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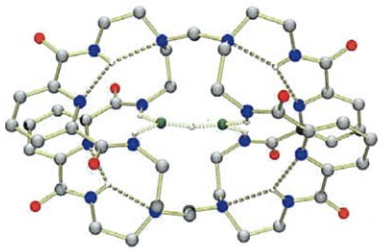
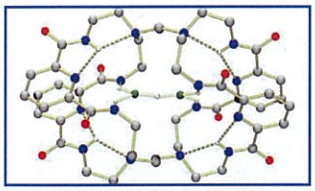


Planning for Graduate Work in Chemistry

Eighth Edition — 2010

Cover Images



Encapsulated Bifluoride Structure Courtesy of K. Bowman-James

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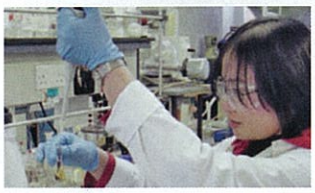

Photo by Michael Freemantle

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Introduction

Graduate work in chemistry is challenging and requires a serious commitment of two to five years of study, a lively sense of curiosity, and a strong work ethic. If you find research and scientific discovery fascinating, then graduate work might be the right path for you.

- Are you self-motivated?
- Do you enjoy scientific challenges, research, and discovery?

Photo courtesy of
the American Chemical Society

Before you decide:

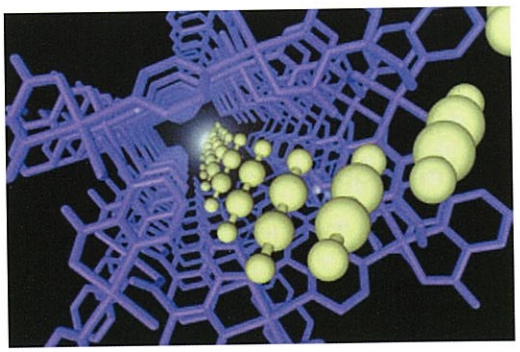
- Think about what you want to accomplish and what you enjoy.
- Consider your own particular talents in relation to what is required for success in graduate work.
- Talk with an advisor, a faculty member, or a friend who has graduate work experience.
- Participate in summer internships and undergraduate research projects to find out whether research or a career in the applied sciences is right for you.

To succeed, you must be:

- Willing to try new things
- Committed to hard work
- Prepared to define and achieve your own goals

Chemistry Careers

A career in chemistry is challenging … and rewarding. Understanding chemistry is the key to a scientific career in any sub-discipline. As an undergraduate student in chemistry, you probably already know that chemistry is the central discipline that:



Metal-Organic Microporous
Material Courtesy of S. Kitagawa

- Provides a molecular vision of science
- Links materials science to physics, the biological sciences to medicine, and geology to astronomy.
- Underlies much of the world's business and commerce.

Some excellent links to career information include:

- ACS What Chemists Do[1]
- Science Careers[2]
- U.S. Department of Labor[3]
- Chemical Careers Insights[4]
- Biomedical Careers in Industry: Part I[5] and Part II[6]

Your Education

Undergraduate Preparation

You actually began preparing for graduate school on the day you entered your undergraduate program! So … you are already well on your way.

While completing your undergraduate degree, you should take a range of courses, spread over all of the subdisciplines in chemistry. These foundation courses allow you to develop your knowledge, integrate the various chemistry subdisciplines, and further your own passion for chemistry. Increasingly, undergraduate chemistry programs are encouraging their students to develop specialties after they complete their introductory and foundation coursework by completing a specialized degree track. Some programs even collaborate with local industries to form highly specialized apprenticeship programs.

ACS-approved undergraduate chemistry programs[7] provide an excellent introduction to the field of chemistry. Completing the ACS certification degree requirements at the same time as your undergraduate degree provides an excellent background for career advancement and graduate research. Get as much lab experience as possible, either in lab courses or in research--hands-on learning is how most people learn best.

Graduate school admission committees look very favorably on undergraduate research experience.

Many institutions have summer research programs for undergraduates. There are also internship opportunities in government research and the chemical industry. You can find out about these opportunities online at the NSF[8] website or at your departmental office. Another source is the ACS Directory of Experiential Programs in Chemistry,[9] a searchable database of internships, co-ops, summer work, and fellowship opportunities for undergraduates in the chemical sciences. Most of your time as a graduate student in chemistry will be spent performing research within the research group of a faculty member, who will serve as a research director. Research, however, entails more than just performing experiments. You will study the chemical science literature, plan experiments, interpret results, and communicate your own research findings to your peers and the global scientific community.

Communication and Time Management Skills

As a scientist, you will need to communicate your research findings. Poor communication skills, or an inability to work with others, can derail a career fast. Skill comes with practice.

Mastery of a foreign language will become more important as we move toward a global economy. Good communication skills (and the more languages the better) offer a tremendous advantage in almost every industry. Attaining basic fluency in another language can lead to international travel and exciting career possibilities in your field.

Technical Skills

Depending on your research interests, it will be necessary to take additional advanced course work in the sciences, mathematics, statistics, or the computer sciences. This course work will depend upon the skills you need to further develop your research interests. In general, you will need effective problem-solving, teamwork, and communication skills as well as extensive scientific knowledge to join a research group. It is important to acquire applied skills in word processing, database searching, spreadsheets, and molecular modeling during your undergraduate work.

The Master's Degree

The Master of Science or Master of Arts degree is generally not a prerequisite for the Ph.D. degree. Many people opt out of graduate school programs to pursue careers enhanced by advanced level training in chemistry. Programs are available for working adults as well as full-time students and can exist as the traditional classroom/lab environment, on-line only, or as virtually any combination of the above.

Automated Synthesizer
Photo Courtesy of KU University Relations

Considerable variation exists among Master's Degree programs; they may require research, a library thesis, satisfactory completion of graduate level coursework or a combination of all three options. These can be very targeted, applied programs with employers paying the bills or they may have a more developmental approach.

Earned in two or three years, the Master's degree is useful in careers requiring chemistry knowledge applied over a variety of settings such as patent law, government work, national defense, and private industry.

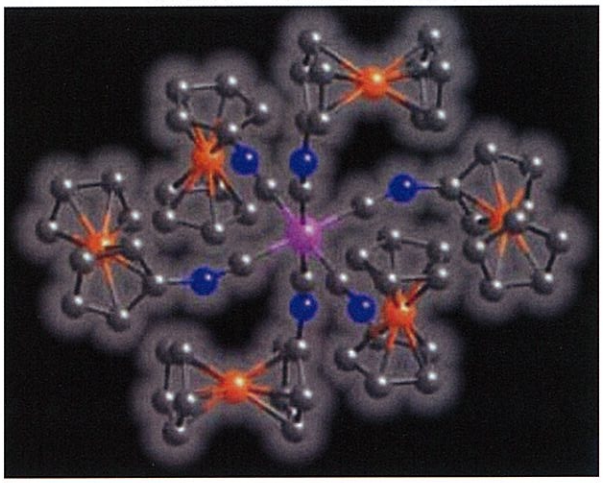
Tip!

There is considerable variation from one academic program to another in master's degree requirements. Be sure to check the requirements at the school you choose for your work before you commit to a degree program.

The Commission on Professionals in Science and Technology (CPST) provides information about master's education in science, mathematics, and engineering.[10] The CPST also maintains a database of master's programs,[11] which lists chemistry master's programs in colleges and universities across the U.S.

The Ph.D. Degree

The doctor of philosophy (Ph.D.), awarded for demonstrated proficiency in original research, usually takes about five years to attain. A Ph.D. program is designed to develop critical thinking skills and provide a template for creative scientific problem solving. This training lays the foundation for professional research in industry, government, or academia.



Homoleptic Isocyanoferrocene Complex
Courtesy of Mikhail Barybin

Once you establish the groundwork by gaining your Ph.D., you can lead research projects of your own and help develop new knowledge; the opportunities are almost unlimited. Although many Ph.D. graduates go directly into the workforce, others choose a post-doctoral experience prior to permanent employment. Postdoc opportunities were described recently in a series of articles published in "Science Careers."

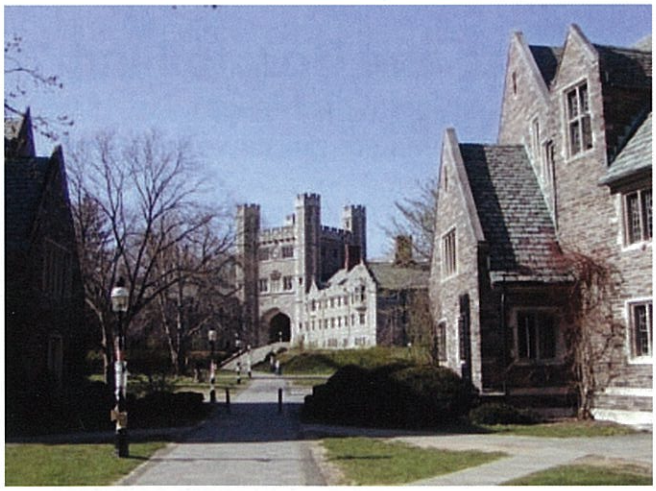
- "Independent Postdocs, Part 1: Gaining Early Autonomy"[12]
- "Independent Postdocs, Part 2: On the Ground Experiences"[13]
- "Independent Postdocs: Resources"[14]

Choosing a Graduate Program

In General

So… you have decided that graduate school is for you. But now you wonder which program you should choose? You are right! No two schools are exactly alike. Use online resources, email, and advisors to identify several schools with at least three professors each with whom you would like to work. Your choice of institution will depend on the following factors:

- matching your interests with those of the faculty,
- possibilities for future employment,
- location of the institution,



Princeton University

- financial aid, and
- admission requirements.

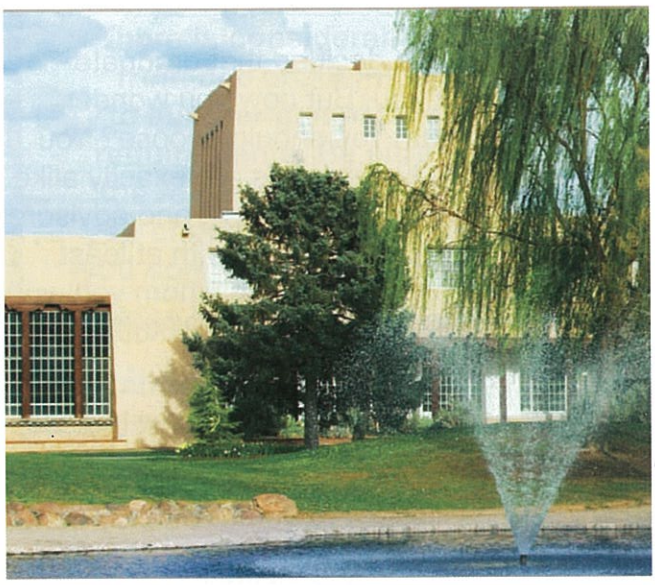
Determine the requirements for admission to all institutions that you are interested in and apply as soon as possible. This should be done 10–12 months before you expect to attend graduate school. Particular departments and their admission policies can be found on the web.

Frequently Asked Questions

- Does the faculty exhibit special strengths and research qualities through their graduate advisees, published work, and funded research?
- Are the libraries, laboratories, computers, and other research facilities adequate for your educational needs?
- Do employers seek the graduates of the school or program?
- Does the department offer a sufficiently large and varied curriculum to allow you a broad offering of courses and options?
- Are potential advisors likely to have a place in their research group for you?
- What are the degree requirements?
- Is financial support available?
- Does the financial aid offered support your lifestyle?
- How long will it take to complete the program?
- How are mentors assigned? Will you have a choice of mentors?

Where and How to Find Answers

- Talk with other graduate students. Find out what they like about their schools, departments, and research group.
- The Survey on Doctoral Education and Career Preparation[15] is a national survey of graduate students from 1999. Candid comments collected from chemistry graduate students offer advice to potential graduate students.



University of New Mexico – Albuquerque

- Consult the ACS Directory of Graduate Research,[16] a comprehensive source of information on graduate programs in chemistry and related areas. You can use this directory to find out about the individual professors whose work appeals to you.
- Search the Internet for graduate school department websites and individual faculty web pages.
- Visit or take a video tour of your prospective institutions to find out whether they have adequate facilities and resources to allow for meaningful research projects.
- Find out whether the schools of interest have at least three professors each with whom you would like to work (the Rule of Three).

Tip!

Approach the selection process with an open mind. You should realize that your plans to study with a specific professor might not materialize. For example, the faculty member you have selected may find it impossible to accept new students at the time you are ready to begin your research. You may also change your mind about your initial choice after visiting the department, or as your training advances.

- Do not automatically commit to a graduate school simply because it has offered you a large stipend or other inducements.

Examining the Options for Graduate School[17] was recently the focus for "inChemistry," an ACS publication for undergraduate students.

Choosing a Graduate School Mentor

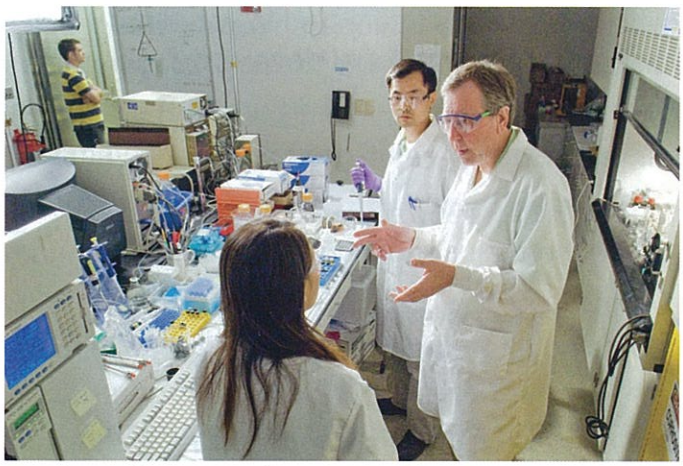


Photo Courtesy of The University of Kansas University Relations

When you become a graduate student, you will need to choose the person who will direct your Ph.D. dissertation research. Building a strong relationship with your research mentor can be one of the most rewarding experiences of your academic career. In some institutions, the selection of a mentor is directly linked to the admissions process. In others, you will choose a research mentor after you have joined the department, usually by the end of the first semester.

Choosing the Right Mentor

The chemistry professional you choose as a mentor will have an enormous developmental impact on your attitude, skills, and insights. So how should you choose the mentor that will not only direct your research, but also help you grow professionally in various directions? Here are some considerations:

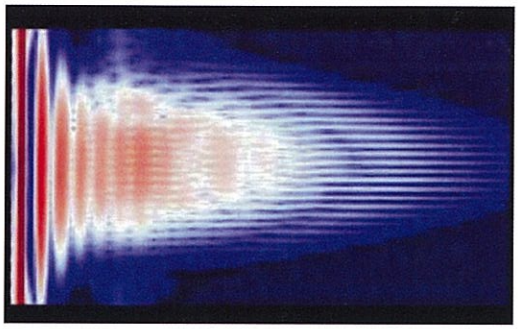
- Choose a research area that is interesting and challenging to you.
- Look around the department to see whose personality and research goals seem to be most complementary with your own.
- Talk first with students working with the mentor you are considering. Talking with other students will give you a sense of what your life will be if you choose to join their research group.
- Relationships develop with time and work; do not rush into any relationship.
- What is the size of the graduate group?
- Would you enjoy a small, intimate research group or a more complex interplay of personalities?
- Are your potential mentors readily accessible and can they provide constructive feedback?
- You will want to find an advisor who understands the balance between providing close direction of your research and facilitating independent thinking.
- It is important to choose someone who is genuinely interested in you, your intellectual development as a scientist, and your emotional development as a person.
- How often does the professor in your proposed research group publish?
- What is the condition of the laboratories? While people count more than infrastructure, facilities also matter since the majority of current research demands state-of-the-art instrumentation.
- Where do most of the graduate students go after completing their PhD? What are the employment opportunities afterward?

Tip!

Do not panic if relationships fail to work out as you anticipate. Relationships take time and support to develop. It is better to lose a little time in selecting an advisor — or changing an advisor — than it is to persevere through a mismatch.

Be flexible and talk with several professors whose work interests you. Having a choice of mentors is important because you will be growing both intellectually and emotionally and your needs will change. For more information, see Choosing the Right Research Advisor[18] or Finding a Mentor.[19]

How Faculty and Administrators Play a Role in Choosing a Mentor



Spectrum of High Order Harmonic Generation of Molecules in Intense Laser Field courtesy of S-I Chu

Some schools use rotations to help students determine their course of graduate study and choice of research mentors. Upon entering graduate school, a student will spend several months working with various professors and research teams to get a sense of the options available before stepping into their own program of study.

While your research mentor is of crucial importance to your graduate career, you will also need to become familiar with the research of other members of the department. They will also play an important role in your intellectual growth and development. An advisory committee is often established once a match is created between a graduate student and a research director. The faculty on this committee provide the student with advice on issues ranging from research to academic courses to professional opportunities.

Make sure the chemistry department you wish to join represents your field of interest. Does the intellectual climate, vitality, and spirit of cooperation within the department suit your needs?

Applying for Graduate School

In General

The majority of graduate school departments have extensive websites as well as mailed advertisements of their graduate programs. You can also write to the Graduate Admissions Officer of the department that interests you. Ask questions about such things as course requirements, types of qualifying examinations, or specific research opportunities.

Do not be bashful! Email the Director of Graduate Admissions and request any information you may need! Let them know you are interested in their work, and you will get answers.

Tip!

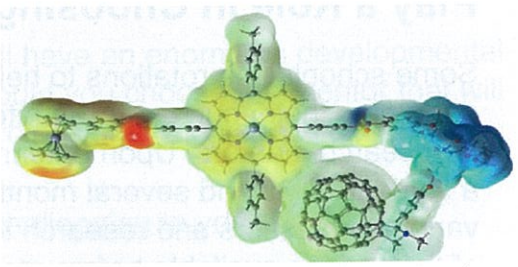
The name that appears on your graduate school application should be IDENTICAL to the name which appears on your passport if you are applying for graduate school from outside the continental U.S.

Applications

Many departments start to consider graduate school applications during the fall semester. Most try to be finished with their decisions by late winter or early spring. You should begin making inquiries early in the fall semester, and submit your applications before the end of the calendar year.

Your Undergraduate Record

Achieving a distinguished undergraduate record from a good institution with high academic standards generally guarantees admission to graduate school. If you have graduated with less than impressive grades, however, keep in mind that motivation and creativity will also go a long way toward a successful application. Develop a plan and use your best creative thinking to develop implementation strategies (i.e. get someone else to pay for it!)



Donor-Acceptor System Courtesy of F. D'Souza

Letters of Recommendation

Required letters of recommendation from people acquainted with your work are often a particular help in allowing an admissions committee to see you at your best. It is especially helpful if the letters identify an aptitude for research and a well-rounded background.

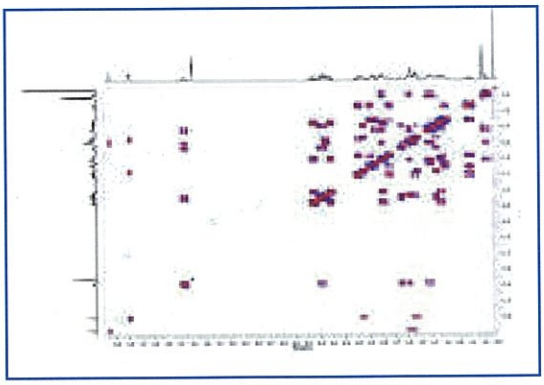
Recommendations regarding your knowledge, skills, and abilities from people you have worked with during undergraduate research programs, or a summer job in a chemistry-related field are especially important for admission into graduate school. Teachers who have been particularly impressed with your critical thinking skills or your writing ability are also good choices from whom to request a letter of recommendation.

Essays

If the graduate program of your choice requires the submission of an essay, do not neglect it! To write a good essay, you must:

- Take time with your writing. Although this is not an English assignment, spelling and grammar count!
- Think creatively. What are your strongest assets?
- Ask friends or teachers to review your application before you submit it.

For more information on how to write a winning essay, get some expert advice from The Center for Communication Practices at Rensselaer.[20]



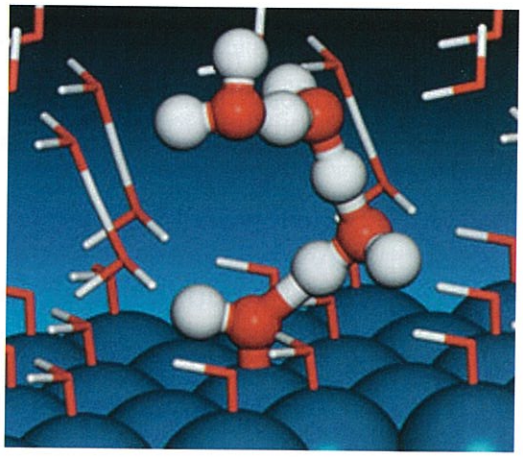
Double Quantum-Filtered COSY spectrum of Cholesterol Courtesy of C.K. Larive

Submitting Your Application

When you think you are ready to drop your application into the mailbox (or press the SUBMIT button) do not forget to check (and double-check!) and have someone else check that you have included all the materials required for the application. Make sure to submit it by the deadline listed!

Communication Issues

It is important to note that individual faculty members do not normally have the authority to admit you to graduate school. This decision is typically assigned to a committee working with the admissions office. Most institutions make their admissions decisions and expect a response from successful applicants by mid-April. You are likely to hear one way or the other by mid-May. You should make your choice as soon as you can, and inform all of the institutions to which you have applied about your decision. It is NOT acceptable to give a positive response to one institution's offer and then turn it down later if "something better" comes along.



Testing

Taking the GRE/TOEFL Exam

The Graduate Record Exam (GRE)[21] is required for admission to most graduate programs in chemistry. Please review the specific test requirements for the school to which you are applying. You may request to have score reports sent to your schools when you take the test. Test prep courses and tutoring are available on-line as well as at various locations.[22]

In most cases, the verbal and quantitative GRE examinations are required. The general GRE is offered in both electronic and paper form. Informal scores are sometimes available at the test site before you leave, but be sure to allow approximately six weeks for score reports to reach the desired institutions.

Some institutions also require chemistry subject area examinations. The Subject Tests are given at paper-based test centers worldwide in October, November, and April.

Tip!

If you take the GRE multiple times your score reports will contain all of your scores.

Score reports are mailed to the schools upon your request approximately six weeks after the test administration date.

For students who speak English as a second language, most institutions generally require the Test of English as a Foreign Language (TOEFL).[23]

Both the GRE and the TOEFL tests should be taken before the end of December of the senior year so that the results will be available by the following February. Many students find it advantageous to take these exams during the summer prior to their senior year of study so they have time to re-take the exam if necessary. Please check with the school that you hope to attend to find out the best time to take the GRE/ TOEFL to meet your deadlines.

School Visits

Once you have selected several graduate chemistry programs to consider, you should visit them. It is good manners to inform schools in advance regarding your plans so they can arrange appointments for you to meet with faculty and graduate students in your areas of interest. Some departments prefer to host prospective students individually, while others host organized events to which they invite selected students interested in graduate work at their institution. Most schools are flexible and will accommodate any special requirements you may have. Please contact the graduate school administration for specific information on each department. Here are some points to consider:

Tip!

Many institutions are prepared to assist you in financing site visits. Try to incorporate visits to several institutions in a single trip.

- What are the funding sources in the department? Some sources of funding are more stable than others.
- Where do graduate students go after leaving the department? What are the employment opportunities afterwards?
- What financial packages are available? Schools often fund graduate studies through research assistantships or teaching assistantships. Which do you prefer?
- Allow time to talk candidly with graduate students. They are a good indicator of what life is like in any particular department and research group.

Visits help assess important differences in educational, cultural, and socio-economic environments. Are you going to enjoy and learn from this experience?

Financial Support for Graduate School

Assistantships and Fellowships

Teaching assistantships, research assistantships, and fellowships generally include tuition waivers or allowances in addition to a stipend that is usually sufficient to support a healthy lifestyle. Some departments provide financial assistance only during the academic year while others provide support for a full calendar year. You should be especially attentive to the financial details of the offers extended to you. Please consider the following points:

Tip!

A graduate program may offer financial support during the summer before you start your program. This is a great opportunity for you to get acquainted with your new department and begin your research.

- Check on the requirements of the specific department that you choose. Some graduate schools require teaching experience as part of their programs.
- Summer research opportunities exist everywhere. There is no obligation for you to select that person as your research mentor so use the opportunity to gain additional experience. Check with your graduate school on the details of your financial aid package.

It is the bottom line that is important: your stipend, minus the fees that will be counted against the stipend — either directly or indirectly — such as health care, state and local tax (if any), tuition, cost of living, housing, etc.

Graduate Teaching Assistantships

Photo Courtesy of R. Hanzlik

At many U.S. institutions, initial financial support is provided in the form of a Graduate Teaching Assistantship (GTA.) If you speak English as a second language, you must achieve a minimum score on the TOEFL Internet-based Test (TOEFL iBT)[23] or the International English Language Testing System (IELTS)[24] to be eligible for this kind of financial aid. Institutions may require prospective GTAs to take an education course or attend a teaching workshop before getting an appointment. Institutions may also require you to take a speaking proficiency exam during on-campus orientation prior to gaining authorization to teach in the classroom. Be sure to ask about this when considering different graduate programs. Many institutions provide students with important information about how to prepare for this campus examination and can provide you with sample questions to help you become familiar with the testing format.

Teaching assistantships provide valuable management experience and an opportunity for you to work with undergraduate students, exercise your knowledge and understanding of chemistry, and associate with experienced teachers as well as other graduate students learning to teach. ACS publishes And Gladly Teach[25], which describes the teaching profession at all levels: from kindergarten to graduate school.

Teaching experience provides such valuable management experience, it is often required for all graduate students.

Research Appointments

Some departments offer first-year research appointments as a way of attracting especially well-qualified graduate students. These appointments are often prestigious and very enticing, but accepting an appointment means that you will not be teaching. If you want to gain teaching experience as a graduate student, this should be done at the beginning of your graduate career.

Tip!

Graduate stipends allow you to be paid for doing something interesting but they must also help you to meet your own goals.

Timeline and Checklist for All Students

First Semester of your Junior year:

- Gain research experience in the lab.
- Study for the GRE and any GRE subject area tests required by your institution.

Second Semester of your Junior Year:

- Talk with advisors and friends about graduate school opportunities and decide whether graduate school is the right path for you.
- Take the GRE.

First Semester of your Senior Year:

- Identify prospective programs.
- Apply for graduate school. Follow the guidelines so your applications are complete.
- Apply for financial aid. This may be a process separate from applying to graduate school. Follow the guidelines so your applications are complete.
- Send an OFFICIAL copy of your college transcripts to the institutions you have selected.
- Take the GRE again if necessary. Request that the score results be sent to the institutions to which you are applying.
- Take a video tour of the institutions to which you are applying if possible.
- Check with the institutions to which you are applying in January to make sure that all of your required information is complete.

- Admission decisions are usually made by April 15:
- Visit the institutions you are considering.
- Investigate financial support.
- Make your decision. Please inform your institutions about your decision as soon as possible.

Additional Timeline and Checklist for International Students

Tip!

Most graduate schools in the U.S. begin in late August or early September.

U.S. colleges and universities have long recognized the important contributions of international students to scientific and cultural life in the United States, but the immigration process can be difficult! Please allow time to complete this process — you are most welcome in the United States and its graduate programs! An excellent source of VISA information is the U.S. State Department website,[26] which is available in several languages. Regional advising centers are also listed.

As an international applicant, you will need to begin planning more than a year prior to the start of graduate school.

June-August (More than one year before you want to start graduate school.)

Take the TOEFL iBT if the institutions to which you will be applying require it. Check the institutional requirements of your prospective graduate schools for additional tests of spoken English. Often, the tests of spoken English are only offered on-campus upon arrival for new student orientation. Admission to and financial assistance for graduate programs will not be granted until the results of the required examinations are received which may take several months. Sign up for these exams 4-5 months before you need to submit the results. Score reports are available on-line approximately 15 days after you take the test. This varies by country. Most score results must be submitted to your institutions by February if you intend to begin graduate school in September. Please check with your institutions since requirements for individual universities may vary.

Recruiting tours and fairs with many different universities are held in various places around the globe. Fair location, dates, and times are organized through the U.S. State Department and offer excellent opportunities for students to meet with representatives from U.S. colleges and universities.

After You Have Been Accepted to Graduate School

Your VISA Application

After you have indicated your intention to enroll, your graduate admissions program will submit information to the Student and Exchange Visitor Information System (SEVIS).

SEVIS is an on-line government database for recording information related to your program of study and U.S. immigration status. The institution will provide you with a Form I-20 (F-1 visa) or Form DS-2019 (J-1 visa). If dependents, such as a spouse or children, are accompanying you, then you will be required to provide the institution with the necessary information for the SEVIS database so that they will also be eligible for visas. The advantages, disadvantages, and eligibility for these two different types of visas are complicated. Please consult with an advising center at the U.S. State Department and/ or your university's international student office since procedures, regulations, and center locations are updated regularly. You must be fully prepared for your interview since the consular or embassy officer responsible for immigration will make a decision based on your specific case at that time.

In Approaching Your Interview

- You will need to pay a $100 SEVIS fee after receiving Form I-20 or Form DS-2019 and prior to your visa interview. (Students unable to show a receipt of payment will be immediately turned away from their visa interview.) Addditional information about this fee can be found at the U.S. Immigration and Customs Enforcement[27] web site.
- Plan your interview as far in advance as possible. It may take longer to get the visa depending on the country. You should do this at least two months before your scheduled departure to the United States, but this process can take much longer. All inconsistencies and incomplete information must be addressed before a visa will be granted. Additional information about visa processing times can be found at from the U.S. Department of State Bureau of Consular Affairs[28] web site.

During Your Interview

The immigration officer will be looking for evidence that you intend to return to your home country upon completion of your degree. ***This is required if you wish to be granted a student visa.*** F-1 and J-1 student visas are both temporary visas designed to enable study (not long-term employment) in the United States.

Bring all documentation to your interview. This may include:

- Your I-20 or DS-2019 form (also referred to as the Certificate of Eligibility).
- Test scores
- Letters from faculty members at the institution you will be attending

- Official letter of graduate admission
- Valid passport
- Extra passport photos
- Be ready to state how a graduate degree from a U. S. college or university will aid in your professional advancement.
- Provide evidence that you can support yourself and your family (if your family is accompanying you) once you reach the U.S. This could include:
  - Bank account statements
  - GTA offer letters
  - Signed letters of financial support from sponsors
  - Grant notification letters
  - Affidavits of support from family with accompanying bank statements

Check with your school's international office to determine how much you will be allocating for living expenses each month for yourself and your family members. This varies across the U.S.

The U.S. State Department can schedule visa interview dates at your nearest U.S. Consulate if you email them. While academic visas are given the highest priority at U.S. consulates, the summer is also the busiest time for these offices. Apply early for your interview.

As You Get Ready to Depart for the United States

Get Ready to Go[29] contains useful pre-departure information which is continuously updated by the U.S. State Department.

Participation in the school's international student orientation program is mandatory to maintain your visa. All schools must provide these programs for their international students if they have issued Certificates of Eligibility through SEVIS. To maintain your visa status, be sure to also report your arrival to your institution's Office of International Programs.

When to Start

Most graduate schools begin in September, but some departments will accept mid-year applications. Departmental policies, requirements, and application processes, however, may differ substantially from those required for fall applications. Ask your graduate admissions office for further details.

American Chemical Society Poster Session

Making the Move

Practical matters now require your attention:

- As you make your travel plans, please remember there may be graduate school orientation sessions scheduled prior to the start of classes.
- Advise your new department of your travel itinerary. Networking on the web is an important professional skill to develop and many opportunities will arise. There will be people both on-site and on-line eager to help you.
- Housing arrangements
- Transportation requirements
- Cell phone coverage in your new region
- Department examinations may be required for appropriate program placement. Examinations are usually in the traditional areas of chemistry: analytical, inorganic, organic, physical chemistry, and biochemistry. Many graduate departments can refer you to standard textbooks to help you prepare.

Tip!

Contact graduate students already in your department for aid in preparing for entrance exams and answering lifestyle questions like, "How do I get from the airport to my housing?"

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