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REQUIREMENTS FOR THE DOCTOR OF PHILOSOPHY DEGREE IN CHEMISTRY

1 September, 2015

This document lists Departmental requirements for the Ph.D. degree in Chemistry, along with a summary of the most significant general regulations of the Graduate School pertaining to this degree. Further details on the Graduate School regulations may be found in the Policy Guide of the Graduate School:

A. PLACEMENT EXAMINATIONS

All entering students must take three Placement Examinations, one each in Organic, Inorganic, and Physical Chemistry. These Placement Examinations cover undergraduate material at a level comparable to that of the corresponding courses offered by Northwestern. A student who does not achieve a suitable score on a Placement Examination will be required to take a specific graduate course in that area. The three courses are Principles of Organic, Inorganic, and Physical Chemistry (Chem. 401, 402, and 403, respectively). If a student is required to take two or fewer Principles Courses, those courses must be completed in the first year. If three Principles Courses are required, one course (not in the student's major field) may, with the agreement of the student's adviser, be deferred to the second year. However, deferral of a course could lead to deferral of admission to the Doctoral Program. (See section D)

B. COURSE REQUIREMENTS

Each student must take (for a letter grade and credit, not P/N) nine courses. These nine courses include the three Principles Courses discussed in Section A, and six courses that are needed to satisfy the specific requirements of a division or a program. These courses should be completed by the end of the spring quarter of the first year, except that, as indicated in Section A above, there is the potential for deferring one course if all three Principles Courses must be taken. A satisfactory score on a Placement Exam will result in a waiver of the associated Principles Course in that area, correspondingly reducing the total number of required courses. (See below for a further discussion of "Waived Courses"). If the number of required courses is reduced to fewer than nine as a result of the waiver of one or more courses, it is expected that the reduced number of courses will be completed by the end of the first year of study.

Each student should choose a major field of study and satisfy the requirements within that major field. The courses listed below for each major field **are in addition** to the three Principles Courses that are required for each of the divisional or program options. It should be noted that 300-level courses in Chemistry, research courses, and research seminar courses, such as 499 and all 500-level courses, **cannot** be used to satisfy the course requirements of any of the major fields of study.

All students are required to take Chemistry 519 – "Responsible Conduct of Research Training"

during the Fall Quarter. This course does not count toward the nine required courses.

Major Fields:

1. Inorganic: **433, 434, 435** (*Adv Inorg, Crystallography, or Solid State & Materials*), one course from 405, 406, 407, and two additional courses*. **Also, all 1st years who declare inorganic as their field of concentration must mandatorily attend BIP. It is also required that all graduate students who are inorganic must give at least 2 BIP presentations throughout their PhD careers.**
2. Organic: Must take one of the following **411-1, 415/435** (*Mass and other Spectroscopies*), at least two from **410, 412, 413, 415, 415** (formally Chem 419) one course from 405, 406, 407, and one (if 410, 412, 413 and 414 are all taken) or two additional courses (which may include 415 courses)*.
3. Physical/Analytical: **442-1, 442-2, 443**, one course from 405, 406, 407, and two additional courses*.
4. Environmental: **406** and one course from **411-1, 415/435** (*Mass and other Spectroscopies*), **433, 442-1**, and two courses from: CivEnv 361-1, CivEnv 361-2, CivEnv 367, CivEnv 440, CivEnv 447, CivEnv 448, ChemEng 365, and Mat_Sci 380; and two additional courses*.
5. Life Processes:
 - a. Option 1: Fulfill any one of the three divisional requirements (Inorganic, Organic, or Physical/Analytical), and take **405** as part of those requirements, and select two electives from among: Chem 414, Chem 415, Chem 435 (*Advanced Inorganic*), BioSci 301, BioSci 321, BioSci 361, BioSci 356, BioSci 323, BioSci 390, IBIS 401, IBIS 402, IBIS 403, IBIS 406, IBIS 410
 - b. Option 2: 405, and one from 411-1, 415/435 (*Mass and other Spectroscopies*), 433, 442-1; and either BioSci 301 or IBIS 401, and both Chem 435 (*Advanced Inorganic*), BioSci 361 and one additional course*.
6. Solid State & Materials: **435** (*Solid State & Materials or Adv Inorg.*), one course from **411-1, 415/435** (*Mass and other Spectroscopies*), **433**, and **442-1**, and two courses from: Chem 435 (*X-ray Crystallography only*), Chem 415 (*Materials Chemistry only*), MatSci 341, MatSci 351-1, MatSci 351-2, MatSci 355, MatSci 360, MatSci 361, MatSci 376, MatSci 395, MatSci 405, MatSci 445, MatSci 465, ChemEng 395, ChemEng 361, EECS 385, and Physics 422-3; two additional courses*.

* The additional courses are to be chosen in consultation with their adviser.

NOT ALL COURSES LISTED ABOVE WILL BE AVAILABLE EVERY YEAR.

Bold type indicates courses that are eligible for being waived, as described in the next paragraph.

Waived Courses: As indicated in Section A, any or all of the three Principles Courses can be waived as a result of performance on the Placement Exams. For each Principles Course that is waived, the number of required courses is reduced by one. In addition, students who are already proficient in the subject matter of a **specific** course (exclusive of the Principles Courses) required for their major field, whether by virtue of having completed a substantially equivalent course at another institution or by independent study, may request **the instructor of the course** in question to waive that particular course requirement. (As an example, 442-1 is only required for the Physical/Analytical major field. Thus, students who plan to pursue this major field are eligible to request a waiver of this course. However, since this is not a specifically required course for students in other major fields, students who major in a field other than Physical/Analytical are **not** eligible to request a waiver of this course.) In requesting a waiver, the student will be expected to present evidence of superior knowledge of the course material to the instructor of the course.

For a waived course, a student must substitute a Research Seminar (Chem 570-78) taken for a letter grade. Research Seminars, may be taken for letter grade during the first and second year to complete the requirement of nine graded courses, but these grades do not count in the student's Departmental GPA.

Courses that are eligible to be waived are in **bold** type in the list of courses set forth above. A waiver of an additional course(s) **does not** further reduce the total number of required courses. If more than one course, exclusive of the Principles Courses, is waived, additional eligible Northwestern courses, selected in consultation with the research adviser, must be substituted for any waived courses(s) beyond the first non-Principles Course that is waived.

Students entering with a Master's degree from an accredited institution are allowed to waive up to two required courses in addition to any Principles Course(s) waived as a result of performance on the Placement Exams. Once again the student is restricted to a waiver of courses in **bold** type that are required for their program/major. A waiver of an additional course(s) does not further reduce the total number of required courses. If more than two courses, exclusive of the Principles Courses, are waived, additional eligible Northwestern courses, selected in consultation with the research adviser, must be substituted for any waived course(s) beyond the second non-Principles Course that is waived.

Students entering from the Medical Scientist Training Program (MSTP) who have received a B.S. or B.A. in Chemistry and who have successfully completed two years of Medical School course work in the Northwestern University Feinberg School of Medicine (FSM) will typically follow the Life Science option. The course work they have completed at FSM will be counted as satisfying the *elective requirements* for the Life Sciences option. Given their advanced standing, MSTP students are allowed to waive up to two additional required courses as described above in the section entitled "Waived Courses."

C. TEACHING RESPONSIBILITIES

Satisfactory performance of assigned teaching duties is a requirement for all advanced degrees in the Department of Chemistry. Regardless of the method of support, or whether any support at all is provided, every full-time graduate student must teach 4 full quarters in order to graduate with a

Ph.D. All MSTP students must fulfill a teaching requirement of 3 full quarters in order to meet graduation requirements. Some students choose to teach additional quarters based on their interest. Inadequate performance of teaching responsibilities shows a lack of progress toward the Ph.D. degree (see Section P).

D. ADMISSION TO THE DOCTORAL PROGRAM

Although students are expected to enter into graduate work with the intention of earning the doctorate, formal admission to the doctoral program is not granted until the student has adequately demonstrated his/her qualifications for entering the program. Admission to the doctoral program is based on the scientific potential of the student as judged by performance in course work and effectiveness in research. A satisfactory teaching record is also required. Decisions are normally made at the end of the first academic year of graduate work (e.g., June for students entering in September).

For continuation in the Department of Chemistry after the first academic year, a graduate student must show competence in coursework, research, and teaching. With regard to coursework, the student must have an overall grade point average > 5.25 and no more than one grade below B in the courses required by the Chemistry Department. The GPA is determined using this grading system immediately below,

where A = 8, A- = 7, B⁺ = 6, B = 5, B- = 4, C⁺ = 3, C = 2, C- = 1, less than C- = 0.

Note that 499 and 500-level courses (e.g., research courses and research seminar courses) taken to fulfill the total course requirements **do not** count in this evaluation. Students who have met these criteria and have demonstrated suitable competence in research and teaching by the end of their first year will be permitted to continue working toward Ph.D. candidacy. **The following guidelines will be used by the faculty in making decisions about a student's status:**

- 1) If the student's GPA is < 5.25 , the faculty will decide, at a meeting that normally takes place in June of the student's first year, if the student should be placed on academic probation or terminated from the program. The decision whether to place a student with a GPA < 5.25 on probation or to terminate the student from the program is based on an evaluation, presented to the faculty by their research adviser, as to the student's competence in research and by an evaluation of teaching competence.
- 2) If the student has a GPA > 5.25 but has more than one grade below B, and is judged to have shown suitable competence in research, he/she will be placed on academic probation.
- 3) If the GPA is > 5.25 with no more than one grade below B but the research and/or teaching competency criteria have not been met, the faculty may choose to place the student on research or teaching probation, respectively, to provide an additional opportunity to demonstrate competency.

For students placed on any kind of probation, the probationary period will continue for approximately two months, during which time the student is expected to demonstrate competence in research. At the end of that period, the Graduate Affairs Committee and the student's adviser

will assess progress in research on the basis of two criteria: a 2 page written report of research results by the student and a letter from the research adviser. The report is due by 5 pm on the next-to-the-last Friday of August of that summer. Students who have demonstrated hard work and an ability to carry out research, as determined by their advisor and the Graduate Affairs Committee in their academic discretion, will be permitted to continue in the program. To remedy teaching deficiencies, a student may be required to perform additional teaching duties to correct the deficiencies, and consideration of admission to the Ph.D. program may be delayed until satisfactory performance has been demonstrated.

If a student has been terminated (excluded) from the program, their enrollment and financial support will end on the last day of the current academic quarter and they are prohibited from doing any further work towards a Ph.D. degree in the department.

E. SELECTION OF A THESIS TOPIC AND RESEARCH ADVISER

One of your most important tasks during the fall quarter is to gather information that will enable you to choose a thesis topic and a research adviser. Because a large fraction of your time during the next four to five years will be devoted to research, it is important that you select a problem that you find interesting and exciting, and a research group in which you will be comfortable. There are many faculty members and a wide variety of research topics; thus, you should have no difficulty in finding several interesting problems and compatible research groups. The number of new students to be accommodated in each research group is limited, so you should develop alternate choices in case you cannot be placed in the group of your first choice.

Although each student is most often assigned to one official adviser, it is possible to complete a thesis under the joint supervision of two faculty members when the thesis problem involves two areas (e.g., theory and experiment; synthesis and structure). Joint advisers need not be in the same division. You may also investigate arrangements of this type. You are not restricted to problems in the branch of chemistry you indicated as your area of interest when you applied for admission, and you are encouraged to investigate problems in all areas. If you worked for a professor previously (i.e.- during the summer), you have no obligation to remain with that group. You are free to investigate all possibilities.

There are many ways in which you can gather the information needed to make your choice; you should make use of all of them.

1. Faculty Presentations. These research presentations, beginning during Orientation, are intended to give you an overview of the type of work being done in each research group. They should help you identify potential areas in which you might like to work. These presentations will help you become generally familiar with all of the research that is underway in the Department. Even though you may not be interested in doing research in many of those areas yourself, you are expected to attend **all** of these presentations.

2. Discussion with Individual Faculty Members. Make appointments with every faculty member in all areas in which you think you might like to do your research to discuss in some depth the research problems that are available. Although there is some merit in scheduling an

appointment after the faculty member has made his or her formal presentation, it is not necessary to wait until after the presentation to schedule a meeting with the faculty member. You should try to make these appointments as early as possible so you will have time to weigh the merits of the various choices. **Do not postpone the appointment until just before the week for the selection of a research adviser.** If you would like to schedule a second or third meeting with any particular professor as you begin to narrow your selection, by all means do so. **It is required that you discuss possible research problems with at least four faculty members who are working in areas in which you would like to do your research. Most faculty members expect to have a least one if not several meetings with students who eventually join their group.**

3. Group Seminars. Most faculty members schedule regular meetings of their research groups for informal discussion of research progress, recent pertinent literature, and other topics of special interest to that particular group. You are welcome to attend such group meetings. They provide an excellent way of getting acquainted with a research group. Ask the faculty member when group meetings are held and indicate you would like to attend.

4. Discussion with Graduate Students. Get acquainted with the graduate students in each of the research groups that you think you might like to join. They can provide insights that you might not get by talking with the faculty. If you wish, ask the adviser to introduce you to some of his/her group members.

5. Reading the Literature. You can learn much about the detailed nature of the research that is being pursued in each group by studying recent publications describing that research. A listing of the most current publications by faculty in our Department is available in the main office. It would be to your advantage to read some of the recent publications of each of the faculty members with whom you might be interested in working before you schedule an interview.

6. Departmental Seminars. Each week there are typically multiple seminars in which a faculty member, a graduate student, a post doc, or an outside speaker discusses some current research effort. You should attend at least one of these seminars each week, and you are welcome to attend as many as you like. If you have already reached a reasonably firm decision as to the general area of chemistry of most interest to you, then attend the seminars relevant to work in that division or program area.

Because the selection of a research preceptor is such an important matter, we want to schedule enough time for you to examine all alternatives in a thorough and leisurely manner. For this reason, **neither students nor faculty are allowed to reach an agreement regarding thesis supervision prior to the faculty meeting dealing with adviser selection.**

Faculty Adviser Preference forms "Form II" are due at noon on Friday, November 6, 2015 at the Graduate Program Assistant's Office. Final decisions for adviser assignments are anticipated within approximately two weeks thereafter.

F. CHANGING AN ADVISER

A student may leave a research group at any time. Likewise, an adviser may use his or her discretion to ask a student to leave their research group. In either case, a student in good standing with the Department and University may look for another adviser for a period of up to five weeks with pay. A student who has not found a suitable adviser by the end of that time is no longer making satisfactory progress toward the degree and will be excluded from the program.

G. MASTER'S DEGREE IN CHEMISTRY

The Chemistry Department's graduate program is designed to lead to the Ph.D. degree, and it is expected that all students who enroll are pursuing the doctorate. However, a student leaving the Doctoral Program is eligible to receive a terminal Master's Degree if all of the following three requirements are met:

- 1) At least three quarters of full-time study are completed.
- 2) The student has been admitted to the Doctoral Program by the faculty (see section D).
- 3) The student has submitted a written research report that is approved by the research adviser(s) and the Graduate Affairs Committee and that demonstrates substantial progress on the student's research project. The report must be written in a form that would be acceptable for publication as an article in the *Journal of the American Chemical Society* or in the form of one chapter of a Northwestern Ph.D. thesis. The decision as to which form is selected must be made in consultation with the research adviser.

H. SEMINAR REQUIREMENT

Students in some division must present one divisional seminar on their research in the Chemistry Department at Northwestern. Guidelines for the timing of the seminar may vary in each division.

I. THE QUALIFYING EXAMINATION

The qualifying examination (QE) is the means by which students advance to candidacy for the Ph.D. The exam can be taken after five quarters of residency, but must be taken before the end of your seventh quarter of graduate study (the first official quarter of graduate study being in September of the first year, even if the student works in a lab the summer before the first year). Students who enter Northwestern with a Master's Degree, or with credit for at least three quarters of graduate study from another Institution that is accredited by The Graduate School, may take the examination after completing three quarters of study at Northwestern, but again must complete the requirement before the end of the seventh quarter of study.

You must prepare a written document, as detailed below, and take an oral examination that covers the material in your document as well as general chemistry topics. The purpose of the QE written document and oral exam is to assess: (i) whether the student is progressing as rapidly as can be expected on their research problem(s), (ii) the student's general knowledge of Chemistry, particularly in the field of Chemistry relevant to the student's research, (iii) the student's ability to put their research project in the context of their greater field within Chemistry, and their familiarity with the relevant literature, (iv) the student's ability to articulate plans for the near-term (next 1-2 years) for their project, and (v) whether the student is likely to produce an acceptable thesis within the next 2 – 3 years.

The student will write his/her QE document in *the format of a research proposal*, where the topic is their own thesis research, and where the Preliminary Results section is a summary of the work they have accomplished so far. The Preliminary Results Section will occupy a significantly higher fraction this document than it would in a typical original research proposal.

I. Format of the Written QE Document. The QE written document will have 7 sections (total maximum of 13 pages, double-spaced, including abstract, figures and tables, but excluding references):

(1) Title and abstract (1 page)

-The title and abstract should be descriptive of the total document – that is, the portion of the work that has been accomplished, and the portion of the work that is proposed for the next 1 – 2 years of research.

(2) Introduction, Background, and Significance of the Research

- should include the “intellectual merit” of the project: what it will do to move the field forward and further fundamental understanding. It should also demonstrate the student’s mastery of the literature in their field

(3) Scientific Objectives (“Specific Aims”)

(4) Preliminary Results (no fewer than 5 full pages, including figures and tables)

- a summary of progress on the research problem thus far

(5) Proposed Research (no fewer than 2 full pages, including figures and tables)

- a research plan for the next 1 – 2 years, including general objectives and specific experimental or theoretical plans.

- a brief description of contingency plans

(6) Summary and Conclusions

(7) References (as many as are appropriate; not included in the page count)

- references should be the following format:

Journal articles:

Kramer, I.J.; Levina, L.; Debnath, R.; Zhitomirsky, D.; Sargent, E.H. Solar cells using quantum funnels *Nano Lett.* **2011**, *11*, 3701-3705.

Books:

Odian, G. Principles of Polymerization; 4 ed.; John Wiley and Sons: Hoboken, NJ, 2004.

The student decides how to partition the document between text and figures, but should note that figures should not be seen as a replacement for text (i.e., the text must be a complete narrative). **All text must be 12-point, Times New Roman, and double spaced.** Pages must be numbered starting with the title/abstract page.

II. Choosing the Qualifying Exam (QE) Committee

The Graduate Affairs Committee chair will assign committee members based on suggestions from the student's adviser. Students must turn in the form listing these suggestions to the Graduate Assistant within the first two weeks of the fall quarter for students with Master's degrees, and within the first two weeks of winter quarter for students with a bachelor's degree. The student's research adviser will not be a member of the QE committee and will not be present during the examination, but will be consulted prior to the examination about the student's progress. After the exam, the QE chair is replaced by the student's adviser for the student's original research proposal and thesis committees; the other members remain.

III. Scheduling the Qualifying Oral Exam (Deadline Before the end of your seventh quarter of graduate study)

The department will arrange for you to meet with the administrative assistants of your committee members to schedule a QE exam date and reserve a conference room. This meeting room must have a projector screen and a chalkboard or whiteboard. Please contact gradasst@northwestern.edu with questions about QE scheduling. **The Graduate Affairs committee strongly recommends that the student begins the scheduling process at least 3 months prior to the desired meeting date.**

IV. Other Information about the QE

The student should bring research notebooks and other similar research related materials to the examination so that any specific information or data that the committee may request can be provided. Students who do not demonstrate satisfactory research aptitude and research progress will be excluded from the doctoral program.

****The QE document must be turned in to committee members at least one week before your examination date.**** If two or more committee members believe that the QE document is not satisfactory to move on with the oral exam portion, then the Chair of the committee must inform the student – *no later than 48 hrs before the scheduled exam time* – that the exam will be postponed. The committee should give the student a general idea about why the written document was rejected, but is not required to provide detailed feedback to the student. It is then the student's responsibility to revise the document and reschedule the exam. The student is advised to consult with the Graduate Program Assistant about a timeline for this process. It is desirable to reschedule within the same quarter, but the student can petition the Chair of Graduate Affairs for an extension.

J. THE ORIGINAL RESEARCH PROPOSAL (ORP) REQUIREMENT

The process of writing an original research proposal (ORP) is broken down into three required parts. This multi-step strategy is intended to develop the skills needed for proposal writing in stages rather than in one concerted activity. These stages are: **(i)** literature search and topic choice, accomplished through construction of *Quad Chart Proposals*, **(ii)** topic development, accomplished through construction of an *ORP outline*, and **(iii)** writing and defense of the *full original research proposal*.

I. Literature Search and Topic Choice: Quad-chart Proposals (Deadline: Last day of Spring

quarter of the third year; students can set up meetings during Winter or Spring quarter of the 3rd year)

By the end of Spring quarter of the third year, students must construct a set of 3 approved “Quad-chart Proposals” (see attached template). These quad charts contain the key elements of original research proposals. All four quadrants of the chart must be filled in for each ORP topic. The student can use text and/or schematic diagrams and figures to illustrate their points in one or more quadrants. They cannot use more space than provided by the quad chart on 8.5x11” paper (with no smaller than 11-pt Arial font), as oriented in the attached template. A list of at least five literature references must accompany each quad chart.

IA. Choice of Topics for the Quad-chart Proposals. Each proposal should be for a focused research project that could be carried out by 1 – 2 graduate students or postdocs over ~2 years. Each quad chart should represent a distinct topic, not, for example, a larger topic split into three parts. In choosing the topics for the quad charts, the students should imagine that they are choosing topics for proposals for postdoc fellowships or faculty applications. Each topic must be an independent idea of the student. The topics can be related to the student’s area of expertise (more expertise usually leads to a more feasible and interesting proposal), **but should not be projects that their research advisor has addressed in the past, addresses currently, or would reasonably be expected to address in the near future as an extension of ongoing research.** A space is provided on the approval form for you advisor to certify that your proposals are independent ideas and satisfy the above criteria. The student can propose a topic in an area unrelated to his/her general expertise; however the student should realize that, in reality, to be considered for a faculty position or fellowship, he/she must be considered a credible principal investigator for the project.

For examples of Quad Charts, please see:

<http://www.chemistry.northwestern.edu/graduate/current/timeline/third-year.html#thirdyear>

IB. Approval of the Quad-chart Proposals. By the final day of the spring academic quarter of the student’s 3rd year, the student is required to have three quad-chart proposals approved by all of their thesis committee members (as indicated by their signatures on an approval form). This approval will occur through individual meetings of the student with each of his or her committee members (there is no full committee meeting in the 3rd year). During these individual meetings, the committee members will provide feedback on the quad chart proposals, and either approve three of them, or ask the student to revise them before approval, in which case additional individual meetings will be scheduled. Students can construct as many quad charts as they like, but the same three quad-chart proposals must be approved by all three members of their thesis committee (or four members, if they have two advisors).

The student should first obtain his/her research advisors’ signature *before* meeting with their other Committee members (if at all possible – in some cases, schedules will not permit this). If three quad-charts are not approved by the committee by the end of the spring quarter, the student will be declared to be not in good standing in the graduate program. The student’s committee can grant a modest extension of the deadline for completion of the quad-charts if it is clear that progress is being made.

We emphasize that (i) although the individual meetings with committee members are only intended to be 30 minutes long, the student should schedule these meetings 3 months ahead of time in order

to ensure that the student can meet the deadline, and (ii) these meetings can take place during either winter or spring quarter of the student's third year.

II. Topic Development: *ORP Outline* (Deadline: Last day of Winter quarter of the fourth year; students can set up meetings during either Fall or Winter quarter of their 4th year)

By the last day of winter quarter of the fourth year, the student will meet with his/her entire thesis committee at once to discuss the student's further development of one of the approved quad-chart proposals. By this time, the student should have chosen one topic (or something closely related), and written an outline of the ORP document (with format described below).

IIA. Format of the *ORP Outline*. The ORP outline needs to be detailed and well-thought-out enough such that the committee can assess the student's progress on the ORP, and can give the student helpful feedback on the further development of the proposal. The ORP outline will have 5 sections (**total maximum of 4 pages, 1.5-spacing, *excluding* tables, figures and references**):

(1) Title

(2) Scientific Objectives ("Specific Aims")

- bullet points that list the specific scientific questions to be answered

(3) Background, Previous Work and Significance of the Research

- bullet points that summarize the "intellectual merit" of the project: what it will do to move the field forward and further fundamental understanding. Why is this project new and important?

- bullet points (with citations) that demonstrate the student's thorough survey and understanding of the literature on the topic.

(4) Proposed Research

- bullet points that outline the general research plan for 2 years

- bullet points briefly describing possible challenges and contingency plans

(5) References (**at least 15**; not included in the page count)

- references should be the following format:

Journal articles:

Kramer, I.J.; Levina, L.; Debnath, R.; Zhitomirsky, D.; Sargent, E.H. Solar cells using quantum funnels *Nano Lett.* **2011**, *11*, 3701-3705.

Books:

Odian, G. Principles of Polymerization; 4 ed.; John Wiley and Sons: Hoboken, NJ, 2004.

Please see attached an example of an ORP outline

The ORP outline document must be turned in to committee members at least one week before the scheduled 4th-year committee meeting date.

II B. The Fourth Year Committee Meeting. During this meeting, the student should be ready to *lead* an organized discussion of his/her ORP outline, and to take notes on the committee's feedback

on the outline. The meeting is not a formal presentation, and the student is not required to present PowerPoint slides. (note this constraint when scheduling your committee). If the student feels that slides are helpful to communicate aspects of the ORP outline, **then he/she should prepare no more than 5 slides.** *The meeting should last no more than one hour.*

As stated above, the ORP outline document must be turned in to committee members at least one week before the scheduled 4th-year committee meeting date.

The recommendation of graduate affairs is for the student to begin the scheduling process at least 3 months prior to the desired meeting date. The 4th year meeting can take place during either fall or winter quarter of the 4th year.

The student passes this checkpoint if all of the members of the committee are satisfied with the development of the proposal and indicate so by signing a form prepared by the graduate program coordinator. Discussion of a student's progress on his or her thesis research during this meeting is not required, unless the student has any particular concerns or questions they would like to discuss.

III. Writing and Defense of the *Full Original Research Proposal* (Deadline: submitted with thesis)

Between the 4th year committee meeting and graduation, the student will develop their ORP outline into a full proposal (format detailed below) to be submitted as an Appendix to the copy of the Ph.D. thesis document that is submitted to the dissertation committee. By default, the proposal *will not* be included in the version of the thesis submitted to the graduate school, and therefore will not be published with the thesis. If the student and the advisor want the original research proposal to be bound with the thesis, the student must submit an explicit request to do so to the Chair of the Graduate Affairs Committee through a form available from the Graduate Program Assistant. The student has the option to allocate time at the end of his/her thesis defense to the proposal (5 minutes maximum in addition to time allotted for the defense presentation), but all students should be prepared to answer questions about the proposal at the thesis defense.

IIIA. Format of the Full Original Research Proposal. The full ORP written document will have 7 sections (total maximum of 13 pages, double-spaced, including abstract and figures, but excluding references):

(1) Title and abstract (1 page)

-The title and abstract should be descriptive of the total document

(2) Introduction, Background, and Significance of the Research

- should include the "intellectual merit" of the project: what it will do to move the field forward and further fundamental understanding. It should also demonstrate the student's mastery of the literature in their field

(3) Scientific Objectives ("Specific Aims")

(4) Previous Work (no fewer than 2 full pages, including figures and tables)

- a summary of the literature on the scientific topic

- (5) Proposed Research (no fewer than 6 full pages, including figures and tables)
- a research plan for 2 years, including general objectives and specific experimental or theoretical plans.
- a brief description of contingency plans

(6) Summary and Conclusions

- (7) References (as many as appropriate, not included in the page count)
- references should be the following format:

Journal articles:

Kramer, I.J.; Levina, L.; Debnath, R.; Zhitomirsky, D.; Sargent, E.H. Solar cells using quantum funnels *Nano Lett.* **2011**, *11*, 3701-3705.

Books:

Odian, G. Principles of Polymerization; 4 ed.; John Wiley and Sons: Hoboken, NJ, 2004.

The student decides how to partition the document between text and figures, but should note that figures should not be seen as a replacement for text (i.e., the text must be a complete narrative). All text must be 12-point, Times New Roman, and double spaced. Pages must be numbered starting with the title/abstract page.

K. REGISTRATION REGULATIONS

I. Each course (except research and independent study) is one unit, and registration for either three or four units constitutes full-time registration. Normal registration is three or four units for the first quarter and four units thereafter, including 1-4 units of research. The minimum period of study for the Doctor of Philosophy degree is eight full-time consecutive quarters including summer.

II. Grading System Regulations:

The Chemistry Department uses an A, A-, B+, B, B-, C+, C, C-, F grading system for internal use. A student's GPA is determined using this grading system. Registration for 500 is an exclusive type of registration in that concurrent registration for any other course is not permitted. Letter grades are required under the following circumstances:

1. For the first nine courses with numbers below 460 taken as a graduate student at Northwestern and for all core courses.
2. For Research Seminars (570 – 578) whenever necessary to fulfill full time registration status if required courses or appropriate electives are not available, as well as to replace waived courses (see Waived Courses in Section B above).

The P/N option is to be used as follows:

For research 590. After the first quarter, each student is expected to register for their advisor(s) research each quarter until time for registration for Post-Candidacy Research.

III. All students who are receiving financial aid of any kind from any source must register as full-time students. For the purpose of this regulation, a full-time student is one who is registered for 3 or 4 courses or units, or one registered for TGS 500 (Advanced Doctoral Study). Deviations from this regulation are allowed only with the written permission of the Chair of the Department and the Dean of the Graduate School.

IV. Students who have completed eight quarters of full-time registration consecutively over two years, including summer, are expected to register for TGS 500 (Advanced Doctoral Study) for every succeeding quarter in which they are in residence. After admission to candidacy for the Ph.D. degree, a student in residence must register in some appropriate way in every subsequent academic quarter until all degree requirements, including the final examination, are completed.

V. The Graduate School offers the TGS 512 (Continuous Registration) for students not being paid a stipend but who are in good standing and are continuing toward the Ph.D. degree. This requires that the student pay the quarterly tuition of \$100.00, which allows the student to maintain full-time student status with access to email and health insurance.

L. DISSERTATION

Each student must complete an original research study and produce a dissertation acceptable to the faculty research supervisor and the Thesis Committee. For students entering in September, thesis research begins in the Winter quarter of the first year of graduate study and continues until a satisfactory thesis has been completed.

M. FINAL ORAL EXAMINATION

The completed dissertation is submitted at least **two weeks** prior to the scheduled date of the oral examination to the student's dissertation committee. Ordinarily the examination is concerned primarily with the contents of the dissertation, but it may include more general questions as well. The examination on the dissertation will be announced and open to the public, but the examining committee has discretion to exclude the public during part of the examination for additional questioning of the candidate.

N. GRADUATE AFFAIRS ISSUES

During your time in the Ph.D. program, your first point of contact for graduate program questions or problems (examples: course work, advisor placement, or lab environment) is the graduate program assistants in the chemistry main office (Tech K148). All conversations with the program assistants are confidential. If a resolution or answer cannot be provided through the main office, the students will be directed to the Graduate Affairs Chair for further assistance. All conversations with the Chair of Graduate Affairs are confidential to the direct parties involved.

O. APPEALS AND PETITIONS

Although most doctoral candidates are normally expected to fulfill all of the foregoing requirements, the faculty recognizes that deviations are not only warranted but even desirable in certain individual cases. Students are encouraged to submit petitions requesting a variation in the requirements whenever they believe that they can adequately justify their request. All such petitions should be directed to the Chair of the Graduate Affairs Committee. The graduate program assistant should be copied on all communication with Graduate Affairs.

P. FINANCIAL CONSIDERATION

Continuation of financial support is conditional upon satisfactory progress toward the degree. Payment of excess tuition beyond the cost of registration for post-Candidacy Research will not continue past nine quarters of full-term registration. A student receiving financial support through the Department may not undertake outside jobs or consulting without the prior approval of the Chair of the Department, the Graduate Affairs Committee, and his/her Research Adviser. A student cannot enter into patent agreements without the University's prior written approval.

It is Department policy to continue the support of all graduate students making satisfactory progress toward the Ph.D. degree for up to 16 quarters (four calendar years). In cases for which additional time for completion of the thesis research is necessitated by the nature of the research project, the student may petition by no later than August 31 of the 4th year to the Chair of the Graduate Affairs Committee for continued support for a period of time not exceeding one year. Such requests will normally be granted if endorsed by the thesis adviser. Additional requests for support beyond the period initially requested will be assessed on a case-by-case basis.

In all cases in which months, quarters, or years are used in stating above deadlines, a summer quarter preceding entry into the regular graduate program in September will not be counted. Thus, a new student who joins the Department in June will be considered to have entered in September.

I, _____, have read and fully understand the document entitled "REQUIREMENTS FOR THE DOCTOR OF PHILOSOPHY DEGREE IN CHEMISTRY" that became effective on 1 September 2012 for Northwestern University's Department of Chemistry. I agree to abide by all requirements and other terms set forth in the document.

Signature: _____

Date: _____

Students are responsible for a complete understanding of these guidelines. If you have any questions, please contact either the Graduate Program Assistant or the Chair of Graduate Affairs.

Return signed and dated form to the Graduate Program Assistant by September 28, 2012.