

# A GUIDE TO THE GRADUATE PROGRAM REQUIREMENTS FOR THE PH.D. IN INORGANIC CHEMISTRY

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Modified August, 2007

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## 1. Overview of the Ph.D. Program in Inorganic Chemistry

### A) Domain knowledge

The domain knowledge requirement is met in two ways: i) by completing a set of courses, ii) by passing cumulative exams.

i) The major course requirements for inorganic chemistry are: two physical inorganic courses (608 & 606) and two descriptive inorganic courses (713 & 613, 714 or 801). Each student must also fulfill the UW graduate school minor requirement, which may be focused in a given area outside inorganic chemistry (i.e. organic chemistry, physical chemistry, materials science or biochemistry) or may be distributed among several fields outside inorganic chemistry. Details are in *suggested coursework for inorganic Ph.D. students*.

ii) The purpose of cumulative exams is to teach you to read the research literature and to broaden your knowledge of inorganic chemistry beyond that provided by formal course work. Six written exams (three in each semester) are given each year, with the topic announced 10 days in advance. Details are in *cumulative exams*.

### B) Thesis background presentation

The thesis background requirement involves a formal research report and an oral defense to take place at the end of your second year of graduate study. The thesis background presentation is intended to allow the members of your faculty mentoring committee to evaluate your research progress, your familiarity with the literature and concepts on which your research is based, and your vision for the future direction of your research.

### C) Literature evaluation

To meet the literature evaluation requirement, you will prepare and deliver a seminar to the inorganic division on a topic unrelated to your thesis research. The purpose of this exercise is for you to evaluate the literature critically, prepare an effective visual presentation, and hone your oral communication skills.

### D) Original research proposal

The primary goal of the Ph.D. degree program is for you to conduct original research in inorganic chemistry. To develop your ability to design an original research project, you will prepare a research proposal on a topic unrelated to your thesis research. You will present a formal written document, in the style of an NIH proposal, and you will defend your proposal before a faculty committee. This process will prepare you for professional situations in which you will design and defend projects to funding agencies, management or program directors.

### E) Thesis planning

To ensure that all students progress toward the Ph.D. in a timely way, those students who complete their 5<sup>th</sup> year without scheduling a thesis defense will meet again with their committee. The purpose is to review research progress and develop a defined plan to complete the Ph.D.

### F) Dissertation (Ph.D. thesis)

Your dissertation is a formal, public written record of your thesis research. The document typically includes a critical assessment of the current literature in the field followed by detailed descriptions of the major research findings. The dissertation is presented publicly in a seminar, and defended before a committee of five faculty members, one of whom must be from a department other than chemistry.

## 2. Choosing a Research Group

***The choice of a research group is the most important decision you will make in your first semester of graduate school.*** Get an early start on thinking about which groups you might want to join. Collect information from a wide variety of sources including the professor, the graduate students, the literature, web sites, and recruiting talks. Attend the group meetings of the groups that you are most interested in.

We require that you interview at least five different faculty members before making your decision. As you narrow down your choice of group, be sure to discuss with the faculty members whether or not they are taking students onto the projects that you are interested in. Let your top choice mentor know that you would like to join his or her group. Be sure to have a second choice in mind in case there is insufficient space.

Because of financial requirements within the department, you must join a group between Nov. 1 and Nov. 15. Your choice is not irrevocable; should you later decide that you would prefer to work in a different group, you may switch groups upon mutual agreement with the new mentor.

To aid in the process of choosing a group, here are a list of questions you may wish to consider in making your decision:

- Is the group right for you scientifically? Does the research interest you? Are you excited about the group's approach to science? Are there several projects on which you would be eager to work?
- Does the professor communicate well with you? Do you like the professor's management style? Will you work successfully with this professor as your research advisor?

Is the group right for your personality? Is the group size comfortable for you? Is the group dynamic right for you? Are you comfortable with the people? (Keep in mind that groups change as students come and go; you will interact longest with students who are closest to you in years in the program.)

## 3. Faculty Mentoring Committee

At the end of your 1<sup>st</sup> year of graduate study, a mentoring committee of faculty members will be established to guide your progress through the Ph.D. program. Your dissertation will ultimately be defended before a group of 5 faculty members: 3 members are typically inorganic division members, 1 is typically from outside the inorganic division, and 1 must be from outside the chemistry department. You may choose to establish this 5-member committee after your 1<sup>st</sup> year, but a 3-member committee consisting only of inorganic faculty members is sufficient to evaluate your thesis background presentation, your literature seminar and your original research proposal. The chair of your faculty mentoring committee will be your Ph.D. advisor. It is recommended that you select other committee members for their interest and expertise in the specific area of your thesis research. You will be asked to name potential committee members. Typically your committee will be composed as you request, although the final composition may be influenced by the need to distribute student oversight responsibilities across the divisional faculty.

#### 4. Satisfactory Progress

In May the inorganic faculty members review the performance of each graduate student in the Ph.D. program. The expectations are as follows. By the end of your 1<sup>st</sup> year, you should make satisfactory progress in course work, i.e. a GPA of B or better, and earn at least two cumulative exam points. By the end of your 2<sup>nd</sup> year, you should complete all coursework, the written cumulative exam requirement, and make progress in your research. By the end of your 3<sup>rd</sup> year, you should complete the thesis background presentation, the seminar and the original research proposal. Once you have completed these formal requirements, you become a dissertator; that is, you have completed all the requirements for the Ph.D. degree except the dissertation and you may devote 100% effort to your research. It is expected that it will take not more than two years as a dissertator to complete your thesis research. Failure to meet the minimal cumulative exam point total or to make adequate or timely progress on other formal requirements may result in a recommendation by the division that you terminate study toward the Ph.D. degree.

#### 5. Components of the Inorganic Ph.D. Program

##### A) Domain Knowledge

###### i) Suggested Coursework for Inorganic Ph.D. Students

The doctorate is a degree earned for the successful pursuit of independent and original research. Accordingly, course work is a minor component of the degree requirement. Students pursuing a Ph.D. degree typically complete all course requirements in two or three semesters. All inorganic Ph.D. students take the following three core courses during their first year.

###### Fall:

- **Chem 608:** *Symmetry, Bonding, and Molecular Shapes* (3 credits)
- **Chem 713:** *Descriptive Chemistry of the Elements* (3 credits)

###### Spring:

- **Chem 606:** *Physical Methods for Structure Determination* (3 credits)

During both fall and spring semesters you should also sign up for:

- **Chem 900:** *Seminar -- Inorganic Chemistry* (1 credit)
- **Chem 901:** *Seminar – Teaching of Chemistry* (1 credit)
- **Chem 915:** *Structure and Bonding in Inorganic Compounds* (1 credit)

In the spring semester of your first year or the fall semester of your second year, you should take one additional inorganic course from the following list to complete your inorganic major.

- **Chem 613:** *Chemical Crystallography* (3 credits)
- **Chem 714:** *Organometallic Chemistry of the Transition Elements* (3 credits)
- **Chem 801:** *Selected Topics in Inorganic Chemistry (any topic)* (2-3 credits)

Every Ph.D. student at UW-Madison must complete a safety course during the first year. Note that this course is offered in January, the week before the beginning of the regular semester.

- **Chem 607:** *Laboratory Safety* (1 credit) Offered only during Winter Break

The UW-Madison graduate school requires all graduate students to complete a minor to give breadth to their Ph.D. major. There are two ways to complete your minor: 10 credits in a single department or minor field of study, or a distributed minor in one or more departments, which may include additional course work in other fields of chemistry. Your minor course work is generally selected to provide the necessary breadth for your research. For example, you may require more training in physical chemistry, organic chemistry, materials or biochemistry. You must complete a form defining your minor course work during your second semester.

Doctoral students typically register for 12-15 credits. A minimum of 12 credits is required to maintain your full time student status. Your credit load is filled out beyond your courses by registering for inorganic research. Typically students in their second and third years will register only for the seminars and research, once the major and minor are completed.

- **Chem 994:** *Research – Inorganic (with advisor)* (1-12 credits)

In your first year and the beginning of your second year, you will take one or two additional courses each semester in an area that most closely matches your research interests. Below is a list of possible courses broken down by research professor. This list is not all encompassing, nor exclusive. Do talk to your advisor once you have joined a group, and be aware of timetable changes that may alter when a class will be offered.

#### RECOMMENDED COURSE PROGRAMS BY RESEARCH AREA

Below you will find a list of specific suggestions for Ph.D. course work based on the research interests of the various groups. It is not necessary for every student in a group to take every course listed. Each Ph.D. student is expected to create an individualized course program that will best suit his or her research needs.

##### Berry Group (Inorganic Synthesis and Structure):

- **Chem 613:** *Chemical Crystallography* (Spring)
- **Chem 775:** *Electronic Structure of Molecules* (Fall/Spring)
- **Chem 801:** *Selected Topics in Inorganic Chemistry: Bioinorganic and Kinetics*
- **Chem 605:** *Spectrochemical Measurements* (Spring)

##### Brunold Group (Bioinorganic Spectroscopy):

- **Chem 675:** *Introductory Quantum Chemistry* (Fall)
- **Chem 665:** *Biophysical Chemistry* (Fall)
- **Chem 775:** *Electronic Structure of Molecules* (Fall/Spring)
- **Chem 860:** *Selected Topics in Physical Chemistry: Molecular Simulations* (Fall)
- **Chem 763:** *Introduction to Molecular Spectroscopy* (Spring)
- **Chem 623:** *Experimental Spectroscopy* (Spring)
- **Biochem 625:** *Coenzymes and Cofactors in Enzymology* (Spring)

Burstyn Group (Bioinorganic and Small-Molecule Sensing):

- **Chem 801:** *Selected Topics in Inorganic Chemistry: Bioinorganic* (Fall)
- **Biochem 601:** *Protein and Enzyme Structure and Function* (Fall)
- **Biochem 625:** *Coenzymes and Cofactors in Enzymology* (Spring)
- **Biochem 624:** *Mechanisms of Enzyme Action* (Fall)
- **Chem/Biochem 665:** *Biophysical Chemistry* (Fall)
- **Chem 613:** *Chemical Crystallography* (Spring)

Jin Group (Nanoscale Materials, Solid State Inorganic Chemistry)

- **Chem 630:** *Selected Topics Focus: Chemistry of Inorganic Materials* (Fall)
- **Chem 630:** *Selected Topics Focus: Nanoscale Materials* (Spring)
- **Physics 551:** *Solid State Physics* (Fall/Spring)
- **Mat Sci & Eng 448/648:** *Crystallography and X-ray Diffraction*
- **Chem Eng 544:** *Processing of Electronic Materials*

Landis Group (Catalysis, Mechanism, Organometallics):

- **Chem 636:** *Topics in Chemical Instrumentation: Introduction to NMR* (Fall/Spring)
- **Chem 637:** *Topics in Chemical Instrumentation: Advanced Methods in NMR* (Summer)
- **Chem 605:** *Spectrochemical Measurements* (Spring)
- **Chem 714:** *Organometallic Chemistry of the Transition Elements* (Fall)
- **Chem 801:** *Selected Topics in Inorganic Chemistry Focus: Kinetics*
- **Chem 641:** *Advanced Organic Chemistry Focus: Physical Organic* (Fall)
- **Chem 647:** *Electron Pushing Mechanisms in Organic Chemistry* (Fall)
- **Chem 841:** *Advanced Organic Chemistry* (Spring) Focus: Synthesis
- **Chem 613:** *Chemical Crystallography* (Spring)

Mahanthappa Group (Catalysis, Organometallics, Materials, Polymer Synthesis and Structure):

- **Chem 636:** *Topics in Chemical Instrumentation: Introduction to NMR* (Fall/Spring)
- **Chem 637:** *Topics in Chemical Instrumentation: Advanced Methods in NMR* (Summer)
- **Chem 605:** *Spectrochemical Measurements* (Spring)
- **Chem 714:** *Organometallic Chemistry of the Transition Elements* (Fall)
- **Chem 654:** *Materials Chemistry of Polymers* (Spring)

- **Chem 664:** *Physical Chemistry of Macromolecules* (Fall)
- **Chem 641:** *Advanced Organic Chemistry Focus: Physical Organic* (Fall)
- **Chem 647:** *Electron Pushing Mechanisms in Organic Chemistry* (Fall)

Stahl Group (Catalysis, Mechanism, Organometallics, Organic Synthesis):

- **Chem 636:** *Topics in Chemical Instrumentation: Introduction to NMR* (Fall/Spring)
- **Chem 637:** *Topics in Chemical Instrumentation: Advanced Methods in NMR* (Summer)
- **Chem 605:** *Spectrochemical Measurements* (Spring)
- **Chem 647:** *Electron Pushing Mechanisms in Organic Chemistry* (Fall)
- **Chem 714:** *Organometallic Chemistry of the Transition Elements* (Fall)
- **Chem 801:** *Selected Topics in Inorganic Chemistry Focus: Kinetics*
- **Chem 841:** *Advanced Organic Chemistry Focus: Synthesis* (Spring)

Yoon Group (Organic Synthesis, Catalysis, Mechanism, Organometallics):

- **Chem 636:** *Topics in Chemical Instrumentation: Introduction to NMR.* (Fall/Spring)
- **Chem 637:** *Topics in Chemical Instrumentation: Advanced Methods in NMR.* (Summer)
- **Chem 605:** *Spectrochemical Measurements.* (Fall/Spring)
- **Chem 647:** *Electron Pushing Mechanisms in Organic Chemistry.* (Fall/Spring)
- **Chem 714:** *Transition Metal Organometallic Chemistry* (Fall)
- **Chem 841:** *Advanced Organic Chemistry.* (Spring) Focus: Synthesis

## ii) Cumulative Exams

Cumulative exams are a teaching tool to help you to extend your knowledge. Ph.D. students are expected to read the current literature and broaden their understanding of inorganic chemistry beyond that provided by formal course work. To enhance the learning experience, cumulative exam topics are announced and students are directed to leading references.

Six written exams (three in each semester) are given each year. The faculty person (or persons) giving the exam will announce the topic 10 days in advance. Each exam will run for 2-3 hours. Exams will be graded A, B, or no pass. A grade of A will receive 2 points and B will receive 1 point. Accumulation of 9 points completes the cumulative exam requirement. Ph.D. students majoring in Inorganic Chemistry will begin the cumulative exams in their first semester and will take **every exam** until the point requirement is satisfied. Successful completion of the cumulative exam requirement by the end of the second academic year is expected of all Ph.D. students in good standing.

**B) Thesis background presentation (2<sup>nd</sup> year research report and oral defense)**

At the end of your 2<sup>nd</sup> year, you will prepare a written research report. This report will include a critical evaluation of the literature in your field, your progress to date in your own research, and your vision and plan for the future directions for your research. Details on how to prepare this document are given below. The written report is due on Sept. 1.

Within two months of submitting your written report, you will schedule the first meeting of your faculty mentoring committee. You will make a formal presentation of your research progress to this committee; a 15-minute overview of your accomplishments, with graphics (e.g. PowerPoint or overheads) is appropriate. The mentoring committee members will ask questions and discuss your research progress and thesis proposal. At this stage of your graduate study, successful results are impressive; hard work that has not yet brought the research to a successful conclusion is expected. This meeting should occur in the latter half of September or in October. (Students who are giving their literature seminar in the early fall may postpone this research meeting until later in the semester.)

Your faculty mentoring committee will typically evaluate your progress in four key areas:

- 1) Knowledge of the scientific literature in your research area
- 2) Ability to apply information learned in courses to research problems
- 3) Demonstrated progress to date in Ph.D. research
- 4) Demonstrated understanding of the scientific method through a coherent explanation of the objectives, goals, and approach for the Ph.D. research yet to be completed.

The combined written report / oral presentation format gives you an opportunity to practice your scientific exposition skills. In addition, the thesis background presentation process encourages you to evaluate your progress after the first year-and-a-half of research, and to formulate future research plans. Preparing the report and oral presentation should provide an excellent opportunity for you to assess your own advancement toward the Ph.D. Honest and accurate self-assessment is essential for professional success. This is a time for you to ensure: 1) that you have mastered the intellectual background for your research, 2) that you understand the significance of your efforts and goals, and 3) that you are committed to pursuing a research-based Ph.D. degree.

Your research report should be written in the style of a paper for the *Journal of the American Chemical Society*, with the general format shown. The document should be approximately 20-30 pages long; it is preferred that you are as

- |                                                         |
|---------------------------------------------------------|
| I. Abstract (<1 page)                                   |
| II. Introduction/Background and Significance (~5 pages) |
| III. Summary of Research Progress (~10-15 pages)        |
| <i>A. Experimental Methods</i>                          |
| <i>B. Results and Discussion</i>                        |
| IV. Future Plans/Thesis Proposal (~3 pages)             |
| V. References Cited (complete citations with titles)    |

concise as is reasonable consistent with effective presentation of your data. Figures and Tables should be included as appropriate to explain your reaction chemistry and to show your data. Specific information on the style of *JACS* may be found on the journal web site under "Instructions for Authors" or in the *ACS Style Guide* in the library. You should consult with your Ph.D. advisor as to the appropriate focus for your report and research plan.



You may have pursued more than one project by the end of your second year. Research on some of these projects may already have been terminated, for example, because the project was completed or because an underlying assumption was shown to be incorrect. It is unnecessary to provide "future plans" for such projects. This type of effort may be discussed in part III, or the description may be placed in an appendix. If you are currently working on two (or more) reasonably distinct projects, you may choose to provide separate write-ups, with sections I-IV, for each project. In this case, the total length for all projects must still fall within the recommended page limits. Alternatively, you may choose to focus the entire report on your most promising project, and place information on other projects in an appendix (or multiple appendices). You may wish to consult with your Ph.D. advisor about how best to document your efforts.

Your report should be submitted to Kristi Heming in the Inorganic Division office. Your Ph.D. advisor may wish to approve your report before you submit it; please be sure to obtain such approval before you turn in it. Kristi will append an evaluation sheet to your report and distribute it to your faculty mentoring committee. The committee will read your report and fill out the evaluation sheet prior to your research progress presentation at your mentoring committee meeting. Copies of the evaluation sheet are available in Kristi's office.

### **C) Literature evaluation (literature seminar presentation)**

You will present a seminar in the regularly scheduled Inorganic Seminar series. The seminar will be a review of the literature on a topic of interest to inorganic chemists. This requirement is designed to offer you an opportunity to expand your knowledge in an area unrelated to your own research, and to make a formal presentation to a knowledgeable audience. Your goals are: to evaluate the literature critically, to prepare an effective visual presentation, and to practice good oral communication skills.

You should prepare for your seminar as soon as you complete the Cumulative Exam requirement. You will be expected to give your seminar in the 2<sup>nd</sup> semester of your 2<sup>nd</sup> year or the 1<sup>st</sup> semester of your 3<sup>rd</sup> year, depending on how rapidly you accumulate cumulative points. *Your seminar topic must be one on which you have not worked previously, it must be unrelated to research being done in the UW Chemistry department, and it must be different from the student seminar topics of the past 5 years.* A topic far removed from your Ph.D. research is preferred, but a similar, though unrelated topic is acceptable. (A strategy that many students have found effective is to learn about a topic for your seminar and then to develop an idea based on what you learn for your Original Research Proposal.)

Your Ph.D. advisor may wish to approve your seminar topic; please be sure to obtain such approval before you begin to prepare your presentation. The Inorganic Seminar Chairperson must approve your seminar topic one month prior to your seminar. You are expected to spend no more than one month on the research and preparation.

You will prepare a short abstract with references (<3 pages, including the reference list) and a print out of your slides (6 slides/page, numbered please) to hand out to the audience before your talk (50 copies, double sided). Please turn in one hard copy or a PDF file of each of these items to Kristi Heming in the Inorganic office. Kristi maintains a file of abstracts and slides from all inorganic student seminars for you to view.

**Planning the Seminar:**

Your presentation should be prepared using Powerpoint or a comparable multimedia program. The computer projection system should be utilized to present the talk; you should practice in room 1315 to be certain that you are comfortable with the technology. Plan to talk for approximately 45-50 minutes with 10-15 minutes for audience questions/comments.

There are many resources to help you to learn to prepare an effective presentation. Given the importance of oral and visual communication for job interview seminars, you are advised to seek out as many opportunities to practice these skills as possible. Such opportunities include group meetings, "super-group" presentations, and posters or talks at scientific meetings. The following web sites give useful information for graduate students to learn about oral presentation skills.

<http://web.cba.neu.edu/~ewertheim/skills/oral.htm>;  
<http://www.chem.umn.edu/groups/haynes/philosophy.html>;  
<http://www.kumc.edu/SAH/OTEd/jradel/effective.html>;  
<http://pages.cs.wisc.edu/~markhill/conference-talk.html>;  
<http://membership.acs.org/y/ycc/lsycc/programs.htm>

Characteristics of a good talk:

- 1) A good talk is a well-organized talk. Attention to organization will benefit your entire audience, and will help everyone to learn from your presentation.
- 2) A good talk has a point to make, and makes that point effectively through wise and judicious selection of the material covered. Present enough material to keep the listeners' attention, but not so much that an informed listener cannot be thinking critically as you speak. Do not try to cover every detail in the field.
- 3) A good talk balances breadth and depth, offering a critical assessment of an area of current research. Identify several key issues and discuss them in depth. Be critical in your reading and presentation. Think about the diversity of your audience when selecting your topic and tailor your presentation so that a broad inorganic audience will walk away with an understanding of the field.
- 4) A good talk points out the holes in arguments, and the limitations of the current state of knowledge. When you present studies and their conclusions, do not simply repeat what you have read. Instead, tell your audience why the explanation is accepted and how other alternatives have been invalidated experimentally. In the best talks, the speaker goes even further, pointing out alternative acceptable hypotheses and/or critical experiments that have yet to be performed.
- 5) A good talk includes a clear context within which to appreciate the material that you are presenting. As the frontiers of chemistry expand, more and more students choose topics displaced from classical inorganic fields. We encourage such choices; however, new methods and concepts must be clearly and thoroughly explained. Show your audience how inorganic chemistry is relevant and important to understanding new fields, by emphasizing the inorganic aspects in your presentation.

Helpful speaking hints:

- Each slide should contain one message. Cluttered slides are often unintelligible to the audience. Be sure that your slides are legible to people sitting far from the screen: a larger font or graphic size is always better.
- Virtually everyone gets nervous before a presentation. The most effective way to counter the effects of nervousness is to know your material as thoroughly as possible. Practice your talk several times in front of other people, in front of a mirror, and in the lecture hall. Memorize the sequence of your slides, as this will imbue your presentation with confidence. It may be helpful to memorize the first few minutes of your talk, but memorize the entire talk only if it is absolutely necessary because a memorized speech is never as compelling as a presentation with a spontaneous edge. Concentrate on speaking loudly, clearly, and slowly. You will naturally speak too rapidly when nervous.
- When using a laser pointer, avoid excessive movement of the dot on the screen. If you are very nervous, try using both hands to hold the pointer, or only turn the pointer on when you need it. If you use the pointer in your right hand, it is easier to point to the screen while looking at the audience if you stand to the right of the screen (audience's right); vice versa for left handed use.

**Seminar Introduction:**

It is the custom that the student speaker who gave the last student seminar prior to yours will introduce you to the audience. Please prepare a very short biography of yourself, <1 paragraph, to aid your colleague in making the introduction. A typical biography should include where and when you received your bachelor's degree, the name(s) of your undergraduate research mentor(s) and the topic(s) of your undergraduate research. Additional details may be included. If you are unsure who will be doing the introduction, please check with Kristi Heming. She will help you to identify the peer who will introduce you.

**Seminar Evaluation:**

All attendees at your seminar will be asked to fill out an evaluation form. Copies of this form are available in the Inorganic office for you to view before your seminar. The peer who introduced you to the audience is also responsible for collecting the evaluations and turning them in to Kristi in the Inorganic office. Approximately 1 week after your seminar, you will receive a computerized printout summarizing the evaluation data, as well as the original copies of the evaluation comments.

Immediately after your seminar, your faculty mentoring committee will meet with you briefly to share their impressions of the seminar. The faculty will provide constructive criticism to help you to improve your presentation skills (both written and oral) as well as a critical evaluation of the seminar topic coverage.

## D) Original Research Proposal

During your third year, you will write and orally defend an original research proposal (RP). Recognition and development of original and meaningful research problems is an important part of a Ph.D. degree and the purpose of the research proposal is to develop and test aptitudes in this area. You should begin to seek out original, independent research ideas that may be used for the RP as early as the beginning of your second year. Current literature, seminars, course work, and material used in preparation for courses are all possible sources of ideas for your RP. The RP should be in the general area of inorganic chemistry. *The topic must be one on which you have not worked previously, and must be unrelated to research being done in the UW Chemistry department.* Proposals far removed from your Ph.D. research are preferred; those in similar, though unrelated areas are acceptable. The proposal will be your own intellectual property and it should represent the best independent research idea that you have had to date. It is highly recommended that you plan to complete your RP early in the third year. The latest date on which a written proposal will be accepted is April 1, with an oral defense scheduled before the end of the semester.

Turn in your written RP to Kristi in the Inorganic Division office; she will distribute it to the appropriate faculty members for review. If you have not heard from your Ph.D. advisor regarding the status of your proposal after two Wednesdays have passed, please notify Kristi.

### Planning the Proposal:

A good research proposal should seek to answer an important scientific question, the approach should be practical and well described, and the experiments designed to give clear-cut answers. The scope of your proposal should be a project to be completed by an advanced graduate student or post doc in two years. You should NOT develop an entire research program.

To help you to select a topic and to develop a good proposal, you should answer the following questions. Write down answers to these questions well before you begin to prepare the formal document. Your answers will help you to develop a well-constructed proposal.

- 1) Why is the proposed research important? What is the perceived need? Why should you do it? What timely scientific question will this work answer?
- 2) Where is the WOW in the science?
- 3) What does your approach enable that no one else can do with existing methods?
- 4) Is the work original?
- 5) What is the long-range goal?
- 6) What are the specific objectives? What are the hypotheses to be tested / questions to be answered?
- 7) Do the specific objectives lead toward accomplishment of the long-range goal?
- 8) What are the experiments that you propose to do? Is the methodology "state of the art"? What are the expected results? What will you do if your first attempts fail? (Contingency plans) What does the first paper look like?

### Written Proposal Guidelines:

Your written proposal should follow the NIH style, as described in the following outline. Your completed proposal should be not more than 10 pages double-spaced including figures and references. Please use Ariel 11 point font. Examples of recent NIH grants submitted by the inorganic faculty members may be found in Kristi's office. These grants, which may be as long as 25 pages single-spaced, are intended to familiarize you with some different approaches to

grant writing. Remember that your proposal is NOT a research program, but rather a modest research project. Kristi also has examples of RPs written by recent Ph.D. students available for you to review to give you a better sense of the proper scope for your proposal.

### A. Specific Aims

- Describe in a few sentences the overall goal of the research and provide an enumerated list of Specific Aims that the proposed studies will address. Clearly distinguish between:
  - *broad, long-term goal* e.g., “explore the mechanisms of organometallic copper oxidase reactions” (hard to quantify progress in achieving this objective)
  - *specific aims* e.g., “use kinetics and spectroscopic tools to investigate the mechanism of copper catalyst oxidation by molecular oxygen” (easy to quantify progress in achieving this objective. The Specific Aims comprise a list of items needed to pursue the broad, long-term goal.)

### B. Background and Significance

- Briefly summarize background information that is relevant for your proposal.
- Critically evaluate the current knowledge in the field.
- Demonstrate your understanding of the subject by identifying the specific gaps that your proposed research is intended to fill.
- State concisely the importance of the research by relating the Specific Aims to the broad, long-term goals.

### C. Experimental Design and Methods

In this section, you should outline the experimental design and procedures that you will use to accomplish the Specific Aims of this project as formulated in section A. The experimental approach should be outlined clearly and in sufficient detail that the plan may be evaluated by the reviewers (inorganic faculty members / your faculty mentoring committee.)

- Number the subsections in the Experimental Design and Methods section according to the numbers used for the specific aims in section A. Use sub-numbering within this section when describing several methods applicable to the same specific aim.
- If applicable, show reaction sequence diagrams for the syntheses of unknown compounds and describe how the success of your synthetic endeavors will be tested using physical characterization methods.
- Explain how experimental and/or computational data are to be collected, analyzed, and interpreted.
- Discuss potential **difficulties** and **limitations** of the proposed procedures and outline alternative approaches to achieve the aims.

**Note:** The Experimental Design and Methods section is the most important part of your RP. Your primary goal in this section is to convince the reviewers that the research tools and approaches you propose to utilize are well chosen for addressing the Specific Aims formulated in section A. Your description should indicate that you really understand and know how to carry out the research you propose, and that you are familiar with the techniques and their limitations.

### D. Literature Cited

- Use *JACS* format, but also include the title of each article and book chapter; e.g.:
  - [1] Andruniow, T.; Kozłowski, P. M.; Zgierski, M. Z. "Theoretical Analysis of Electronic Absorption Spectra of Vitamin B<sub>12</sub> Models", *J. Chem. Phys.* **2001**, *115*, 7522-7533.
  - [2] Johnson, M. K.; Robinson, A. E.; Thomson, A. J. "Low Temperature Magnetic Circular Dichroism Studies of Iron-Sulfur Proteins", In *Iron-Sulfur Proteins*; Spiro, T. G., Ed.; Wiley-Interscience: New York, 1982; pp 367-406.

- Choose wisely the references that you include. Your choice of citations tells the reviewer about your quality as a scientist, i.e. your ability to evaluate the work of others and to distinguish the important from the mundane.

**Proposal Evaluation:**

All inorganic division faculty members and all members of your faculty mentoring committee will receive a copy of your proposal for evaluation in the four categories listed below.

1. *Scientific Merit*: Is the proposed research worth doing; does it answer important questions; does it lead to new and nontrivial results?
2. *Practicality*: Does the proposed research address a suitably chosen scientific problem; would an advanced graduate student or postdoctoral fellow be expected to make substantial progress in a reasonable amount of time?
3. *Technical Competence*: Will it work? Are theoretical arguments sound; will the experiments lead to conclusive results; has the student overlooked reasonable alternatives; will synthetic steps work (i.e., are the references to well-documented analogous reactions appropriate)?
4. *Presentation*: Is the proposal understandable; does it clearly describe the significance of the problem and the proposed solution; does it include pertinent references to the literature?

After review by your faculty research committee, your proposal will be accepted (with minimal or minor revisions), returned for revision, or rejected. If your proposal is acceptable, it will be approved for oral defense. If it is returned for revision, your major professor will provide a summary of critical comments to help you in preparing a satisfactory version. If it is rejected, you must develop a new proposal. If you are asked to make major revisions, your revised proposal will be re-evaluated. The revised document should be accompanied by a cover letter detailing the changes you have made to the text and how you addressed the specific comments you received from the faculty. When your research proposal accepted, with minimal or minor revisions, you will schedule a defense **within the next 30 days**.

**Proposal Defense:**

The research proposal presentation is both an oral *examination* and a *defense* of the proposal. The proposal itself will loosely define and limit the boundaries of the examination; however, you are expected to be fully knowledgeable about the subject including background information, descriptive chemistry, theory, techniques, methodology, and alternatives. You are also expected to be fully aware of the connections between your proposal and your courses, recent seminar presentations in the department, or recent papers in key journals.

You will present and defend your proposal to your faculty mentoring committee. You should prepare a presentation on the proposed research of no longer than 20 minutes. Your presentation should focus on the proposed work; introduce background material only as needed and when it is required to understand your proposed experiments. It is customary for questions to be asked both during and after the presentation; you should expect to be interrupted as you make your presentation. You should strive to answer the questions as clearly and concisely as possible, with expert use of relevant chemical concepts and vocabulary. Immediately following the exam, the committee will evaluate your performance on a pass / conditional pass / fail basis, and will inform you of its decision. If you receive a conditional pass, you may be asked to

undertake modest additional work to complete your requirement. If you are judged to have failed, you will be asked either to reschedule another defense or to prepare a new proposal.

### **E) Thesis Planning Meeting**

If you enter your 6<sup>th</sup> year and are not ready to defend your dissertation, you should convene a meeting of your faculty oversight committee in early September. At this thesis-planning meeting, you will summarize your research progress and outline your plan for completing your Ph.D. research and thesis. This meeting is intended to support you in bringing your research to a successful conclusion within 6 years. You may wish to review with your committee experiments that are proving difficult, hypotheses that remain untested, or other challenges that you are experiencing. Your committee will provide guidance to you on overcoming these challenges, or may suggest other avenues by which you may bring your work to a successful conclusion. Your committee will also provide guidance and support for your writing process.

### **F) Dissertation / Ph.D. Thesis**

Your dissertation is the formal, public written record of your Ph.D. research. The document typically includes a critical assessment of the current literature in the field followed by detailed descriptions of the major research findings, written in a style appropriate for publication in the major research journals in your field. In preparing this final document, you should follow the tradition and style appropriate to your Ph.D. advisor and research group. Ideally, at the time you write your dissertation, several of your chapters will be published and/or ready for submission for publication in leading chemistry journals. The final formal requirement to receive the Ph.D. is a public presentation and oral defense of your research to your faculty mentoring committee. At this time, if your committee was not already so constituted, your committee must consist of five faculty members, at least one of whom is from a department other than chemistry and (typically) one of whom is from outside the inorganic division. This final defense is an opportunity for you to engage in a collegial intellectual dialog with your committee about the work to which you have devoted enormous time and effort. Congratulations!