# Chemistry Graduate Student Handbook
# Approved August 2016

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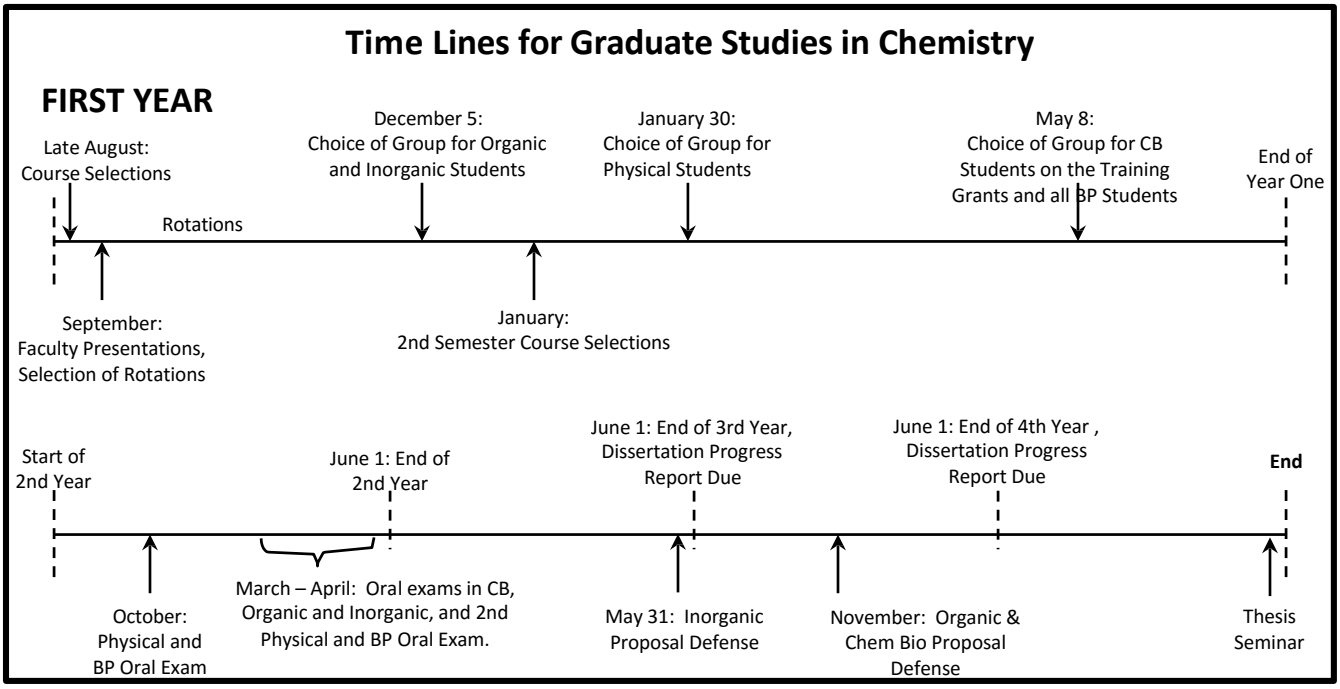


This document provides information on the curriculum choices and degree requirements for a Ph.D. in the Department of Chemistry at Yale University. The Graduate School maintains a set of additional requirements that have been provided to you separately and are not included here. For answers to additional questions, students should consult the Graduate School Bulletin on Programs and Policies, the Director of Graduate Studies, the Departmental Graduate Registrar, or the appropriate official of the Graduate School.

## I. Course Registration and Course Schedules

### A. Registration and Departure.

Registration for Fall semester courses is conducted when arriving at Yale in late August, and registration for Spring semester courses is conducted in January. The Chemistry Department will provide schedules and forms to register for courses.

Each student who registers for courses is required to discuss the course schedule with his or her course advisor before completing the online registration form. Approval of the courses by the advisor is then conducted online. A designated member of the Graduate Committee serves as the course advisor for first-year students. The course advisor will be asked to initial a hard copy of the form to confirm that a discussion about courses has occurred. All upper-year students must register for research and group/departmental seminars, in addition to any course that is being taken for credit. Guidelines for course registration are available separately from Susan dos Santos.

Students who leave New Haven before January 31 or September 1 but who intend to submit their thesis after these dates should inform the Department Registrar. They should return their student I.D. cards at that time.

### B. Course Schedules.

In conjunction with the course advisor, a program of coursework for the first year is chosen based on the student's field of interest, previous education and experience, and need for some breadth of study.

Graduate students must complete six credits prior to graduation, a majority of which should be completed in the first year. Graduate courses are graded on a scale of Honors (H), High Pass (HP), Pass (P) and Fail (F). The Chemistry Department requires that the average of the top five grades, exclusive of Chem 700, be at least HP for a student to remain in good standing. The Graduate School requires that each student receive at least two semester grades of Honors within the first two years, exclusive of research, seminar and shop courses. Only one of the required two Honors can be earned in a laboratory course, such as Chem 560L. Chem 700 is a research/seminar course, and Chem 562L and Chem 564L are shop courses. Permission to complete fewer than six credits prior to the end of the second year requires approval of the Director of Graduate Studies In addition, all first-year students are required to take Chem 590a "Ethical Conduct and Scientific Research" in the fall semester.

Each sub-discipline has specific course recommendations that are outlined on the following pages. In some cases, recommended courses are not offered every year, and you should take advantage of the course when it is offered. The course requirements have been designed for students with a primary interest in some form of preparative chemistry or in physical chemistry. The physical chemistry course curriculum is slightly different for those interested in biophysical chemistry and for those interested in physical chemistry and chemical physics. Students with interests in Materials chemistry typically choose either the Inorganic or Physical track, as there are not yet separate requirements for the Materials division.

**1. Course Requirements in Preparative Chemistry.** A student who will be conducting research in the Inorganic, Chemical Biology, or Organic track must complete six course credits during the first three semesters. These courses should reflect the breadth of current research in these areas of chemistry. Thus, the student should strive to complete one course in synthetic chemistry, one course in biological chemistry, one course in transition metal chemistry, and one course in theory or reaction mechanisms. In addition, it is recommended that each student complete a course in physical and spectroscopic methods. These courses can be completed with several possible distributions to fit your background and the schedule of course offerings. You may enroll in three courses each of the two semesters of the first year, four courses the first semester and two the second, or three courses the first semester, two the second semester and one course the first semester of the second year.

The following table provides guidelines on which courses would provide an exposure to synthesis, biological chemistry, transition-metal chemistry and reaction mechanisms. Courses in brackets will not be offered during the 2016-2017 academic year, but may be offered in subsequent years.

| **Synthetic Chemistry** | **Transition Metals** | **Biological Chemistry** | **Theory and Mechanism** |
|---|---|---|---|
| Synthetic Methods 523 | Organometallics 552 | Chemical Biology 521 | [Advanced Organic 519] |
| Organometallics 552 | Modern Coordination Chemistry 557 | Bioinorganic Chemistry 554 | [Inorganic Mechanisms 555] |
| | [Bioinorganic Chemistry 554] | [Biochemical Rates and Mechanisms 556] | [Enzyme Reaction Mechanisms 556] |
| [Natural Product Synthesis 528] | [Advanced Inorganic Chemistry 550b] | [Structure and Chemistry of Proteins and Nucleic Acids MBB741] | [Computational Chemistry and Biochemistry 526] |
| | [Inorganic Mechanism 555] | | |
| Materials Chemistry 549 | Materials Chemistry 549 | | |

**Chemistry/Biology Interface Training Program**

Chemical biology students supported by the Chemistry/Biology Interface (CBI) training grant are expected to take three full-semester courses for credit each term of their first year. Specific courses will be chosen in consultation with a designated faculty advisor. It is expected that by the end of the second year in residence, students supported by the Chemistry/Biology Interface (CBI) training grant will possess a solid background in both organic and biological chemistry, as well as a sophisticated understanding of important methodologies in cell and molecular biology. These requirements may, however, be fulfilled in whole or in part through courses taken as an undergraduate.

**Selection of Elective Courses**

In addition to fulfilling the core requirements for Preparative Chemistry, students supported by the Chemistry/Biology Interface (CBI) Training Grant will take one elective from each of the two course listings below. All students will audit the Current Topics in Organic Chemistry Seminar Series (Chem 740), Seminar in Chemical Biology (Chem740), or Seminar in Inorganic Chemistry (Chem760) throughout their residence at Yale.

**CBI Electives (One elective from each list is required):**

| Biochemistry/Structural Biology | Cell and Molecular Biology |
|---|---|
| MBB600 Principles of Biochemistry I | MCDB603 Cell Biology |
| MBB601 Principles of Biochemsitry II | MCDB625 Genetic Analysis |
| MBB720 Macromolecular Structure and Biophysical Analysis | [MBB705 Mol Genetic Prokaryotes] |
| [MBB721Macromolecular Interactions and Dynamic Properties] | MBB734 Advanced Eukaryotes Molecular |
| Chem556 Biochemical Rates & Mechanisms | MCDB570 Biotechnology |
| MCDB630 Biochemical and Biophysical Approaches | PHAR502 Pharmacology I/II |

**2. Course Requirements in Biophysical Chemistry.** Students are expected to take three full-semester courses for credit each term of their first year. Programs will be designed in consultation with a designated faculty advisor using the following guidelines.

By the end of the second year in residence, it is expected that students will have obtained a solid background in physical and biological chemistry and an understanding of the major molecular biophysical methods (NMR, spectroscopy and X-ray crystallography). The specific course requirements are listed below. Requirements may, however, be fulfilled in whole or in part through courses taken as an undergraduate.

In addition, students supported by the Biophysics Training Grant will take the Biophysics Research Rotations and Ethics course, Chem 700, in their first year. Other Biophysical Chemistry students are encouraged to audit Chem 700. All students will audit Biophysical Chemistry Seminar Series (Chem 750) throughout their residence at Yale.

Course requirements:

(1) Four one-semester courses in biophysical/physical chemistry:

- Molecules and Radiation I (Chem 540a),
- Biochemical Rates & Mechanisms (Chem 556b),
- Statistical Methods and Thermodynamics (Chem 530a),
- Biophysics (Chem 559b)

(2) Two elective one-semester courses. We recommend that one be an advanced biological course, such as molecular biology, cell biology, chemical biology, or bioinorganic chemistry, and the other an advanced course on physical methods such as EPR spectroscopy, NMR spectroscopy, biophysical spectroscopy, or computational chemistry.

A typical first-year program of study is as follows

Fall Term: Chem 540a, Chem 530a, elective, Chem 700a, Chem. 730a
Spring Term: Chem 559b, Chem 556b, elective, Chem 700b, Chem 730b

For students who have not taken biochemistry as an undergraduate, MB&B 600a/601b is required in addition to the above course requirements.

**3. Course Requirements in Physical Chemistry.** Students are expected to take three full-semester courses for credit during each term of their first year. Students will arrange their schedules in consultation with a designated faculty advisor, taking into account their undergraduate experience. By the end of the second year of residence it is expected that a student will have completed at least six courses for credit, thereby demonstrating proficiency in the material covered by the following 7 core classes:

Quantum Chemistry (Chem 570a or b)
[Advanced Quantum Mechanics (Chem 572a)]
Statistical Mechanics and Thermodynamics (Chem 530a or b)
Molecules and Radiation (Chem 540a and Chem 542b)
[Advanced Instrumentation Laboratory I (Chem 560La and 561Lb)]

Entering students who already have completed classes with substantially the same content as those listed above need to complete a total of only 6 full-semester courses for credit. In addition to fulfilling the remaining core requirements, their courses may be selected from the list found below. Alternative classes may be considered, where appropriate, with approval of the advisor and Director of Graduate Studies.

**[**Research Topics in Physical Chemistry (Chem 535a)**]**
[Nuclear Magnetic Resonance in Liquids (Chem 548b)]
Advanced Organic Chemistry I & II (Chem 518a and Chem 519b)
[Spectroscopic Methods of Structure Determination (Chem 525b)]
Materials Chemistry (Chem 549a)
Organometallic Chemistry (Chem 552a)
Inorganic Mechanisms (Chem 555b)
Modern Coordination Chemistry (Chem 557a)
Classical Mechanics (Phys 410a or b)
Solid State Physics I & II (Phys 448a and Phys 449b)
[Electromagnetic Fields and Optics (Phys 430b)]
Introduction to Atomic Physics (Phys 522a)
Mathematical Methods of Physics (Phys 460a or Phys 506a)
[Mathematical Methods in Engineering (ENAS 397b)]

With agreement of their designated faculty advisor, a student may replace one or more of the core courses by an appropriate alternative course, including, but not limited to, those given on the above list.

The mathematical background of Physical Chemistry students should include linear algebra and calculus at least to the level of differential equations. Courses appropriate for strengthening mathematical background include Math 222a or b, ENAS 194a or b, and Phys 301a.

All students are expected to audit the Molecular Science Seminar Series (Chem 730) throughout their residence at Yale.

## II. Choice of Research Advisor

The choice of research advisor is an extremely important decision and should be made with information from several sources: attendance at research presentations during the first weeks of the first year, multiple discussions with the faculty members, reading of manuscripts from the research groups of interest, attendance at group meetings, visiting of group websites, and discussions with students in the research group. To facilitate the gathering of this information, Yale Chemistry has a system of research rotations.

### A. Research Presentations, Rotations, and Deadlines for Research Group Choices

During the first three weeks of classes, the faculty will present brief research seminars to provide information on their research groups to first year graduate students. All students, regardless of their research interests, are required to attend these meetings. These seminars provide the best opportunity during your graduate career to gain an overview of research occurring in the department and the interests of each faculty member. Times and places for these seminars will be distributed electronically and posted on the graduate student bulletin board.

Beginning with the third week of the Fall term, participation in a formal laboratory rotation is required. Rotation schedules vary between subdivisions (see below). By Sept. 17, students in areas of preparative chemistry should submit to the Department Registrar a list of at least three research groups with which they will rotate, and students in areas of physical chemistry and chemical biology should submit a list of three (biophysical, chemical biology) or four (physical chemistry and chemical physics) research groups with which they will rotate. The schedule for rotations will be posted on the following Monday.

**B. Rotation Schedules and Deadlines for Research Group Choices.** The content of the rotation depends on you and the faculty member, but one is expected at a minimum to visit with the faculty member for an introduction, to meet a second time to follow-up on the initial discussions, to read key publications from the group, to attend group meetings, and to discuss projects with the graduate students and postdocs of the group. You should have established this type of contact with several research groups and faculty members prior to the deadline for choosing a group. Each division uses a form, which is turned in to the Graduate Registrar.

**1. Rotation Schedule in Preparative Chemistry.** Students in preparative chemistry will conduct rotations during three three-week periods. A student may choose to conduct two rotations simultaneously, allowing for a total of six rotations. A rank-ordered list of three research groups is due one week after the end of the third rotation, though an extension of this deadline may be requested if necessary.

Chemical Biology students supported on a training grant UF are required to register for Chem 700-02 for Credit (Sat/Unsat), which will include three long rotations and a formal presentation of the results from each rotation. Chemical Biology students who are not supported by a training grant UF should register for Chem 720, Current Topics in Organic Chemistry for Audit. They have the option to do short rotations and select the research advisor at the end of the third rotation, or to do long rotations and select the research advisor in the spring.

**2. Rotation Schedule in Physical Chemistry.** Students in physical chemistry will conduct four three-week rotations. A rank-ordered list of three research groups is due one week after the end of the four rotations, though an extension of this deadline may be requested.

**3. Rotation Schedule in Biophysical Chemistry.** Biophysics students supported on the biophysics training grant are required to register for Chem 700-01 for Credit (Sat/Unsat). First-year biophysics students not supported on a training grant should register for Chem 700-01 for audit. Chem 700 (fall) and Chem 701 (spring) include three long rotations and a formal presentation of the results from each rotation. The following lists a schedule of the rotations and choice of advisor.

**A summary of the schedule for events related to group selection in 2016-17 follows:**

All First-Year Students:

| | |
|---|---|
| Sept. 7 - Sept. 14 | Evening presentations by faculty |
| Sept. 15 | Submission of selection of rotations. |

Chem 700-701 Students:

| | |
|---|---|
| Sept. 19 - Nov. 18 | First rotation |
| Nov. 28 - Feb. 24 | Second rotation |
| Feb. 27 – May 5 | Third rotation |
| May 8 | Submission of top three choices for advisor by the biophysical and CBI students. |

All Other Students:

| | |
|---|---|
| Sept. 19 - Oct.7 | First rotation |
| Oct. 10 – Nov. 4 | Second rotation |
| Nov.7 - Dec. 2 | Third rotation |
| Dec 5 – Jan. 27 | Fourth rotation |
| December 5 | Submission of three choices of advisors by students in preparative chemistry |
| January 30 | Submission of three choices for advisor by students in physical chemistry. In addition, any student who has participated in the short rotations and is planning to work in a biophysical group should sign up for the third long rotation at this time. |

**C. Advisor Selection.**

Students should discuss joining a research group with a faculty member before submitting their list of choices to the Graduate Registrar. All agreements for choice of research advisor require review and approval by the Director of Graduate Studies. The Director of Graduate Studies should also be consulted promptly if any difficulties arise in reaching an agreement.

**D. Selection of an Advisor Outside of the Chemistry Department.**

Faculty members who hold joint appointments in Chemistry or are affiliated with the Chemistry Department through the Biophysics or Chemistry/Biology Interface training grant can be selected as a research advisor without restriction. It is also possible to join a research group of a faculty member who is not affiliated with the Chemistry Department provided that the student works on a thesis project that has sufficient chemical content. If a student wishes to join a group outside of the Chemistry Department, the student must meet with a committee consisting of the proposed advisor and two faculty members whose primary appointment is in the Chemistry Department to consider the proposed thesis project. This committee must approve the proposed project prior to joining the research group.

**E. Changing of Research Advisors.**

Because of the obvious disruption of progress toward the Ph.D. degree from changing research advisors, students are strongly urged to make informed and careful choices of research advisors. A desire to change research groups should be discussed with the Director of Graduate Studies and with the current and proposed new research advisors. Prior to a change in group, the student must clean his/her equipment and lab, and a comprehensible research report, lab notebooks, and data must be provided to the advisor.

## III. Second-Year Oral Examinations.

**A. General Information on Second-Year Oral Examinations.**

Oral exams are conducted by a three-member faculty committee that is comprised of the student's research advisor and two faculty members familiar with the student's area of research. In all cases, at least two of the committee members must be faculty whose primary appointment is in the Chemistry Department. The student, in consultation with his or her research advisor, may suggest appropriate members during the second year. The committee that administers the second-year oral examination normally forms the student's final thesis committee.

When the time comes for the oral examination (see below), the student needs to find a date and time that is compatible with the committee members, and reserve a room (which can be done at the Chemistry Main Office). This reservation should typically be done at least 1-2 months in advance. Any written documents should be provided to the committee at least a week before the exam.

Results of the oral examination are provided immediately after a brief discussion of the examination among the members of the thesis committee. A student who does not pass one or both of the oral examinations should consult with members of the exam committee for advice and, if applicable, options for additional opportunities to fulfill the oral examination requirements. Such options often include: retaking the oral exam in the areas in which the student's understanding is deficient, enrolling in additional courses or submitting a written paper on subjects in which the student's understanding is deficient.

**B. Specific Description of the Oral Examinations.**

**1. Second-Year Oral Examinations in Preparative Areas of Chemistry.** The requirements for the second year oral examination are slightly different for students formally enrolled in Organic Chemistry and Chemical Biology compared with those in Inorganic Chemistry. The specific requirements for the two different types of student are outlined below:

### a. Organic Chemistry and Chemical Biology

The oral examination will consist of a two hour examination based on a proposal for research on the topic of your thesis work. You will be expected to demonstrate a thorough knowledge of the thesis area and related areas of chemistry and to discuss competently the results that have been obtained and the future direction of the project. The exam will emphasize fundamental chemistry, including the material of your course work. In addition to your performance during the oral and written part of the exam, you will be judged on progress in research. The chair of the examining committee will provide to the student and Registrar a written summary of recommendations. You should obtain a form for this purpose from the Registrar and bring it to the examination. The examination must be taken by May 31.

The proposal must be written with the structure of an NIH grant proposal. Details of this format can be found on pages I-43 and I-44 of "Application for a Public Health Service Grant" at http://grants.nih.gov/grants/funding/phs398/phs398.doc ".

This format consists of the following parts. For a ten-page proposal, the suggested lengths are given in parentheses.

A. Specific Aims (0.5 pages)
B. Background and Significance (two pages)
C. Preliminary Results (five pages; you should summarize your own results)
D. Experimental Design and Methods (Proposed Research, two pages)

The proposal should be provided to your thesis committee two weeks in advance of the scheduled examination. It is the student's responsibility to verify with his or her committee members their availability for the oral exam three to four weeks in advance. Once a date and time has been established, a room should be reserved with the Main Office personnel.

### b. Inorganic Chemistry

The oral examination in inorganic chemistry is two hours, consisting of two consecutive one-hour parts on the same day. One part consists of a proposal for research on the topic of your thesis work, and the second part consists of a proposal on an outside topic separate from the thesis research. On the first part, you will be expected to demonstrate a thorough knowledge of the thesis area and related areas of chemistry and to discuss competently the results that have been obtained and the future direction of the project. On the second part, you will be expected to recognize the key issues in your idea, show a logical approach, anticipate pitfalls, and offer alternative routes. Both sections of the exam will emphasize fundamental chemistry, including the material of your course work. In addition to your performance during the oral and written part of the exam, you will be judged on progress in research. The chair of the examining committee will provide to the student and Registrar a written summary of recommendations. You should obtain a form for this purpose from the Registrar and bring it to the examination. The examination must be taken by May 31 at the end of your second year.

It is the student's responsibility to verify with his or her committee members their availability for the oral exam, typically 1-2 months in advance. Once a date and time has been established, a room should be reserved with the Main Office personnel. At least **two weeks** prior to this oral examination, you should submit to your committee members two written proposals on the topics. Both proposals must be written with the structure of an NIH grant proposal. Details of this

format can be found on pages I-43 and I-44 of "Application for a Public Health Service Grant" at http://grants.nih.gov/grants/funding/phs398/phs398.doc ". Ten to fifteen pages of 1.5 spaced, 12 point font, 1 inch margin text (plus figures and references) is plenty of space to describe each proposal adequately; do not go over this length. The suggested lengths for different parts are given in parentheses below.

A. Specific Aims (0.5 pages)
B. Background and Significance (2-3 pages)
C. Preliminary Results (2-5 pages; you should summarize your own results)
D. Proposed Research (4-6 pages)

The outside research proposal, covered in the second part of the exam, must be original and conceived by the student. The topic chosen should fall outside the area of thesis research, differ significantly from work currently being carried out within the department, and should be unrelated to previous undergraduate or industrial research or a trivial derivative thereof. In general, a proposal will be considered to lie outside the thesis area if the advanced literature survey required for its preparation shows, at most, minor overlap with that required for the thesis. Before prepare your original proposal, it is important to consult about the appropriateness of your chosen proposal topic (as described above) with your committee. You should begin the process of obtaining approval of your proposal topic in January. As a guideline for the scope, it would be a project that takes 1-2 students roughly 2-3 years.

For each half of the exam, students should plan at most 25 minutes worth of prepared material, but should expect to be interrupted with questions. In order to prepare yourself, we encourage you to discuss with more senior inorganic students in the department.

**2. Second-Year Oral Exams in Physical Chemistry.** Two oral examinations with accompanying written reports must be passed during the second year: a thesis-area exam in the Fall term and an in-depth progress report in the Spring term. The thesis-area exam covers the area of proposed thesis research and is intended to be more an advisory procedure than an academic hurdle. The second oral examination evaluates progress in the initial stages of research, including knowledge of the relevant literature.

For the first oral exam, it is expected that each student will think through, in detail, the particular research project about to be pursued. Students are encouraged to consult with other members of the faculty prior to making a long-term commitment to their research project. The examination will be administered by the two members of the student's thesis committee and chaired by a third member substituting for the advisor. The written report is due on October 15 and the oral exam must take place before November 1.

It is the student's responsibility to verify with her/his committee members their availability for the oral exam three to four weeks in advance. Once a date and time has been established, a room should be reserved with the Main-Office personnel. The written report should be approximately 10 printed pages and should be constructed in the format of a grant proposal as follows:

a. Aims: State the specific objectives of the research project described in the proposal. One page is recommended.

b. Background: Briefly describe existing knowledge relevant to the proposed research and identify any gaps that the proposed work is intended to fill. Two to three pages are recommended.
c. Preliminary Results: Summarize your own completed and ongoing studies.
d. Experimental Plan: Outline the experimental design and the procedures to be used to accomplish the specific aims of the project. Five to six pages are recommended.
e. Bibliography: List relevant literature citations. For appropriate style, consult either ACS (e.g., *J. Am. Chem. Soc.*) or APS (e.g., *J. Chem. Phys.*) guidelines.

Oral examinations should begin with no more than a 10-15 minute oral presentation by the student on the subject of interest. Questions and responses that follow will probe the candidate's knowledge of necessary background material, including topics that go beyond those specifically related to the thesis.

The second oral examination will entail a detailed description of progress made on the candidate's research project, with substantial advances expected to have been made in the time since the first oral exam. Specific difficulties encountered and the next steps to be taken should be discussed. Students must schedule the second oral examination before or during the week *prior* to final examinations. In addition to assessing progress in research, it is expected that the second oral exam will explore questions of basic physical chemistry so as to establish a broader context for the proposed research plan.

The thesis committee should meet immediately before the second oral examination to discuss the student's performance thus far in graduate school. In both exams, the committee chair should provide to the student and registrar a written summary of recommendations. A form for this purpose must be obtained by the student from the registrar and brought to the examination.

**3. Second-Year Oral Exams in Biophysical Chemistry.** Two oral exams with accompanying written reports must be passed during the second year: a thesis-area exam in the Fall term and an independent research proposal exam in the Spring term. The thesis-area exam covers the area of proposed thesis research and is intended to be more an advisory procedure than an academic hurdle. The second oral examination evaluates your design and research of a research project that is outside of your thesis research area.

For the first oral exam, it is expected that each student will think through, in detail, the particular research project about to be pursued. Students are encouraged to consult with other members of the faculty prior to making a long-term commitment to their research project. The examination will be administered by the two members of the student's thesis committee and chaired by a third member substituting for the advisor. The written report is due on October 15, and the oral exam must take place before November 1.

It is the student's responsibility to verify with his or her committee members their availability for the oral exam three to four weeks in advance. Once a date and time has been established, a room should be reserved with the Main Office personnel. The written report should follow NRSA F31 formatting guidelines. Use Arial or Times font 11 pt min., 0.5–1" margins. Page limits include all tables and figures. The proposal should contain the following sections.

Specific Aims (1 page):
State the objectives of the specific research described in the proposal.

Research Strategy (6 pages)
A. Significance. Explain the importance of the problem or critical barriers to pgress in the field that the proposed project addresses. Explain how the proposed project will improve scientific knowledge, technical capability, and/or clinical practice in one or more broad fields. Describe how the concepts, methods, technologies, treatments, services, or preventative interventions that drive this field will be changed if the proposed aims are achieved.
B. Approach. Describe the overall strategy, methodology and analyses to be used to accomplish the scientific aims of the project. Discuss potential problems, alternative strategies, and benchmarks for success. Point out any procedures, situations, or materials that may be hazardous and precautions to be exercised. Include preliminary information on preliminary studies (including data collected by others in the lab), if any. Discuss your own preliminary studies, data and/or experiences pertinent to the proposal.

References Cited
Provide a bibliography of any references cited. Each refefence mus include the names of all authors (in the same sequence as they appear in the publication), the article and journal title, book title, volume number, page numbers, and year of publication.

The first Oral examinations should begin with no more than a ten-minute oral presentation by the student of the topic under question. Questions and responses that follow should probe the student's knowledge of necessary background material and go beyond that specifically related to the thesis.

The second oral examination will be carried out in two steps. First, a written one paragraph summary detailing the project goals and the steps taken to achieve them is submitted for approval to the committee by the first Monday after spring break of the second year of residence. The final proposal will follow the outline for an NIH-style grant application as for the first exam, except 'Preliminary Results' will, of course, not be included. This proposal is designed to test the student's ability to assess the literature and successfully develop an independent project. The second oral must be original with the student, should be outside the area of thesis research, not too closely related to work currently being carried out within the department, and should not include a student's previous undergraduate or industrial research or a trivial derivative thereof. In general, a proposal will be deemed to lie outside the thesis area if the advanced literature survey required for its preparation shows, at most, minor overlap with that required for the thesis. The candidate must schedule the second oral examination before or during the week *prior* to final examinations. In addition to assessing the student's progress in research, it is expected that the oral exam will explore questions of basic physical or biophysical chemistry to establish the broader context of the specific research plan. The focus of these broader issues will be drawn from the list of references explicitly stated in advance as part of the committee's comments on the written progress report.

The committee should meet immediately before the second oral examination to discuss the student's performance thus far in graduate school. The research supervisor should bring all of the student's records kept by the graduate secretary to this meeting. In both exams, the

committee chairman should provide to the student and registrar a written summary of recommendations. A form for this purpose should be obtained by the student from the registrar and brought to the examination.

### C. Advancement to Candidacy.

At the end of the second year of study, qualified students will be advanced to candidacy for the Ph.D. degree. At this time a student's progress is judged thoroughly. Students who are advanced to candidacy at this time can be reasonably assured that they will be able to complete the degree requirements.

To advance to candidacy, you must have:

1. Completed the Honors requirement: As noted above, the Graduate School requires that each student must receive at least two term grades of Honors within the first two years, exclusive of those for research, seminar and shop courses. Only one of the required two Honors can be earned in a laboratory course, e.g. Chem 560L. Note that Chem 700 is a research/seminar course, and Chem 562L and Chem 564L are shop courses.
2. Passed the oral exams.
3. Passed the SPEAK test or equivalent if you are an International student.
4. Made satisfactory research progress, as judged by the thesis committee.
5. Provided a thesis prospectus to the registrar. Normally, the written report of thesis work for the oral examination is the thesis prospectus.

A student who has not satisfied these requirements by the end of the second year will be reviewed by the Department. If the Department feels that this student cannot complete the requirements for the Ph.D., he or she will be asked to withdraw, but if the Department feels that this student can achieve the degree, he or she will be given a deadline for the completion of the requirements for advancement to candidacy.

### D. Master's Degrees.

You may apply for a Master of Science degree when the necessary requirements are met or if you decide to leave the Ph.D. program. The requirements for the M.S. are:

1. Residence: A student must have one full year of residence.
2. Courses: A student must pass at least five graduate level term courses in the Chemistry Department exclusive of seminars and research. In addition, an overall average (exclusive of seminars and research) of High Pass must be maintained in all courses. The Director of Graduate Studies may approve substitution of graduate-level courses in other departments.

## IV. Requirements beyond the Second Year.

### A. Advanced-Year Seminars, Reports and Oral Examinations.

In the third, fourth and fifth year, students should meet with the thesis committee. By the end of the fourth year, the student must make at least one public presentation of his or her research progress. Before final approval of the Ph.D. dissertation, the student must, in addition, present a public thesis seminar.

**1. Annual Progress Reports.** During April, you should prepare for the thesis committee a written summary of research progress and plans and meet with the committee to discuss your research progress. Organizing and scheduling this meeting is the responsibility of the student.

The written summary should consist of two (or three) pages of double-spaced text or outline. A copy of this report may then be used as the text for the annual dissertation progress report required by the Graduate School and you should provide this written report to your thesis committee members at least one week prior to the meeting on research progress.

By the end of May, you should meet with your thesis committee to discuss research progress. It is acceptable to meet with the committee members individually, though a coordinated meeting is typically more beneficial for research feedback.

In any year when you present your research progress in public (see below) in a forum attended by at least two members of the thesis committee, the requirement of an annual meeting will be waived. You must file a Public Research Presentation form that indicates approval of the presentation by all committee members, and should seek their feedback. You may still request a committee meeting and at a minimum you should make at least informal contact with your committee annually.

**2. Research Proposal for Students in Preparative Areas of Chemistry.** The requirements and timeline the research proposal are slightly different for students formally enrolled in Organic Chemistry and Chemical Biology compared with those in Inorganic Chemistry. The specific requirements for the two different types of student are outlined below:

**a. Fourth Year Organic and Chemical Biology Proposal.**

A research proposal that is original and conceived by the student should be written and defended to the thesis committee no later than December 1st in the fall of the fourth year in graduate school. The topic chosen must be distinct from any prior or ongoing research carried out by the student and must be approved by the student's mentor. The process of approval of a proposal topic should commence no later than the start of the fall semester. Approval of the proposal topic should occur prior to beginning an in-depth investigation of the area.

For help on strategies and tactics for writing research proposals, see: The Grant Application Writer's Workbook (http://www.grantcentral.com/workbook_nih_sf424_shortened.html).

The proposal format should be based upon the NIH Ruth L. Kirschstein National Research Service Award (NRSA), according to the Individual Fellowship Application Guide https://grants.nih.gov/grants/how-to-apply-application-guide.html. Important research proposal instructions are paraphrased below.

1. Specific Aims [Limited to one page] State concisely the goals of the proposed research and summarize the expected outcome(s), including the impact that the results of the proposed research will exert on the research field(s) involved. List succinctly the specific objectives of the research proposed, e.g., to test a stated hypothesis, create a novel design, solve a specific problem, challenge an existing paradigm, address a critical barrier to progress in the field, or develop new technology.
2. Research Strategy [Limited to six pages, including all figures, charts, tables, and diagrams] Organize the Research Strategy using the instructions provided below. *Significance:* Explain the importance of the problem or critical barrier to progress in the field that the proposed project addresses. Explain how the proposed project will improve scientific knowledge, technical capability, and/or clinical practice in one or more broad fields. Explain how the approach pursued differs from others. What key insights have been established that will

render this approach superior to what has come before. If no related work has been done in the area, discuss the merits of the key conceptual advances that form the underpinning of the approach. *Approach*: Describe the overall strategy, methodology, and analyses to be used to accomplish the specific aims of the project. Discuss potential problems, alternative strategies, and benchmarks for success anticipated to achieve the aims. If the project is in the early stages of development, describe any strategy to establish feasibility, and address the management of any high risk aspects of the proposed work.

3. Literature Cited [No page limit] Provide a bibliography of any references cited. Each reference must include the names of all authors (in the same sequence in which they appear in the publication), the article and journal title, book title, volume number, page numbers, and year of publication.

Excerpted proposal format specifications are as follows:

(i) Use an Arial, Helvetica, Palatino Linotype, or Georgia typeface, a black font color, and a font size of 11 points or larger. Type density, including characters and spaces, must be no more than 15 characters per inch. Type may be no more than six lines per inch.

(ii) Set page margins to 0.75 inches.

(iii) For figures, Graphs, Diagrams, Charts, Tables, Figure Legends, and Footnotes you may use a smaller type size but it must be in a black font color, readily legible, and follow the font typeface requirement. Color can be used in figures; however, all text must be in a black font color, clear and legible.

(iv) Avoid jargon. If terms are not universally known, spell out the term the first time it is used and note the appropriate abbreviation in parentheses. The abbreviation may be used thereafter.

**b. Third Year Inorganic Chemistry Proposal**

The formal proposal defense consists of two components: a written component and an oral component. The defense is essentially analogous to the proposal defense in the second year oral examination. The student is required to write a research proposal in an area separate from the student's thesis research. The general proposal area should be discussed well in advance with the committee to make sure it is acceptable. The written proposal should be given to the student's thesis committee one week before the oral examination and should follow the NIH guidelines referred to above in section B.1.b. The oral examination will take approximately one hour and the student will be required to justify the scientific approach outlined in the proposal. The proposal can be based on the second year proposal but in this case substantial refinement and extension is expected. The oral examination should be held before the 31$^{st}$ of May of the 3$^{rd}$ year.

**3. Public Presentation of Research Progress.** By the end of the fourth year, and at least six months before the final thesis defense, you must present in public a report on your ongoing research and file the public research presentation form with the departmental registrar. The report may consist of a lecture or a poster presentation. Acceptable forums for this presentation include the departmental seminar series, the student seminar series (Biophysical Journal Club, Club Med, and Metal Mania), the annual Graduate Research Symposium and Poster Session, and regional or national scientific meetings approved by the research advisor. The deadline for this public presentation is September 15. Whatever the forum, the student should inform the thesis committee of the time of the presentation so that at least two members may attend. A student who makes a public presentation of research outside the department may

petition the Director of Graduate Studies to allow this presentation to satisfy the requirement even though committee members cannot attend.

**B. Time Required for Completion of Degree.**

Although it is difficult to stipulate the exact time required for completion of the Ph.D. degree, 4-5 years is considered normal. Progress toward a degree after advancement to candidacy is evaluated largely on the basis of research potential. Yearly Dissertation Progress Reports from the student are reviewed by the thesis advisor and submitted to the Graduate School. During the third or fourth year, if a student's advisor feels that the student is struggling, the thesis committee may be asked to provide an evaluation of the likelihood that the student will complete the thesis research project. On the basis of that report, the student's progress may be deemed inadequate and support beyond the fourth year may not be provided.

**C. Thesis Requirements**

**1. Thesis Seminar.** An open seminar to present the thesis work to the department will conclude your research activities. Exceptions may be made in rare cases of truly extraordinary circumstances, and with the concurrence of the thesis advisor and DGS. At least two of the thesis committee members must attend, and every effort must be made to ensure the attendance of all committee members. At least two weeks prior to the thesis seminar, you should provide each committee member with a copy of the thesis that is complete and formatted according to the requirements of the Graduate School (see below).

**2. Thesis Format.** The Graduate School has a number of detailed requirements for the format of the thesis. A list is available from the Chemistry Main Office. After all of the changes recommended by the thesis committee have been made, two copies of the final thesis are submitted to the Chemistry Department registrar in the following format: one hard-bound copy with the title, the author's name and year of degree award printed on the cover and spine; and one unbound copy to be submitted in either a large envelope or some other secure method. The "readers" and the graduate school degree committee make the final acceptance of a thesis.

**3. Thesis Deadlines and Tuition Bills.** All Ph.D. candidates in years one through four will be charged full tuition. These charges are normally covered by research grants of their advisors and/or University Fellowships. Once a student has met the four-year tuition requirement, he or she will be charged a continuing registration fee (CRF) of $540 per term until the dissertation is submitted or the terminal date (end of sixth year) is passed. A special petition from the department is required to extend a terminal date beyond the sixth year.

The dates for submitting the thesis for a December and May degree are:

| | |
|---|---|
| Wednesday, October 1, 2015 | December degree |
| Monday, March 15, 2016 | May degree |

## V. Teaching and English Language Requirements.

**A. Teaching Requirements.**

Students are required to serve as teaching assistants at the level of a level 20 TF for two semesters during their studies. The workload inevitably varies with the course assignment, but a student should report to the Director of Graduate Studies, if his or her duties exceed 225 hours per semester for a "TF20" assignment.

In later semesters, graduate students may teach additional semesters, at the discretion of the research advisor. Students should also know that the Center for Teaching and Learning at Yale offers in-depth instruction on teaching, for students who have teaching in their career aspirations.

**B. English Language Requirements.**

International students must demonstrate proficiency in spoken English prior to serving as a Teaching Fellow. The oral English proficiency standard can be met by any of the following:

**1.** Receipt of a Bachelor's degree from an institution where the language of instruction is English (with 3 years minimum enrollment).

**2.** Scoring 26 or above on the speaking portion of the TOEFL-iBT.

**3.** Passing Yale's Oral Proficiency Assessment, often called OPA2.

**4.** Scoring 50 or greater on a Yale administered SPEAK test.

Note: Completing an MA/MS degree in an institution where the language of instruction is English does NOT meet the proficiency standard.

The OPA2 assessment is given at Yale three times each year. Information about the OPA2 including test dates and eligibility can be found here. Students who have not completed the spoken English proficiency requirement must enroll in a spoken English course offered by the Yale's English Language Program. Attendance of a course in spoken English is mandatory during each academic term and over the summer until the spoken English proficiency requirement is completed.

## VI. Safety, Waste Disposal, Conduct and Departure

**A. Safety.** Safety should be a primary concern of all students working in a research laboratory. Safety in the laboratories begins, first and foremost, with a sense of responsibility to yourself and your colleagues, because it puts everyone at risk. All incoming graduate students are required to complete the Web-based chemical safety training program (http://ehs.yale.edu/trainings/Lab-Chemical-Training) prior to beginning any lab work. Each year during orientation, the department holds a safety meeting at which attendance of all incoming students, lab safety officers, and teaching fellows is required. Departmental safety policies are posted online at http://www.chem.yale.edu/resources/docs/SafetyManual04.pdf. Individual research groups also have more specific safety policies.

Adherence to the established safety procedures is required for all individuals to remain in good standing. There are occasionally individuals who are repeatedly unable or unwilling to abide by safety policies. We have instituted the following program to resolve such cases:

Step 1: Individuals whose research advisors find them to be repeatedly out of compliance with our safety policies will be required to discuss the issues in question with their advisor. In the case of graduate students, the Director of Graduate Studies will attend. This is meant to give both parties an opportunity to articulate their position and basis for behavior, and ideally come to a mutually agreeable solution that addresses all issues. The individual may be reprimanded by actions including but not limited to suspension from laboratory work, assignment of additional laboratory duties, or routine safety inspections. A written summary of this meeting will be recorded.

Step 2: If the efforts above are unsuccessful, the issue will be brought to the attention of the individual's advisory committee via a formal meeting. In cases where a committee is not

formed (*e.g.*, first-year graduate students, postdoctoral fellows, undergraduates, etc.), an *ad hoc* committee composed of three faculty members will be established. The committee may recommend additional actions to reprimand the individual. A summary of this meeting will be recorded.

Step 3: If both meetings above are unsuccessful the individual may be dismissed. Graduate students will be referred to the graduate school with the recommendation that the student be transferred to an alternative program or dismissed from the University.

Other individuals (visiting scientists, postdoctoral fellows, *etc.*) may be terminated per the discretion of their advisor.

Each laboratory will have one or more designated Laboratory Safety Officers (LSOs). These are typically senior graduate students. The duty of the LSO is to ensure that laboratory members are in compliance with all safety rules on a day-to-day basis. Thus, the LSOs are obligated to correct laboratory members who are out of compliance. The LSOs are also instructed by the faculty to bring repeated instances of non-compliance to their faculty advisor.

**B. Health and Mental Health.** Research productivity should not be allowed to compromise students' health and safety. Students should obey all University-declared weather emergencies, and discourage other students from putting themselves in harm's way (*e.g.* walking alone at night). Lab-related injuries should be reported immediately to the research advisor, and to EHS personnel.

Research and life can be stressful, and students are encouraged to seek professional counseling when needed. Yale Health offers free and confidential mental health screenings.

The Yale Graduate School manages requests for leaves due to physical or mental health, and also offers parental leaves for new parents of either gender. Please consult the GSAS website for more information.

See the next page for some key phone numbers.

Selected contact information:

Environmental Health & Safety (EHS): 203-785-3550

Safe Ride: 203-432-WALK

Mental Health: 203-432-0290

**C. Waste Disposal**. The U.S. Environmental Protection Agency (EPA) and Occupational Safety and Heath Administration (OSHA) have strict regulations on the handling of chemicals and waste. The Yale safety and waste management offices conduct periodic inspections of the laboratories, and laboratories found to violate the EPA and OSHA regulations during these inspections may be closed for a period of time.

Your chemical waste must be placed in a waste container in secondary containment. It is critical that the bottle is labeled with a proper waste tag provided by the Yale Safety Office, that the contents of the bottle be listed in English words, not formulas or structures, and that the cap is always on except when you are actively adding material to the bottle. Please see http://ehs.yale.edu/chemical-waste for more details.

**D. Tutoring.** The Graduate School will allow most graduate students to tutor in courses they are not teaching. However, specific approval must be obtained from the research advisor. Generally, only limited hours will be approved because the focus of your Ph.D. is research.

**E. Graduate School Regulations on Outside Work.** The Graduate School has set rules and regulations regarding employment outside of the chemistry department. The Graduate School regulations (http://www.yale.edu/printer/bulletin/htmlfiles/grad/financing-graduate- school.html) state, "Study toward the Ph.D. degree is expected to be a full-time activity. Accordingly, part-time employment for compensation, at the University or elsewhere, should not conflict with the obligations of the Ph.D. program or interfere with academic progress. Part-time

employment beyond an average of ten hours per week requires permission of the director of graduate studies in consultation with the appropriate associate dean." Outside employment of any type by a graduate student must also be approved by the student's research director.

**F. Vacations.** Four weeks of vacation time per year (including University holidays) is generally acceptable, but regulations about vacation time fall under the jurisdiction of the research advisor.

**G. Pets.** Non-research animals (e.g., dogs) are not to be kept in the building or courtyard.

**H. Noise.** Excessive noise, such as loud music, will not be tolerated within the Chemistry buildings.

**I. Departure.** Before students leave the Department, it is necessary to certify that all keys, books and laboratory records have been returned and that the student's research area has been cleaned and left free of hazards. Proper disposal of residual chemicals by each student is required prior to departure because it is tremendously expensive to dispose of unknown chemicals. Students who are considering leaving the Ph.D. program prior to their terminal degree should schedule a confidential discussion with the Director of Graduate Studies.