsible conduct of research (<http://researchadministration.yale.edu/responsible-conduct-research>).

### **Grading:**

Students enrolled in CHEM 480 earn one (1) graduation credit upon successful completion of the semester and are graded on a Pass/Fail basis. In addition, the faculty mentor must submit a substantive report that describes the nature of research endeavors undertaken by the student and explicitly evaluates her/his overall performance. These documents will be shared with the student and the Director of Undergraduate Studies (DUS) for Chemistry, with a permanent record being kept in the office of the student's Residential College Dean. CHEM 480 may be taken multiple times for Pass/Fail credit, subject to restrictions imposed by Yale College.

### **Enrollment Procedures and Formal Requirements:**

It is expected that individuals wishing to perform independent research will have demonstrated proficiency in the basic aspects of chemistry required for their planned activities, as ascertained and certified by the supervising faculty member. For each term of enrollment, students must complete a CHEM 480 registration form, have it signed by their faculty research mentor, and submit it to Chemistry DUS for final approval *no later than the last week of classes in the immediately preceding academic term*.

In addition to the explicit time commitment of at least 10hrs per week, a 2-3 page report (single-spaced, 12-point font, exclusive of figures, bibliography, and cover pages) must be submitted electronically (to [chemistry.dus@yale.edu](mailto:chemistry.dus@yale.edu)) by the last day of classes for each term of CHEM 480. This document should include (1) a brief outline of goals and objectives, (2) a description of basic methodology and specific techniques, and (3) an enumeration of actual research progress and accomplishments. These materials will be reviewed by the faculty mentor and the Chemistry DUS, and will be taken into account for the issuing of a final grade and the granting of permission to enroll in subsequent semesters of independent research.

## Department of Chemistry – Yale University

### Undergraduate Research Registration Form 2019-2020 (For research not for Yale College credit)

#### Student Responsibilities for Undergraduate Research:

A student conducting independent research must agree to the following:

- To have a basic proficiency in aspects of chemistry required for my planned activities.
- To fulfill basic safety requirements, including completion of all pertinent training.

By signing below, the student affirms they have read the extended description of the requirements for undergraduate research (attached document), and will abide by all stipulations and requirements listed therein:

Student Name: \_\_\_\_\_ SID: \_\_\_\_\_ College/Class: \_\_\_\_\_

Student Signature: \_\_\_\_\_ Date: \_\_\_\_\_

E-Mail Address: \_\_\_\_\_ Major/Degree: \_\_\_\_\_

Phone Number (optional): \_\_\_\_\_

Emergency Contact (name/phone): \_\_\_\_\_

Faculty Research Mentor (in Chemistry): \_\_\_\_\_

Title of Proposed Research: \_\_\_\_\_

When will Research will be Performed (select all that apply)? Fall  Spring  Summer

#### Undergraduate Faculty Research Mentor Responsibilities:

A mentor supervising independent undergraduate research must agree to the following:

- To ensure student meets basic safety requirements before starting laboratory work.
- To administer to student any specialized training required for planned research activities.

Faculty Mentor Name: \_\_\_\_\_

Faculty Mentor Signature: \_\_\_\_\_ Date: \_\_\_\_\_

Please list any rooms that the student needs key or card access to: \_\_\_\_\_

#### Undergraduate Research Safety Certification:

Cognizant staff from Yale's Office of Environmental Health and Safety (EHS) or the DUS of Chemistry (upon consultation with EHS personnel) must affirm that the student has fulfilled basic safety requirements *prior to them engaging in any research activities*. This includes completion of online courses on laboratory chemical handling and hazardous waste disposal, as well as any other specialized training deemed necessary.

EHS Staff/DUS Name: \_\_\_\_\_

EHS Staff/DUS Signature: \_\_\_\_\_ Date: \_\_\_\_\_

#### Final Departmental Approval:

DUS Name: \_\_\_\_\_

DUS Signature: \_\_\_\_\_ Date: \_\_\_\_\_

## Undergraduate Research in Chemistry (For research not for Yale College credit)

The following information affords a more detailed description of the requirements for undergraduate research in a Chemistry Department Laboratory with a faculty research mentor, enumerating the basic Departmental expectations for students.

### **Brief Description:**

Undergraduates may perform research as either a volunteer or as part of the work-study program in a Chemistry Department Laboratory with a faculty research mentor during the academic year and over summer. Students working in this capacity do not receive Yale College credit. Individuals wishing to perform research as a volunteer or as part of the work-study program must have demonstrated proficiency in the aspects of chemistry required for planned activities, as ascertained and certified by the supervising faculty member. A student who is performing research as either a volunteer or as part of the work-study program must complete the Undergraduate Research Registration Form, have it signed by their faculty research mentor, and submit it to Chemistry DUS for final approval *no later than the end of the first week of classes in the academic term they wish to start research or prior to commencing research over the summer.*

### **Program Overview:**

The primary purpose of independent research is to provide undergraduate students with a hands-on exposure to basic research in the chemical sciences and a practical introduction to the modern research environment. The goal is to build on concepts and techniques honed during formal coursework, and allow students to direct their efforts towards the generation of chemically relevant data designed to engage and address a specific research problem, as coordinated and supervised by their selected faculty mentor. Students are responsible for finding a faculty mentor, who will provide guidance and laboratory facilities. A student who performs research as a volunteer or as part of the work-study program does not receive Yale College credit for research and is provided with guidelines about expectations from their faculty mentor. Performing research as a volunteer or as part of the work-study program provides undergraduates with greater flexibility than completing research for Yale College credit through a course such as CHEM 480 is recommended for students still completing the core requirements towards the Chemistry Major.

### **Time Commitment:**

A student performing research as either a volunteer or as part of the work-study program will determine with their faculty mentor the time commitment required per week. Typically students work between 4 and 15hrs per week during the academic year. Over summer the time commitment is generally greater.

### **Safety Requirements:**

Undergraduates performing research must fulfill basic safety requirements, including *at least* the online courses entitled “Laboratory Chemical Training” and “Hazardous Chemical Waste Training” as administered by the Yale Office of Environmental Health and Safety (EHS) at <http://ehs.yale.edu/training>.

Students must complete these courses successfully and receive formal certification from EHS *prior to beginning any laboratory activities*. Depending on the nature of specific efforts undertaken by the student, additional safety courses or other training requirements might be imposed by the faculty mentor and/or EHS personnel.

**Ethical Conduct:**

Academic and professional dishonesty are antithetical to science, which critically depends on the integrity and ethical conduct of its participants to ensure the successful advancement of scientific knowledge and understanding. Students performing undergraduate research should be familiar with regulations composed by Yale's Office of Research Administration to govern the responsible conduct of research (<http://researchadministration.yale.edu/responsible-conduct-research>).

**Registration Procedure:**

It is expected that individuals wishing to perform independent research will have demonstrated proficiency in the basic aspects of chemistry required for their planned activities, as ascertained and certified by the supervising faculty member. Students should complete the Undergraduate Research Registration Form, have it signed by their faculty research mentor, and submit it to the Chemistry DUS for final approval *no later than the end of the first week of classes in the academic term they wish to start research or prior to commencing research over the summer..*