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Tenure Evaluation Statement

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Jay Baltisberger  
Tenure Evaluation Statement

Introduction

I have taught at Berea College for just over six years and during this time I have tried to improve the teaching of my courses and implement an active research project in the area of physical chemistry. In this document, I will detail various areas of activity I have undertaken during this period (teaching, research and service), the successfulness of these activities and a summary of future goals and plans over the next five to ten years. In particular I will demonstrate in this portfolio that I have achieved the five criteria listed below in order of importance, from the faculty manual:

1. Excellence as a teacher, involving knowledge of one’s subject and its relation to other fields of study, and a proven capacity to inform and stimulate undergraduates.
2. Continuing professional growth, reflected in research, scholarship, or creative work that contributes to teaching effectiveness.
3. Ability to help students toward personal maturity, using such means as academic advising, informal counseling, student activities, and labor supervision.
4. Constructive participation in College governance.
5. Service to the wider community at the local, regional, national or international level.

Of these criteria, teaching excellence is of greatest importance; because of this, we should be careful to define excellence. The following sections will describe my performance on each of these measures, focusing primarily on the first.

Teaching at Berea College

In this section I will primarily discuss the first of the five criteria for tenure, that of teaching excellence. First, I will describe the courses I have taught at Berea College, followed by a description of my general teaching philosophy as well as a discussion of the criterion “excellence as a teacher.” Finally, I will then discuss how in each individual course I have achieved the level of excellence called for in the faculty manual.
Courses Taught at Berea College

I will address individually the efforts I have made at Berea College to achieve my teaching goals in each of the courses I have taught, including:

- Natural Science (GSTR 232)
- Fundamentals of General and Biological Chemistry (CHM 113)
- General Chemistry I: Structure (CHM 121)
- General Chemistry II: Dynamics (CHM 320)
- Thermochemistry (CHM 361)
- Quantum Chemistry (CHM 362)
- Special Topics (CHM 486, Advanced Quantum Mechanics and NMR Spectroscopy)
- Senior Seminar (CHM 492)

During the Short Term I have taught several courses across a variety of disciplines, including a theater literature course (THR 177), a FORTRAN computer programming course (CSC 120), physical chemistry research (CHM 265), and instrumental analysis (CHM 442, a regular departmental offering taught during Short Term due to sabbatical needs). The regular departmental offerings I have taught are comparable in content and degree of difficulty to the chemistry courses taught at most universities and colleges. The special topics course (CHM 286) in nuclear magnetic resonance spectroscopy (NMR) and advanced quantum mechanics is one I have designed as an upper level course to follow CHM 362. In this course, the students learn advanced quantum theory and its application to magnetic resonance. This introduces Berea students to one of the most important techniques in physical and biophysical chemistry: Nuclear Magnetic Resonance (NMR). I am satisfied with my overall progress in each of these courses based on my examination of the entire record of student evaluations, peer review comments, and personal reflection of each of the courses I’ve taught.
Teaching Philosophy

The first step in evaluating my teaching is to understand my teaching philosophy. My primary goal in teaching is to initiate students into a process of continued learning. When I say continued learning (or lifelong learning), I am referring to the kind of goal described in Being and Becoming. In particular, the goals of developing critical thinking skills, understanding science and technology, and becoming creative and independent thinkers and learners resonate closely with my teaching philosophy. Of course, my role in this educational process is somewhat different for non-majors than for chemistry majors. For non-majors, the goal is to offer the breadth of both basic and applied knowledge necessary to look critically at the world and to make some sense of the wide array of chemical concepts they encounter on a daily basis. For chemistry majors, my task is to provide a much deeper understanding of chemistry and related subjects so that the students graduate with the skills and desire to push forward the frontiers of knowledge and share this desire and knowledge with others. For both groups, communication skills are a critical element in my teaching goals since our world has become so intertwined and interdependent. An example of this kind of communication need is seen in the current proposals by the US Army to incinerate nerve gas at the Blue Grass Depot. All participants to some degree have failed to communicate the scientific facts of the case to the general public in a way that the public can understand them. This case is truly interdisciplinary, mixing biology, biochemistry, chemistry, physics, earth science, political science and psychology in presenting a complete picture of the risks and facts surrounding the incineration question. In addition, an historical perspective on all course material is important and since the lessons of history are often repeated, sometimes to the detriment of society. The goal of integrated science education is one that I stress over and over in all of my courses. I believe with the interdependence of so many fields in science comes a responsibility for educators to help
make links to all areas that overlap their own. Another way to describe my philosophy is that I want the students to leave my classes not only with concrete knowledge of chemistry but more importantly with questions about the topics covered and the desire to continue to pursue these questions.

In terms of the execution of my philosophy in general, I believe there are many specific tasks and activities that a faculty member can perform to achieve the goal of continued learning. I am convinced that first and foremost a faculty member has a responsibility to be available to help students on a daily basis. I have always kept my office door open and have invited students to come ask questions any time. In addition, by working with my office door open the students can observe me as I perform my daily tasks which include continued learning by myself. To see me engaging a problem on the computer, reading a scientific text or paper, or grading student assignments teaches the students by being a role model. When we work a problem together in my office they learn that I don’t know all of the answers off the top of my head but that I solve questions using the same tools they do.

The second cornerstone of the execution of my teaching philosophy is to include extensive homework which is assigned on a daily or weekly basis. I also try to collect most of this work for grading so that students see that they are getting some reward in the form of points used for grading as well as valuable feedback for their efforts beyond the enhanced overall learning and improved preparation for exams. This is especially true in upper-level physical chemistry courses where the material requires a high level of mathematics and the students can easily become discouraged. Also, students themselves need to be active members of the classroom. In much the same way that doing homework outside of class helps students master the material, bringing
questions to class and discussing them with their peers can often bring about greater learning than having a professor lecture for the full class period. It is important to establish a comfortable learning environment where the students can interact well with the faculty members. Examples of how I try to do this include learning all of the names of the students early on, grading some of the homework myself rather than using a teaching assistant, and working with the students one-on-one in the lab. To show the interconnectedness of our world, I have included examples in lecture which relate to everyday events and use examples from the real world. An example of this would be how I relate error handling in the form of accuracy and precision to pitching a baseball or playing darts. When students think about how the real world example applies to the chemical problem of dealing with errors in measurement they gain a better understanding of why we truncate and round numbers the way we do.

Finally, a quality laboratory experience is essential for undergraduate students to become proficient in chemistry. I am convinced that simply doing problems and reading books cannot truly prepare students to actually do the chemistry they encounter in the real world. In many of the careers chosen by our students, they are called upon to perform experiments and interpret results. The only real preparation that counts is time spent doing chemistry. I am continuing to look for places in my courses where we can replace lectures and homework exercises with laboratory experiences. In summary, I try to give students the tools to solve the problems they will encounter in chemistry once they leave Berea College.

**Excellence as a Teacher**

In the faculty manual, the primary criteria for tenure is “excellence as a teacher” and this phrase has a wide range of possible interpretations. I believe the intent of this phrase is to ask si-
multaneously about both the absolute effectiveness and relative quality of the teacher. When looking at how one defines excellence from an absolute point of view you must consider the appropriateness of an instructor's goals and the degree of success to which they are achieved. In particular, an excellent teacher is one who takes into account a diverse set of information in continually improving his or her teaching. There certainly are different levels of this absolute excellence in teaching in much the same way that we have students who earn an A+ and students who squeeze out an A–. I think the ultimate statement of teaching excellence is to take students and inspire them to become better than they already are. This definition of excellence is probably beyond what is intended by the faculty manual definition, but it hints toward the direction in which an excellent teacher should aspire.

The relative standard of excellence is more difficult to determine than the absolute standard due to the array of challenges found in evaluating a given teacher relative to a specific pool of other teachers. When evaluating a candidate for tenure, I feel that “excellence in teaching” should not imply that the candidate exceeds the Berea College average for teaching ability. Rather, this phrase asks if the candidate exceeds the average of all teachers in a similar environment, with this environment being defined as any college campus with an instructor in the sixth or seventh year teaching a course in a specific discipline. Webster’s dictionary defines excellence as “the state, quality or condition of excelling; superiority; pre-eminence.” Inherent in this definition is the question: What is meant by excelling or superiority? The answer from the same source is “to go beyond a limit or standard.” When evaluating my teaching excellence, we need to look at the standards established for college chemistry education and ask if I meet or exceed this standard. Also it is reasonable to consider the timeframe of one’s teaching career. I certainly hope that I will
be a better teacher in ten years than I am now and that my potentially greater effectiveness in the future should not be used to judge my current excellence today. This tenure review is truly a “moment in time,” to use the words of Dean John Bolin, it is snapshot of myself and the standard of excellence used must reflect this particular moment. In the next few pages, I will make a case that my educational goals are reasonable and are being successfully achieved by my students and that I do indeed exceed the academic norm for teaching quality in chemistry and thus am truly an excellent teacher.

Evaluation of Excellence

To gauge the degree of my teaching success, I look toward a wide range of indicators: student responses to teaching evaluations, student comments, peer comments, self reflection, and alumni success and comments. First, I will discuss student course evaluations. The annual reviews of my courses have usually been within one standard deviation of the college averages. This numerical ranking is difficult to interpret beyond saying that I am not that much better or worse than the average due to the limited sample sizes, dependence on class rank, class size, and grading. I try to use IEQ numbers to improve my courses by focusing on the areas students feel are weak or missing from my course. Examples include assigning additional homework problems, stating my expectations more clearly, or giving more tests. Unfortunately, the changes I have made in courses are not always immediately reflected in the IEQ scores. However, the fact that I usually score better on upper level courses than on lower level courses is probably a result of student populations in these courses, e.g. older students, smaller groups, and higher-level material. Perhaps it is better to evaluate my teaching ability by reviewing students’ written assessments of me on the IEQ forms. These provide a wide range of responses some of which include:
“…he teaches above our heads…,” “I learned a lot about chemistry and I also worked very hard,” “I have learned more and worked harder in this class than in any other class,” “…interesting, concerned, awesome attitude…,” “I love Dr. J’s teaching style. I actually understand what I am doing.” “…go slower and have more exams…,” “…Dr. Jay is the best teacher I have ever had…,” “Jay teaches on a level that is needed for the understanding of the material presented…”

It is obvious that some students (a majority) respond more favorably to me than others. It is also clear from the sum of all of the comments that the students recognize that I am a fair teacher with high expectations who teaches at a challenging level. My discussions of this topic with Tom Beebe and Lee Roecker have corroborated the interpretation that my student expectations are high and that the students perceive me as challenging. Neither Tom nor Lee has expressed any concern with the numerical scores that I receive each term, or with the student comments expressing occasional difficulty or dissatisfaction with my courses. Lee echoes the student perception in his own letter of support for my tenure in which he says “…I find him to always be challenging and encouraging to students.” I am particularly glad to hear that my teaching helps the department and that Lee states “…he has taught me to do my job better.” It is important that these peer comments not be missed since we work closely together in the chemistry department and share teaching ideas regularly.

My own discussions with students have led me to understand that they are more pleased with my performance as an educator now than when I began at Berea. Students have responded favorably in personal conversations to many of the changes I have made in course policy and teaching style. One of the ultimate gauges of my success is the number of graduates who come back after leaving Berea College to tell me about their current successes and to thank me for
helping to educate and guide them. Similar comments can be found on the written evaluations from alumni collected for my tenure review. Though this is only a small sampling of the total number of students I have taught (on the order of 50 alumni) and may be considered anecdotal at best. However, most of the students surveyed commented favorably and ranked me with an average of greater than four, with five being the highest possible score representing the top twenty percent of all Berea faculty. Many of the chemistry majors stated on these alumni surveys that they thought I was one of the best, if not the best, instructor they had taken a course from while at Berea. While this makes me feel good about my teaching, I am certain that every instructor at Berea College has students who feel they are the “best.” One of the things I found pleasantly surprising was that of the seventeen alumni who had taken GSTR 232, eight gave me a rating of four or five grouping me in the top 40% of Berea College faculty. Given the response this course has generated on the IEQ’s, I was surprised that any students would view a Natural Science instructor this favorably (better than half of their instructors while at Berea College.) I was also pleased that the majority of the alumni surveyed stated that they would encourage their children to take a class from me; only seven of the fifty-three indicated a negative to this question. The comments themselves do give me confidence that I must be doing something excellent when I read statements such as:

“…he made me believe in myself…,” “...(his) office was always open and even his home (was)...,” “...I don’t think there are any graduated chemistry majors who would not recommend Dr. Jay...,” “...he was extremely challenging...,” “...(he) encouraged free thinking...,” “...he expected the best out of everyone...,” “...(he) made us think about problems instead of giving the answers to us...”, “...I was challenged more by this professor than any other...,” “...he had no fears of questions, any questions.”
In general, the majority of the comments from previous chemistry majors, who are in my opinion in the best positions to evaluate my teaching, were highly favorable. The negative comments I have received have primarily come from Natural Science (GSTR 232) students as well as some General Chemistry II (CHM 122) students who did not become chemistry majors. In the past, the GSTR 232 course has been taught as a series of disciplinary micro-courses and the student response has generally been one of dislike due to the large volume of material and the controversial nature of this material, e.g. evolution or cosmology. Given that this course can trigger such strong emotions, it is not surprising to read some negative comments from this group. This course in particular will be discussed with an emphasis on how I (and other faculty members on the Committee for the Reform of the Natural Science course, CORN) have worked to try to make it a course that students will enjoy more and fear less. See the following section on Natural Science where this topic is discussed more fully.

Beyond the various formal evaluations, the conversations I have with students and with educators at other institutions (through events such as the Project Kaleidoscope and Second Nature conferences) continue to give me new teaching ideas. Additionally, I read current professional literature such as the *Journal of Chemical Education*, which I use each year as the basis for adding new experiments to my upper level courses, as well as more research oriented journals such as the *American Mineralogist*, *Journal of Physical Chemistry*, *Physical Review Letters* and others. My purpose in reviewing these journals is to look for ideas that might be applicable at the undergraduate level. Ultimately, I am always working toward the goal of finding new ways to bring real-world lab experiences to these courses. In the next few paragraphs, I will describe examples of some of the changes I have implemented in my various courses.
Natural Science (GSTR 232)

The natural science course at Berea is one of the most difficult courses to teach as a new faculty member. Shortly after arriving at Berea College and being assigned to teach GSTR 232 in the fall of 1995, I discovered that this course has a strict multidisciplinary structure in which each core science discipline is taught independent from the others in four short mini-courses. At the end of each section students are tested over the material once. Thus the student philosophy in the course is one of survival—if they can pass the test they can leave that material behind them for good. This general philosophy (course and student) is distinctly in opposition to my teaching philosophy in which I hope to enhance the desire of students to become lifelong learners.

Given this situation, I, along with other faculty members, have spent the last six years trying to make changes in the structure of the course. Megan Hoffman, Eric Pearson and I made one such change during the summer of 1996 when we taught three sections of students together. In this course, we changed some of the structural elements that we found troubling and tried to make a more integrated multidisciplinary course. Our goal was to present the material in a step-wise fashion as opposed to requiring rote memorization of a list of learning objectives. Many of these students were happy with the resulting course and found taking GSTR 232 in the summer a good experience because they could focus a great deal of time on the course. The students’ enjoyment of the summer GSTR 232 course is not well documented in the course evaluations where my averages from the summer 1996 GSTR 232 section were not substantially higher or lower than some of the same questions from the fall 1995 and spring 1998 sections I taught. This lack of numerical distinction on the IEQ’s does not reflect that our changes made no real impact on the course, but rather that the evaluation tool did not pick up the attitudinal shifts that were very apparent in discussions with students in that summer section. This provides another example where the
IEQ numbers fail to give insight but the comments given by the students paint a very clear picture. Lee Roecker has taught GSTR 232 in the summer two other times since then and has implemented even more radical changes in the course structure. His work centered on using books and articles from the popular press as focal points and building the standard topics of cosmology, evolution, chemistry, etc. around these focal points. I believe that his model has proven quite effective. It helps guide the way for additional approaches to be used in the future by other faculty members. On the whole, with each of these changes the course has been given back to the new GSTR 232 instructors as it loses its ties to the original structure developed over ten years ago. I am not suggesting that the original structure was then or is not now a good educational model, but rather it is a model that some younger faculty members do not enjoy using to teach this course and one that perhaps is not as “in touch” with today’s students as it needs to be. The reasons for this falling out are many, but fundamentally they come from the shift of science toward integration and the explosion in total knowledge required to understand the many different individual fragments of science. We can not cover every topic we think students need to know; the list is too long. The best we can hope to do is to motivate the students to learn more science throughout their entire lives.

When I have taught GSTR 232 during the normal school year, I have written two or three new lectures each time as opposed to simply following existing lecture notes as some faculty have done (see Appendix G). I wrote a 10-20 page textbook-like chapter on each subject we discussed. This required a great deal of work, since the actual textbook did not follow the existing structure very well. This set of lecture notes needed to have clear objectives identified and provide the only material over which students would be tested. These objectives are extremely specific goals (e.g.
“solve Kepler’s law problems,” “define isotope,” “use half-life formula,” etc.) Unfortunately this required GSTR 232 structure resulted in a course in which the students wanted to be taught only the objectives and nothing else. This was clear from out-of-class comments I heard from students who expressed dissatisfaction and even anger when on rare occasions I presented material from outside the lecture objectives in recitation section. This student (as well as instructor) frustration has mounted enough and we, the science faculty, finally have agreed to a model that will allow faculty to explore new and different approaches to this course.

I will be teaching a section of GSTR 232 in this new model during the academic year 2000-2001. The course outline I am exploring is one in which we take a truly interdisciplinary approach to the natural sciences and examine everyday objects with the goal of understanding how the world around us works. An example of a question we might explore could be something as simple as “Why does a match light when we strike it?” or “How can a heat pump be used to both heat and cool air in a home?” When students are asked to evaluate the way everyday objects around them operate, they will be encouraged to learn the underlying principles of science. I will use these questions to expand into larger questions such as “How does the sun work?” or “What is an earthquake?” and ultimately to confront questions such as “Where did we come from?” This model has not been tested at Berea and it is not absolutely certain that it is the best teaching approach (in fact there may be no single best approach). The only evidence I have that this is a better approach is from conversations with colleagues at other schools which have adopted a thematic approach to the introductory science course for non-majors. These people almost universally have told me that they once used a discipline by discipline method similar to the current GSTR 232 at Berea College which has now been abandoned at these schools. Students want more of the current
topics and real-world in their introductory Natural Science course than is currently part of the course. As an instructor I believe that the core topics can be taught without the necessity of including some of the topics that seem out-of-date to the students. I am sure the students will still find the course challenging and many will still complain that it is too hard or too fast. However, I hope that by using a theme-based approach, I will teach a course that I enjoy and that I hope more of the students will enjoy as well.

An advantage of the new GSTR 232 teaching structure will be that the course will have ownership vested in the faculty teaching the material. Instead of being bound to a standard GSTR 232 model, we will now be able to explore alternative teaching approaches. As such it will be possible to assess the choices they have made and ask questions about teaching effectiveness. In the current format the evaluations are difficult to use to enhance teaching effectiveness. In fact, since an individual faculty member would previously teach only a fraction of the lectures and all testing and grading was done collaboratively, much of the evaluations' results would really only be valid for the course as a whole rather than an individual. This is an important issue to look at when evaluating my teaching excellence in this course. The wide range of variance in the institutional teaching questionnaire must be examined within a framework in which the course is understood to be a group-teaching effort. The fact that my scores are good some years and poor others should not be used to indict my teaching effectiveness. In essence, the student-completed questionnaires evaluate the course as a whole of which I am only a part. It is surprising to look at the GSTR 232 student evaluations and see such a wide range of averages on questions that should be consistent within the course. An example from the spring 1998 evaluations comes from the questions asking whether the “instructor’s assignments were helpful to my learning” and “the instructor’s grad-
ing was fair.” To these questions my evaluations had an average of 3.16 and 3.53 respectively while the other GSTR 232 instructors averaged 4.03 and 4.16 respectively. Considering that we gave no individual assignments in this course and only one writing assignment was graded independently by individual instructors (accounting for less than 5% of the total grade), these deviations are certainly unusual and demonstrate the extreme difficulty inherent in evaluating a team–taught course. My activity as a teacher in recitation section could not alone produce such a large shift and I am left wondering if these deviations are the result of some external factor beyond my control such as an unpopular section meeting time or random population fluctuations. Alternatively, this deviation may represent the level of statistical significance of the evaluation instrument. The new Natural Science format will allow a more fair evaluation of the teaching skills of an individual instructor since the courses will be much more flexible, allowing an instructor to respond to the students immediately. I am confident that within this new structure, students will experience a much more effective style of teaching from both myself and others in the course.

**General Chemistry (CHM 121 & 122)**

In my General Chemistry course, I have made substantial progress regarding changes and improvements. My exams are now consistently within an appropriate range of average student scores as opposed to exams from my first two years which were more widely fluctuating in student performance. This indicates my improved success at understanding the aptitude level of my students and understanding more of the Berea College student mindset. Specifically, I have included more questions similar to those they will ultimately encounter on standardized exams on which our chemistry students have historically performed below their abilities. I have added daily quizzes to gauge preparedness and overall aptitude. This most recent semester (Fall 1999), I spent
a great deal of time stressing the importance of the quizzes and how they fit into the overall grading scheme. Once the students realized that extra quizzes actually helped their grades (only the best 20 quizzes were kept for grading purposes), they actually asked for more quizzes. Along with this desire for more quizzes and the resultant grade improvements, the students actually tried to prepare more diligently for the quizzes than earlier in the semester.

I have tried in both the physical and general chemistry courses to include more chemistry problems that relate directly to the students’ everyday lives. For example, I have asked, “How much volume of gasoline is required to generate the energy needed to heat a house?” and “Why does table salt dissolve in a glass of water while the glass itself does not?” I hope that these real-world issues will raise the students’ overall interest in the material.

Another lecture improvement I implemented both in the Spring 1999 and Fall 1999 was to eliminate some of the content lectures and include more problem-solving lecture sessions. Students really enjoyed the extra problem solving days because we covered exercises similar to those they encountered on tests and quizzes. The drawback of this approach was that I spent less time discussing new material, although working problems is another form of reviewing new material. Though we had to skip a few sections of the book that we might normally have covered. However, the benefit of reviewing older material outweighed covering new, less critical information. I am sure this has helped improve student enjoyment of the course, but it is not clear to me how far one should take this more problem-based approach. Certainly eliminating sections has helped alleviate the “Dr. Jay goes too fast, slow down” type comments on the IEQs. We cannot eliminate too many sections before the course drops below the academic standard of what must be included in a general chemistry course. In the future I plan to shift this course to include more material from
organic chemistry and has more specific real-world examples. On the whole, the professional organizations in chemistry are supporting a move to a modular system of chemistry education where students do more real-world problem solving with greater laboratory involvement. The chemistry department at Berea College is heading in this direction and we have begun discussions in our departmental meetings this year on this topic.

I have continued to add more lecture demonstrations to enhance learning of lecture material and I intend to develop this area more in the future. As I have continued to add more in-class chemical demonstrations, I have also worked to improve my overall presentation of such information. In recent years, I have asked a student from the labor program in chemistry to assist in demonstration preparation each week, a strategy that has worked quite well. As described earlier, it is difficult to strike a balance in the introductory lecture between lecturing on reading and homework assignments and discussing real-life examples and demonstrations. The students need to have the knowledge and skills for the tests, but they also need to hear about chemistry around them to begin to appreciate the subject and be encouraged to engage the material more deeply. I consider this balance very carefully as I select lecture demonstrations that illustrate the book knowledge and problem-solving skills while simultaneously entertaining and engaging the students.

I have added a new writing component in the last two years to all of my chemistry courses. It involves attending a chemistry seminar sponsored by the Berea College ACS Student Affiliates group and writing a response. This assignment has worked well in the general chemistry course, although students occasionally seem confused about what to write about. I am trying to improve the assignment description to assist in structuring their observations. In this year’s syllabus, I included a sample of what a written seminar summary might look like (in Appendix B with my gen-
eral chemistry syllabus for the Fall 1999). I try to grade this writing assignment for the quality of writing skills rather than technical accuracy of the chemistry content. Early in their careers, students need to get feedback about what technical writing should look like and not be punished for not grasping the subject matter completely. The seminar speakers, who come from a wide range of local graduate schools, are instructed to present seminars for the chemistry department student affiliates group at a level appropriate for the junior chemistry majors. This means even the sophomore chemistry majors will sometimes encounter material that is difficult to digest. The difficulty the general chemistry students face in attending these seminars is daunting if they are expected to have complete comprehension of the seminar. Instead, I focus on their trying to get a general picture of what chemistry research might entail; I encourage students to look at the subject matter as a whole and try to skip the details. Even a beginning student can see the value of research studying the effectiveness of a new drug or the importance of a new industrial process.

Physical Chemistry (CHM 361 & 362)

I have made great strides in improving my teaching in the physical chemistry courses (CHM 361 and 362) as well. I have made adaptations in the textbook used and in the amount and level of material covered in order to meet students’ needs and abilities. In this course, I initially adopted a text that was too difficult. This was in response to seeing the textbook that was previously used, which I consider unsuitable for graduate school preparation. My desire to push students to the higher level may have caused some initial difficulties. Subsequently, I have adjusted my overall course expectations and requirements to more reasonable levels and adopted a more appropriate text, which is still adequate for graduate school preparation. I now regularly finish all topics I set
out to cover in this course by building in time to discuss more difficult material so that the students may feel free to ask questions about these difficult topics.

Secondly, I have added to the course laboratory experiments that relate in a direct and timely fashion to the current lecture material. I am currently developing new and interesting demonstrations as well as hands-on laboratory experiences. Many of the traditional physical chemistry laboratory experiments being done at many colleges including Berea are somewhat out of date and need to be updated. In particular, our new National Science Foundation grant to purchase a 300 MHz NMR spectrometer will open the door to a wide range of new physical chemistry experiments for both CHM 361 and 362. I am particularly excited about adding some new imaging experiments to help show students the fundamentals behind the magnetic resonance imaging (MRI) instruments that have grown in importance in the medical community in the last ten years.

Another area of change in all of my courses is that I have added oral communication assignments. It is critical that students be able to articulate their knowledge in order to be successful in the scientific community. These assignments assist students in developing the communication skills they need. In the physical chemistry classes, students are chosen at random each day to work a problem at the board in front of their peers, which I feel encourages them to read and prepare for class more thoroughly. I am also adding more writing assignments to this course both in the form of conceptual essay problems on tests and formal laboratory reports. Another approach that I began in my general courses and have applied to my upper-level courses is the inclusion of “problem-solving” lecture days. On these days we solve homework and related exercises from the book and other sources. This helps prepare the students for the exams and improves their problem solving skills in general, one of the goals I alluded to earlier in my teaching philosophy.
Research (CHM 498)

I have contributed substantially to the research experience of many of our chemistry majors. Research is a very important part of the chemistry educational curriculum. Generally, it is not taught as a specific course but as independent studies or directed readings during the regular terms and as non-credit labor positions in the summer. In our new departmental vision for a revised curriculum that we are currently developing, we envision that research and advanced laboratory work will be more intimately tied together. Students who participate in research experiences generally go on to have successful scientific careers. My research students have attended Johns Hopkins University, University of Kentucky, University of Cincinnati, Eastern Kentucky University, and other graduate and professional programs. The universal comments I have received from returning graduates is that the research experience at Berea College was one of the most important educational experiences of their careers here, a fact that is also reflected in the alumni surveys. I have had a large number of research students in the last six years and the vast majority tell me they have enjoyed the work. My research is never formally evaluated using any Berea College teaching questionnaire, but the educational importance and successful outcomes of this program are a significant factor in my high level of success in working with chemistry majors. I anticipate that in the coming years I will add some formal evaluation instrument to my undergraduate research projects to get a more accurate picture of the student response to this work.

Additional Projects

I have also been involved in the Communication Across Campus (CAC) IV group (see Appendix I) in which a variety of teaching techniques were encouraged. I found the experience of working with my colleagues from a variety of disciplines very useful in providing insight into alternative ways of teaching. Some of the books used in the CAC workshops have provided numer-
ous sources of inspiration for teaching ideas I have implemented. On the whole, the CAC experience really encouraged me to fearlessly seek and develop new teaching methods.

**Conclusions about teaching**

I believe my teaching as a whole shows that I am an educator who achieved the standard of excellence in teaching and who works hard to push students to succeed. This assessment is supported by the comments of my peers (and in particular Lee Roecker and Tom Beebe) who have written letters supporting my tenure at Berea College. Granted, there are many ways I can still improve, as a limited number of student evaluations indicate. These students, however, represent a small minority that is present in the population of students of every instructor. This population will continue to shrink, and I am confident in five years I will be an even better teacher than I am today. In summary, my teaching skills certainly meet what I believe to be Berea’s definition of excellence in teaching in both the absolute and relative forms described earlier.

**Scholarly Work at Berea College**

**Research Activity**

I have been involved in on-going research in addition to writing up results in professional journals. In particular, I have written more than a dozen research grant proposals since coming to Berea and have been awarded money from the National Science Foundation, the Petroleum Research Fund (administered by the American Chemical Society), Research Corporation, Appalachian Colleges Association and Dreyfus Foundation. These grants have totaled almost $300,000 including the matching portions from Berea College. I am finally reaching a point at which my research program has enough momentum to continue to move forward for some time without extensive additional funding. The new NMR spectrometer will enhance my research—along with that
of my Chemistry Department colleagues—enormously. With this new instrument, I now have the equipment necessary to run my research program entirely at Berea College throughout the academic year and summer. My goal is to continue to develop a research group at Berea in which students commit to work for more than one semester at a time in order to gain a greater understanding of the goals of our research projects. Having longer-term research assistants promises to make the transition from one student to the next much smoother. In addition, it will enhance the overall quality of the learning experience of a student who moves from novice beginner working under myself and other students to the polished expert who eventually helps me teach new research assistants.

I have continued to work with other researchers at larger universities. My summer research has taken me and my students to Ohio State University, Indiana University, University of Kentucky, Stanford University and Centre College in collaborative efforts. The net result of these collaborations has been the publication of four papers while I have been at Berea (see Appendix D). These are entitled “Solid-State $^{17}$O Magic-Angle and Dynamic-Angle Spinning NMR Study of the SiO$_2$ Polymorph Coesite,” “Local Structure and Oxide-ion Motion in Defective Cubic Perovskites,” “Multiple-Quantum Magic-Angle Spinning and Dynamic-Angle Spinning NMR Spectroscopy for Quadrupolar Nuclei,” and “Triple-Quantum Two-Dimensional $^{27}$Al Magic-Angle Spinning Nuclear Magnetic Resonance Spectroscopic Study of Aluminosilicate and Aluminate Crystals and Glasses.” I am currently preparing a paper for resubmission this spring to the Journal of Physical Chemistry entitled “Nuclear Magnetic Resonance Investigations of Distributional Effects in Sodium Phosphate Glass.” This paper summarizes much of the research I have undertaken with Berea College undergraduates over the last five years. I hope that this paper,
along with future work, will continue to be published in important research journals in the fields of chemistry and geology. Refer to my curriculum vitae for full citations of each journal article and to Appendix D for a complete text of each.

Professional Meetings

I have kept up professional contacts through both my research and attendance of national meetings. Periodically, I try to attend the meetings of the Lexington ACS section, which meets at both UK and a variety of other local colleges and universities, in order to meet other local chemists. Likewise, most years I have attended the Experimental NMR Conference (ENC) at which the major NMR researchers gather to discuss new and exciting experiments. At previous ENC meetings I have presented more than six posters including the poster describing the phosphate glass research two years ago. I plan to continue to present my research at these meetings in the future. I have used this conference as a springboard for developing future collaborative relationships as well as meeting prospective research associates who might provide sabbatical employment opportunities in the future. In addition, by keeping professional contact with my friends in the NMR community, I have been able to help Berea College students find undergraduate research positions in the summers that allow them to leave Berea and see other institutions. Jeff Ellington is an example of one student who got a position at OSU with Dr. Philip Grandinetti through his contacts with me. Due to these reasons, I plan to continue to attend these types of meetings.

I have attended the Project Kaleidoscope (PKAL) national meeting three of the last five years as a member of the PKAL Faculty for the 21st century group (F21). The F21 group was organized to bring young faculty together who will provide leadership in the years to come. In particular, PKAL has stressed the importance of becoming a proactive change agent at the home in-
stitutions of F21 members as well as active members of the academic community as a whole. Through groups such as PKAL, I have increased my usage of multi-media and computer elements in my classroom presentations and made additional professional contacts that can enhance my teaching methodology. I also was a presenter at a recent workshop at Centre College in the summer of 1999 where the use of NMR spectroscopy in the undergraduate curriculum was discussed. Many of the participants were chemists who had recently acquired NMR instrumentation but who lacked the necessary background in the subject. The participants were very interested in hearing my teaching and research goals and seeing the applications of new NMR techniques in the undergraduate setting. This conference promises to help form a local network that can share information on the utilization of this valuable tool. I have also participated in a workshop (Fall 1998) held by the Second Nature group that focused on adding sustainability and environmental issues to educational institutions in a variety of forms. This conference, like the F21 gathering, allowed me to meet other educators and learn about new approaches for presenting information. Additionally, it provided a good reference network to assist me in making my students more aware of the global environmental issues facing all of us.

Through my professional exposure, I have been called upon to review proposals and journal articles frequently. I served on an NSF review panel in February 1999 to examine proposals to the Division of Education CCLI program. This same program provided funding for our 300 MHz NMR spectrometer. This was a good opportunity for me to learn about the proposal review process, to meet other faculty members from a wide range of institutions, and to provide my input into helping shape the CCLI program. Since this was the first round of evaluations for the CCLI program, the way we as a group interpreted the guidelines will have a profound impact on how the
program is interpreted in the future. This kind of work is crucial to helping our nation carry the scientific research and educational successes of the past into the future. I plan to continue to perform all of these types of services because they are important in maintaining contact with professionals and in providing unbiased and quality reviews of the work of others.

**Advising at Berea College**

One of the more important activities I perform at Berea College is advising students. This activity is critical in helping students discover what field they wish to pursue and what courses to choose. Advising extends beyond simply choosing courses into helping provide career guidance and personal counseling at times. I have always been told by my advisees that they find me very effective as an advisor and I have no evidence that suggests any major problems in this area. I have advised three groups of freshman advisees (over 50 total students) in the last six years and have taken on a number of students who requested me as an advisor upon major declaration. I attended the advisor training workshop the summer of 1998 and am well versed in the requirements for students in both my own department and in other majors. I have tried to open the eyes of my advisees to a variety of career opportunities available with a liberal arts degree. I frequently spend half an hour sitting in my office with a student in the late afternoon talking about educational opportunities or future job prospects. I have tried especially hard to help out the international students who seem to face greater challenges in terms of finding graduate programs and job opportunities in America.

I am a firm believer in a liberal education with large numbers of writing and speaking experiences. This arises from my undergraduate experience at Wabash College. I encourage my advisees in particular and all of my students in general to participate fully in the college curriculum
both inside and outside the classroom. I try to attend sporting events, concerts and performances in which my advisees are involved. It is important for students to see that their teachers are concerned about them beyond the classroom. In general, I strive to achieve friendly relationships with my advisees and students so that they can feel comfortable sitting down in my office and discussing a variety of issues. Rarely is advising as simple as choosing the right courses and right career in a vacuum. Berea students in particular need a great deal of encouragement to look outside the boundaries they are familiar with and explore diverse educational and career opportunities. Advice on these issues is better received from someone to whom the students can relate and respect as a friend as well as advisor. Overall, I have enjoyed my work as an advisor and have done a good job helping my advisees overcome a variety of challenges.

**Service to Berea College and Beyond**

*Departmental Work*

In the Chemistry Department, I have served as the advisor for the ACS student affiliate group for seven years. In the last two years the student interest in the ACS affiliates has grown substantially and we now have a large number of activities, including having worked on a Habitat for Humanity home, participating in the Berea Buddies programs, and entering a float in the homecoming parade this year. In addition, this group has invited a number of different speakers from outside the college to present research and industrial experiences. Bringing in a wide range of outside speakers is critical to exposing students to the array of career opportunities they have with a chemistry major and a liberal arts background, beyond simply medical school and graduate school. These out-of-class experiences enhance the students’ overall learning and therefore are something I am striving to increase and improve at Berea. One way to increase the number of out-
side seminar speakers has been to team up with other colleges to bring in joint speakers. I have developed a collaborative interaction with Alan Schick, Assistant Professor of Chemistry at Eastern Kentucky University (EKU), where we now jointly sponsor four or five seminars each fall. This has allowed both EKU and Berea to attract better speakers from a more diverse range of institutions than we had been able to do individually. The speakers generally speak at both Berea and EKU giving unique talks appropriate to the somewhat different audiences at each school.

I am also involved in the departmental labor program, in which I normally supervise four to six teaching assistants each semester. These students are involved in grading some of the introductory chemistry homework and laboratory notebooks as well as helping prepare demonstrations and chemicals for our laboratory experiments. In addition, I help out the department substantially by doing part of the instrument repair and maintenance, especially on our NMR, FTIR and HPLC instrumentation. The NMR spectrometer in particular requires regular liquid nitrogen and liquid helium fills to remain functional. I am the only person in the college who is completely comfortable working with these cryogens. However, I am in the process of training the other chemistry faculty as well as some labor students to work with them as well.

I have worked hard over the last five years to develop and maintain the Berea College chemistry departmental worldwide web pages. These are referenced in the Appendix H and may be viewed on any of the campus computers. I have tried, with some success, to encourage other members of my department to enhance their own web presence (in fact I was helping Lee Roecker get some web pages on-line just this Short Term 2000). In the long run I hope to utilize a chemistry labor position to maintain some of this data, but for now I am happy to try to lead the department in this area.
Finally, I am hopeful that in the near future the chemistry department will approach ACS certification as well as upgrade our major so that students may receive an ACS certified chemistry major if they choose. ACS certification is one of the areas of discussion in our current departmental self-study and I suspect that we will be making progress towards my goal of ACS certification in the coming years. This goal has been slowed by the ACS requirements regarding journal holdings. Berea only carries about one-half of the suggested journals and I have not found a solution to overcome this requirement. Currently, I am trying to evaluate the importance of ACS certification in terms of how this might affect our graduates’ hiring potential.

I recently worked with Lee Roecker to develop a proposal to the faculty in which our departmental course descriptions and titles were revised. We used this proposal to bring the catalog up to par with what Lee and I are actually teaching. We also changed the physical chemistry requirements so that students may choose which course (Thermochemistry or Quantum Chemistry) they take to meet the major requirements. Allowing students to choose one of the two physical chemistry courses is not an ideal solution, but it is moving toward my goal of all chemistry students taking two semesters of physical chemistry. I am excited about participating in our self-study and working with the new biochemist, Matthew Saderholm, to develop improvements to our curriculum as a whole. It is important for a department to sit down and look at how all the various pieces of the puzzle fit together. With new departmental leadership, our new biochemist, and the departmental self-study well on its way to completion with a substantial number of new and exciting outcomes, I am very excited about the future of the chemistry department.
Committee Service

I have served on multiple committees at Berea and I have worked hard to try to contribute my thoughts and experiences to the college. I am currently a member of the Campus Committee on Hearings which has not yet required me to participate in any meetings or hearings. In many ways this appointment feels a bit like sitting on jury duty for two years in that a member is ready to serve if called. This committee assignment is likely to be less time-consuming than my work in previous years with the IE Team and SLOC, but certainly no less important. Perhaps it would be even more important in the event of a serious hearing. I served on the recently disbanded Special Learning Opportunities Committee (SLOC) from Fall 1997 to Spring 1999, serving as chairperson the last year. I found this work quite rewarding as it provided me an opportunity to see the kinds of educational opportunities we have at Berea College outside the science building.

Through my experiences with SLOC, I have become a strong proponent for independent majors at Berea College and would like to see the college move to a system that allows ever-greater diversity of curricula allowed for students. Last year, I submitted a proposal to the Academic Program Council (APC) that outlined some of my thoughts on interdisciplinary majors. This proposal was very general, using the Neuroscience program proposed by Megan Hoffman and Gene Chao as the flagship example, and attempted to provide a framework to develop more such majors in the future. Ultimately, this proposal was tabled until the need is more strongly documented, but I am certain that this represents the future of education in our country. I cannot say I was not disappointed when the initial attempt to pass the neuroscience major failed, but this setback will not end this program as an independent major, though it may reduce the number of students who find out about it. I hope that we can find the time to review this type of program again in the future and provide a better framework for the construction of such majors. It is critical
that Berea College be prepared to meet these new and diverse needs of the 21\textsuperscript{st} century student body.

I have also served on the Institutional Effectiveness Team (IE) for part of one year. This was near the end of the life of this committee and we really were superseded by the Strategic Planning Committee and its constituent subcommittees. The IE team had excellent goals that were partially realized. The dream of having each department develop long-term planning is now becoming a reality.

The most recent active committee on which I have served is the Committee On Reform of Natural Science (CORN), which began meeting the Fall 1998. This committee was formed under COGE to reevaluate the goals, content and structure of Natural Science (GSTR 232). Over the last two years, there has been a great deal of discussion in the science building about how GSTR 232 might be restructured. Along with this have been some experimental offerings by various faculty members. CORN hopes to try to pull together a variety of resources and come to some strong conclusions and recommendations. Overall, I have been very pleased with these committee experiences. They have provided me with a great deal of insight into the operations of the college and the science building. These challenges encourage me to expand my role as a faculty member at Berea College. I look forward to serving on other committees that might provide leadership and guidance for the college and students in the future.

**Long Term Goals**

My goals remain roughly the same as they were three years ago at my mid-term probationary review. I hope to be granted tenure and promotion to associate professor of chemistry at Berea College this or next year. Depending on the status of my wife’s health, I hope to spend a sabbati-
cal away from Berea working in Lyon, France with Professor Lyndon Emsley; this should occur between June 2001 and July 2002. This sabbatical experience will allow me to bring fresh ideas back to Berea regarding my research as well as new teaching methodologies and laboratory experiments. Further down the road, I hope be promoted to associate and then full professorship and maybe someday, if called, I’ll serve as an administrator such as a departmental chairperson or dean. I plan to develop new laboratory experiments, demonstrations, and lecture material for my courses. I plan to focus substantial efforts into adding new physical chemistry laboratory experiments that utilize the 300 MHz NMR spectrometer. I will continue to write additional grant applications to raise money for research. Having succeeded in acquiring funding for the high field NMR spectrometer for research and classroom experiments, I have reached a major funding goal I set for myself. In the next five years, I want to continue with smaller grants that support our instrumentation in place and begin to think about acquiring some x-ray diffraction equipment. This would probably be a joint purchase by both Physics and Chemistry that would need an approximate $50,000 to $150,000 in new grant money over the next five years. I plan to continue to attend professional conferences in my area of research as well as conferences on communication and teaching at least once per year as well. The conference participation will help keep me abreast of current developments in my field of research as well as offer new ideas and innovations in teaching methods. I would like to continue to do research both here at Berea with undergraduate assistants as well as keep up collaborative projects with colleagues at UK, Stanford, and OSU, which will ultimately lead to a minimum personal goal of one publication per year. With the purchase of our new NMR spectrometer, I now have the primary tool to increase the amount of regular-term research involving students that ultimately can help me reach my publication goal. The projects we are developing are designed to produce results that will lead to more publications in
reviewed journals. The students in this program will learn NMR spectroscopy and quantum mechanics that is significantly more advanced than they would encounter in course material. With the success of the initial research projects, both at Berea and with collaborators, I think gaining additional funding is highly feasible. Assuming the research continues as well as it has the last five summers, these publication and conference attendance goals will be easily reached with our current instrumentation.

Conclusion

I believe that I have presented strong evidence that I am an excellent teacher on both an absolute and relative scale when viewed within the population of science educators near the beginning of their careers. I am not suggesting that I have no flaws or that I will not continue to improve, but merely that at this moment in time I am at that level dictated by the tenure criterion 1 in the faculty manual. My professional growth is well on track and my research is expanding. I have shown proficiency as an advisor of many students in many roles and I have participated to the best of my ability in the college governance structure. In short, I believe my activities and qualifications merit a favorable review outcome in this tenure process.
List of Annotated Appendices

Appendix A: Current Curriculum Vitae

Appendix B: Example Course Syllabi
1997 CHM 121
1995 CHM 121
1997 CHM 122
1998 CHM 261 (including attachments)
1996 CHM 113
1998 CHM 262

Appendix C: Sample Tests
1996 CHM 113 final exam
1995 GSTR 232 test #2
1998 CHM 262 test #3
1997 CHM 121 test #1
1997 CHM 122 test #2

Appendix D: Scholarly Writing
Journal of the American Chemical Society, 118, 7209-7214 (1996)
Submitted J. Phys. Chem. includes student authors (see highlighted names)

Appendix E: Sample Grant Proposal
1995 Petroleum Research Foundation proposal ($20,000), funded.

Appendix F: Sample Committee Submission
1998 Independent majors proposal to APC, currently tabled.

Appendix G: Natural Science Lecture Notes
1998 GSTR 232 Lecture 8
1998 GSTR 232 Lecture 9

Appendix H: Berea College Chemistry Department WWW pages
Samples from our web pages I have written. Complete site found starting at
http://207.168.194.200/~jhb/chemistry.html

Appendix I: Communication Across Campus IV Report
Appendix A: Current Curriculum Vitae

Jay H. Baltisberger

Address
Department of Chemistry
CPO 1722
Berea College
Berea, KY 40404
PH: (606) 985-3298
FAX: (606) 986-4506

Education


Positions and Appointments
Assistant Professor - Berea College, Berea KY (August 1993 to present).

Visiting Researcher - Stanford University, Palo Alto CA (July 1996); worked in laboratory of J.F. Stebbins studying aluminate compounds using multiple-quantum NMR.

Visiting Research Professor - The Ohio State University, Columbus OH (June 1995); worked in laboratory of P.J. Grandinetti studying silicate glasses.

Research Assistant - University of California (August 1989 to July 1993); performed doctoral research under A. Pines studying solid state dynamic-angle spinning.

Graduate Student Instructor - University of California; head T.A. for Introductory chemistry (fall 1990 and fall 1991); Introductory chemistry laboratory (fall 1989).

Counselor - National Youth Science Camp, Bartow, West Virginia, (summer 1989).

Undergraduate Research Assistant - University of Utah Chemistry Department (summer 1988); solid state NMR research. Idaho National Engineering Laboratory (summer 1987); theoretical plasma physics research. University of North Dakota Energy Research Center (summer 1986); coal ash deposit research with surface techniques.

Professional Societies
Phi Lambda Upsilon (Chemistry Honor Society); American Chemical Society (ACS); American Physical Society (APS); National Council on Undergraduate Research (NCUR); Mineralogical Society of America (MSA); Project Kaleidoscope Faculty 21 Class of 95 (PKAL-F21)

Honors and Awards
National Science Foundation Graduate Research Fellowship in Chemistry – 1989; Phi Beta Kappa – 1989; Wabash College Lewis Mackintosh Graduate Fellowship – 1989; Wabash Col-

Grants (including institutional match from Berea College)
Berea College Undergraduate Research Program, 1999 ($7,000)
National Science Foundation – Instrumentation for Laboratory Instruction Grant, 1998 ($200,000)
Appalachian Colleges Association Mellon Research Grants, 1998 ($8,500), 1997 ($5,500) & 1996 ($7,000)
American Chemical Society - Petroleum Research Foundation GB Research Grant, 1997 ($20,000)
Research Corporation Cottrell College Grant, 1995 ($45,000)
Julian Capps and Gerrit Levey Memorial Research Fund, 1994 ($5,400)
Camille and Henry Dreyfus Faculty Start-Up Program for Undergraduate Institutions, 1993 ($10,000)
Berea College Start-up Grant, 1993 ($12,000)

Publications


**Seminars**

“Extracting Order from Disorder: Using NMR Spectroscopy”, Eastern Kentucky University, Richmond, KY, March, 2000 (as currently scheduled)

“Extracting Order from Disorder: Using NMR Spectroscopy”, Berea College, Berea, KY, October, 1999

“Spin Gymnastics – Unusual Experiments with NMR in the Undergraduate Curriculum”, Centre College, Danville, KY, June, 1999

“Introduction to Solid-State NMR and Novel Applications to Glasses”, University of Cincinnati Chemistry Department Seminar, Cincinnati, OH, February, 1997

“Introduction to Solid-State NMR and Novel Applications to Glasses”, University of North Dakota Chemistry Department Seminar, Grand Forks, ND, February, 1997


Posters


Appendix B:  
Example Course Syllabi

I have chosen to include different samples of course syllabi for your evaluation. I have tried hard to make my courses be uniform in that all my syllabi contain similar information which I feel is complete and necessary for a student to undertake one of my courses. You will notice in comparing the older syllabi to the newer (for 121 and 113) that this amount of information has slowly gotten longer and longer. This is due to the fact that I have found students respond favorably to having as much information up front as possible. Thus I give them not only a lecture schedule but a list of all the homework assignments for the term as well as samples of written work (for the CHM 121 course). Included you will find the syllabi for the following courses: 1999 CHM 121, 1995 CHM 121, 1997 CHM 122, 1999 CHM 361 (including attachments), 1999 CHM 113, and 1996 CHM 113.
In this course I hope to introduce you to the fundamentals of chemistry. As an introductory course which is only the first step in a multi-course sequence, the material we cover will not present a complete picture of chemistry. The picture will by necessity focus on inorganic chemistry (rocks, minerals, salt, etc.) and specifically the topics of bonding and structure. Some time will be spent on stoichiometry, chemical equations and equilibrium effects as well. There will be no biochemistry, organic chemistry (chemicals that make you live and breathe like DNA, proteins, sugars, etc.) and only minimal physical chemistry in this course; these topics will wait for later in your careers (though I am happy to discuss any chemistry topic outside of class if you have interest.) In addition, you will gain some insight into the process known as the scientific method as it relates to the development of theories in chemistry.

What does all this mean to you as a student? Hopefully, it means you will have a better understanding of what makes your car run (combustion reactions), how Crystal Drano works (acid/base chemistry) or be able to differentiate a diamond (molecular crystal) and a salt (ionic crystal). Maybe you’ll get a feel for what makes a reaction generate heat or how that heat can be used to do work. In addition, I hope you are left with a feeling for the evolution of atomic theory and some understanding of the complexities of quantum mechanics. The schedule of lectures for the course will be somewhat different than I have used in the past. Specifically, we will use one lecture per chapter to purely focus on problem solving and the others on introducing material. Even with these introduction lectures, we will focus on doing more problems. The advantage to you the student will be more exposure to doing the word problems that students seem to find so challenging in chemistry. The disadvantage is that you will need to read the text more thoroughly and come prepared to think problems more. If at any time in the course you wish I would do something different, let me know. My door is open for comments and questions and I really do hope to see all of you regularly.

We meet Monday, Wednesday and Friday in Room 106 at 10:00 am. I will hold 10 office hours where I will guarantee normally to be available in my office unless otherwise posted. These will be Monday from 8-10, Wednesday from 8-10 & 2-4, and Friday 8-10. Any other times that my door is open I am available for questions or comments (please recognize that if you cannot go to a scheduled office hour, you should talk to me about finding times that will work for you). The laboratory for this course will be in room 313 (section A) or room 305 and (section D) meets from 2-5 on Monday (sec-
tion A) or Tuesday (section D) afternoons (10-40 minute pre-laboratory lecture will be in room 306). Note that the laboratory sessions are not optional and you are expected to attend both the pre-laboratory and subsequent laboratory sessions.

The grading policy will be based on the following schedule. You will be required to hand in homework problem sets (see last page of syllabus for complete assignments and due dates) which will be worth account for 80 points (10 points each). These will be graded primarily based on completion of the assignment (2/3 of grade) and accuracy of solutions (1/3). In general, we will randomly select 2 or 3 problems each chapter to grade carefully, while the others will only be quickly scanned. If you have questions about homework solutions you should consult with the TA’s or the instructor of the course. There will be 10 laboratory experiments and pre-laboratory assignments worth 200 points (20 points each). The pre-laboratory exercises will be worth 3 points each while the remaining 17 points will be derived from the lab notebook. Laboratory notebooks will be graded based on completeness (did you answer all the questions, did you conduct the experiment, did you interpret your data) rather than quantitative accuracy (this can wait until CHM 341). There will be three one hour long tests worth 360 points (120 points each). The tentative test days will be Monday, September 27th; Monday, November 8th; and Monday, December 6th. There will be a final exam worth 200 points on Monday, December 13th at 3pm. Tests will be graded very objectively for accuracy of answers. Normally each test will have about 1/3 multiple choice questions to help you prepare for the future when you will take MCAT, LSAT, GRE which are entirely multiple choice. As well there will be some fill in the blank, short essay and word problems on these exams. There will be quizzes given most days (20 quizzes) which will consist of a single short question and will account for 100 points (5 points each). You will also be expected to attend one of the three or four scheduled chemistry seminars (currently we have the following already scheduled: Tuesday evenings at 7 PM, October 12th, November 9th and 30th) and write a short (200 – 400 words, 1 page, double spaced, 12 point times font) essay on what was discussed in the seminar which is worth 60 points. An example essay is included on the last page of this syllabus. You will be graded based upon the quality and organization of your writing and not upon technical substance (you don’t have to fully understand all the presented science.) The grading for the course will be 100-92% for an A (minimum 920 points), 91-79% for a B (minimum 790 points), 78-63% for a C (minimum 630 points), 62-50% for a D (minimum 500 points) and anything less an F.

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<th>Points each</th>
<th>Total Points</th>
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<td>Laboratory Write-ups (10)</td>
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<td>Quizzes (20)</td>
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<td>100</td>
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<tr>
<td>Final Exam</td>
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<td>200</td>
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<td>Chemistry Seminars (1)</td>
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<td><strong>Grand Total</strong></td>
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The textbook used for this course is *Chemistry: The Central Science*, 7th Ed., by Brown, LeMay and Bursten. The laboratory manual is Berea’s own and may be found at the college bookstore next week (the first week’s experiment will be handed out). In addition you will need a laboratory notebook (bound and lined, do not bring use a spiral bound notebook for laboratory), laboratory splash goggles, laboratory apron (no shorts or sandals permitted in lab), permanent-ink pen, and a scientific calculator (might find at Wal-Mart, etc.) Upper division chemistry majors will offer tutoring (as part of their labor assignments) on some of the evenings in the science library; times and dates will be announced later.

The attendance policy shall be that all labs must be completed, including laboratory write-ups. Also, it is expected that you attend all lectures. Up to two days may be missed without excuse, any subsequent absences will lead to a grade reduction of 15 points for each additional missed day (for example, if you skip class a total of 8 times, you would lose 6 x 15 = 90 points). Absence shall not be an excuse for failure to learn information covered in the course examinations. In cases involving extended absences for a good reason (for example hospitalization, emergency at home, etc.) a special arrangement will be made between us as to how to make up the missed material or exams.

### Chemistry 121 Lecture/Homework Schedule

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<th>Chapter</th>
<th>Notes</th>
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<td>Study of Chemistry, Matter</td>
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<td>September 6th</td>
<td>Measurement, Uncertainty</td>
<td>1.4-1.6</td>
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<td>September 8th</td>
<td>Problem solving from chapter 1</td>
<td>2.1-2.4</td>
<td>Due Sept. 17th</td>
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<td>Compounds</td>
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<tr>
<td>September 20th</td>
<td>The Mole, Empirical Formulas</td>
<td>3.4-3.5</td>
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<tr>
<td>September 22nd</td>
<td>Calculations with Chemical Equations</td>
<td>3.6-3.7</td>
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<tr>
<td>September 24th</td>
<td>Problem solving from chapters 1-3</td>
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<td><strong>September 27th</strong></td>
<td><strong>Examination 1</strong></td>
<td></td>
<td><strong>Monday</strong></td>
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<tr>
<td>September 29th</td>
<td>Go over test, Aqueous solutions</td>
<td>4.1-4.2</td>
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<td>HW 4.7, 4.12, 4.16, 4.20, 4.27, 4.34, 4.47, 4.54, 4.61, 4.74</td>
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<td>Acids, Bases &amp; Salts, Ionic Equations</td>
<td>4.3-4.4</td>
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<td>October 4th</td>
<td>Reactions</td>
<td>4.5-4.6</td>
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<td>October 8th</td>
<td>Problem solving from chapter 4</td>
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<tr>
<td>Date</td>
<td>Topic</td>
<td>Chapter/Deadline</td>
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<td>Stoichiometry and Chemical Analysis</td>
<td>Chapter 4.7</td>
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<td>October 13th</td>
<td>Energy, First Law of Thermodynamics, Enthalpy</td>
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<td>Chapter 5.4-5.7</td>
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<td>October 20th</td>
<td>Problem solving from chapter 5</td>
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<td>October 22nd</td>
<td>Waves, Photons, Bohr Model</td>
<td>Chapter 6.1-6.3</td>
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<td>Wave behavior of matter, Quantum Mechanics, Orbitals</td>
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<td>October 27th</td>
<td>Problem solving from chapter 6</td>
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<tr>
<td>October 29th</td>
<td>Many electron atoms, Electron configuration</td>
<td>Chapter 6.7-6.9</td>
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<tr>
<td>November 1st</td>
<td>Periodic table, Sizes of atoms, Ionization energy</td>
<td>Chapter 7.1-7.3</td>
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<td>Due Nov. 8th</td>
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<td>November 3rd</td>
<td>Electron affinity, Groups</td>
<td>Chapter 7.4-7.7</td>
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<td>November 5th</td>
<td>Problem solving from chapter 7</td>
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<td><strong>November 8th</strong></td>
<td>Examination 2</td>
<td>Monday</td>
<td></td>
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<tr>
<td>November 10th</td>
<td>Go over test, Octet Rule, Lewis Symbols, Ionic Bonding</td>
<td>Chapter 8.1-8.3</td>
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<td>HW 8.6, 8.13, 8.22, 8.28, 8.36, 8.44, 8.47, 8.54, 8.61, 8.69, 8.92</td>
<td>Due Nov. 19th</td>
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<td>Covalent bonding, Polarity, Lewis structures</td>
<td>Chapter 8.4-8.6</td>
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<td>November 15th</td>
<td>Problem solving from chapter 8</td>
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<td>November 17th</td>
<td>Resonance structures, Exceptions, Oxidation numbers</td>
<td>Chapter 8.7-8.10</td>
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<td>November 19th</td>
<td>Molecular Shape, VSEPR</td>
<td>Chapter 9.1-9.2</td>
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<td>November 22nd</td>
<td>Polarity, Orbital Overlap, Hybrid Orbitals</td>
<td>Chapter 9.3-9.5</td>
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<td>November 24th</td>
<td>Problem solving from chapter 9</td>
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<tr>
<td>December 1st</td>
<td>Multiple bonds, Molecular orbitals, Diatomics</td>
<td>Chapter 9.6-9.8</td>
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<tr>
<td>December 3rd</td>
<td>Review from chapter 7-9</td>
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<tr>
<td><strong>December 6th</strong></td>
<td>Examination 3</td>
<td>Monday</td>
<td></td>
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<tr>
<td>December 8th</td>
<td>Go over test, review chapter 1-6</td>
<td></td>
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<tr>
<td><strong>December 13th</strong></td>
<td>Final Examination</td>
<td>Monday, 3 PM</td>
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</table>
I attended the seminar by Professor Pines on Tuesday evening, May 4th. In his seminar he described a wide range of experiments he has led while studying nuclear magnetic resonance (NMR) at the University of California at Berkeley. I was rather confused by all the talk of quantum mechanics and operators, but when he showed the stick picture of “rotating magnetization”, I was able to get some idea of what he was trying to explain. The example of dropping a person on a piano and listening to the result rather than playing it note by note made a lot of sense. It is clear that all the notes are present when you drop the person and that the person landing on the piano might hit some notes harder where they are bigger/heavier and thus by analyzing the intensities you get a picture of the person. Pines explained that modern medical imaging is related to this sort of idea by making our “spins” depend upon where they are in the person and them taking a picture of the person using them. I have read a lot about magnetic resonance imaging (MRI) and how it helps to determine injuries and illnesses. The other aspect of Pines’ talk that I found very interesting was how he was doing experiments that no one else had ever thought of before. It was impressive how he seems to know so much about such a wide range of topics. It was neat to see how he has used NMR over the years to do things like figure out the structure of a molecule, to count the number of atoms in a cluster or even to spin the sample in those fancy “trajectories” to get very pretty looking spectra. It is fascinating to me that each molecule has a unique fingerprint, much like people, that can be found in the NMR spectra. On the whole, a lot of what Pines said confused me but many of his simple stick figure models made sense and ultimately I learned a little bit how MRI works. I would be interested in learning more about this important medical technology in the future.
Sample Syllabus: CHM 121, 1995

Structure—Chemistry 121

Dr. Jay H. Baltisberger
Science Bldg. Room 304  x6274

In this course I hope to introduce you to the fundamentals of chemistry and structure. As an introductory course which is only the first step in a multi-course sequence, the material we cover will not present a complete picture of chemistry. The picture will by necessity focus on inorganic chemistry and specifically the topics of bonding and structure. Some time will be spent on stoichiometry, chemical equations and equilibrium effects as well. There will be no biochemistry, organic chemistry and minimal physical chemistry in this course, these topics will wait for later in your careers (though I am happy to discuss any chemistry topic outside of class if you have the interest.) We meet Monday, Wednesday and Friday in Room 106 at 10:00 am. I will hold 9 office hours where I will guarantee normally to be available in my office unless otherwise posted. These will be Monday from 9-10, Wednesday from 9-10 and 1-2, Friday 9-10 and 1-2, Tuesday from 9-11, and Thursday from 9-11. Any other times that my door is open I am available for questions or comments. The laboratory for this course will be in room 313 and meets from 2-5 on Monday afternoons (10-40 minute prelab lecture will be in room 106).

The grading policy will be based on the following tentative schedule. You will be required to hand in homework problem sets which will account for 8% of the points in the course. There will be 9 laboratory experiments worth 18% of the points. There will be three one hour long tests worth 39% of the total points. The tentative test days will be Monday, September 25th; Monday, October 30th; and Wednesday, November 29th. There will be a final exam worth 20% of the total points on Monday, December 11th at 3pm. There will be quizzes given each day (nominally 20 quizzes or so) which will consist of a single short question and will account for 10% of the total points. You will also be expected to attend at least one chemistry department ACS student affiliate sponsored seminar scheduled once each month (either September, October, November or December). You will write a short one page report on the seminar summarizing what information you received worth the remaining 5% of the total points. The grading will be such that 100-90% is an A, 89-75% is a B, 74-60% is a C, 59-50% is a D and anything less is an F. The textbook used for this course is Chemistry: The Central Science, 6th Ed., by Brown, LeMay and Bursten. The laboratory manual is Berea's own and may be found at the college bookstore. In addition you will need a laboratory notebook (bound and lined, do not bring use a spiral bound notebook for laboratory), laboratory splash goggles, laboratory apron (no shorts or sandals permitted in lab), permanent-ink pen, and a scientific calculator (might find at Wal-Mart, etc.)
sion chemistry majors will offer tutoring (as part of their labor assignments) on some of the evenings in room 401; times and dates will be announced later.

The attendance policy shall be that all labs must be completed, including laboratory write-ups. Also, it is expected that the student attend all lectures. Up to two days may be missed without excuse, any subsequent absences will lead to a grade reduction of 3% of the total points for each additional two missed days. Absence shall not be an excuse for failure to learn information covered in the course examinations. In cases involving extended absences for a good reason (e.g. hospitalization, emergency at home, etc.) a special arrangement will be made between myself and the student as to how to make up the missed material or exams.
<table>
<thead>
<tr>
<th>Lecture 1-3</th>
<th>Introduction: Some Basic Concepts</th>
<th>Chapter 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>HW 1.5, 1.8, 1.12, 1.18, 1.21, 1.27, 1.30, 1.40, 1.52, 1.58</td>
<td>Due Sept. 11th</td>
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<tr>
<td>Lecture 4-6</td>
<td>Atoms, Molecules and Ions</td>
<td>Chapter 2</td>
</tr>
<tr>
<td>HW 2.1, 2.3, 2.14, 2.16, 2.26, 2.30, 2.39, 2.42, 2.60</td>
<td>Due Sept. 18th</td>
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<tr>
<td>Lecture 7-10</td>
<td>Stoichiometry: Calculations with Formulas</td>
<td>Chapter 3</td>
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<tr>
<td>Examination 1</td>
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<td>September 25th</td>
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<tr>
<td>Lecture 12-16</td>
<td>Aqueous Reactions</td>
<td>Chapter 4</td>
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<td>HW 4.4, 4.10, 4.18, 4.21, 4.27, 4.28, 4.35, 4.40, 4.48, 4.52, 4.61</td>
<td>Due Oct. 9th</td>
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<td>Lecture 17-19</td>
<td>Thermochemistry</td>
<td>Chapter 5</td>
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<td>HW 5.4, 5.7, 5.10, 5.13, 5.18, 5.27, 5.34, 5.37, 5.43, 5.44, 5.48, 5.70</td>
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<td>Lecture 20-23</td>
<td>Atomic Structure</td>
<td>Chapter 6</td>
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<td>HW 6.3, 6.6, 6.12, 6.16, 6.24, 6.29, 6.34, 6.35, 6.43, 6.53, 6.60, 6.63</td>
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<td>Examination 2</td>
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<td>October 30th</td>
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<td>Lecture 25-27</td>
<td>Periodic Properties</td>
<td>Chapter 7</td>
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<td>HW 7.5, 7.10, 7.11, 7.20, 7.30, 7.38, 7.51, 7.55, 7.59, 7.68</td>
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<tr>
<td>Lecture 28-30</td>
<td>Chemical Bonding</td>
<td>Chapter 8</td>
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<td>HW 8.5, 8.9, 8.12, 8.19, 8.22, 8.30, 8.34, 8.37, 8.42, 8.50, 8.53, 8.59, 8.69</td>
<td>Due Nov. 20th</td>
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<tr>
<td>Lecture 31-35</td>
<td>Molecular Geometry</td>
<td>Chapter 9</td>
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<tr>
<td>Examination 3</td>
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<td>November 29th</td>
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<tr>
<td>Lecture 37-39</td>
<td>Gases</td>
<td>Chapter 10</td>
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<tr>
<td>HW 10.2, 10.4, 10.18, 10.23, 10.32, 10.36, 10.42, 10.49</td>
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<tr>
<td>Final Examination</td>
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<td>Monday, December 11, 3 PM</td>
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</table>
Chemistry 122 is a continuation of the ideas you learned in chemistry 121 (Structure). In this course we will begin to focus more on changes in time and space rather than the more static structural issues addressed in Chemistry 121. This will include topics such as electrochemistry, gas laws, kinetics, intermolecular forces, advanced equilibrium topics, acid-base equilibria and buffers, and some nuclear chemistry. If time permits, we may also look at some special topics such as environmental chemistry or materials science. The knowledge you learn in this course will carry throughout many of your future chemistry courses while building on all of the information we learned in chemistry 121. The laboratory assignments have been designed to mirror the lectures and hopefully they will provide additional real world examples of the in class phenomena we discuss.

We meet Monday, Wednesday and Friday in Room 106 at 11:00 am. I will hold 9 office hours where I will guarantee normally to be available in my office unless otherwise posted. These will be Monday from 9-10, Wednesday from 9-10, Friday 9-10, Tuesday from 9-11 and 1-2, and Thursday from 9-11 and 1-2. Any other times that my door is open I am available for questions or comments. The laboratory for this course will be in room 313 and meets from 2-5 on Monday afternoons or 3-6 on Tuesday afternoons. Note that the laboratory sessions are not optional and you are expected to attend both the prelab and subsequent laboratory sessions.

The grading policy will be based on the following schedule. You will be required to hand in homework problem sets (see last page of syllabus for complete assignments and due dates) which will be worth account for 100 points (10 points each). These will be graded primarily based on completion of the assignment (2/3 of grade) and accuracy of solutions (1/3). There will be 8 laboratory experiments worth 80 points (10 points each) as well as 9 pre-lab question assignments worth 18 points (2 points each). Laboratory notebooks will be graded based on completeness (did you answer all the questions, did you conduct the experiment, did you interpret your data) rather than quantitative accuracy (this can wait until CHM 241). There will be three one hour long tests worth 300 points (100 points each). The tentative test days will be Friday, February 28th; Wednesday, April 9th; Wednesday May 7th. There will be a final exam worth 200 points on Thursday, May 22nd at 1pm. Tests will be graded very objectively for accuracy of answers. Normally each test will have about 1/3 multiple choice questions to help you prepare for the future when you will take MCAT, LSAT, GRE which are entirely multiple choice. As well there will be some fill in the blank, short essay and word problems on these exams. There will be quizzes given most days (approximately 20 quizzes) which will consist of a single short question and
will account for 60 points (3 points each). The grading will be such that 100-92% is an A (minimum 695 points), 91-78% is a B (minimum 590 points), 77-63% is a C (minimum 475 points), 62-50% is a D (minimum 380 points) and anything less is an F.

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<td>Laboratory Write-ups (8)</td>
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<td>Pre-Labs (9)</td>
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<td>Midterm Exams (3)</td>
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<td>Quizzes (20)</td>
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<td><strong>Grand Total</strong></td>
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The textbook used for this course is *Chemistry: The Central Science, 6th Ed.*, by Brown, LeMay and Bursten. The laboratory manual is Berea's own and may be found at the college bookstore. In addition you will need a laboratory notebook (bound and lined, do not bring use a spiral bound notebook for laboratory), laboratory splash goggles, laboratory apron (no shorts or sandals permitted in lab), permanent-ink pen, and a scientific calculator (might find at Wal-Mart, etc.) Upper division chemistry majors will offer tutoring (as part of their labor assignments) on some of the evenings in room 401; times and dates will be announced later.

The attendance policy shall be that all labs must be completed, including laboratory write-ups. Also, it is expected that you attend all lectures. Up to three days may be missed without excuse, any subsequent absences will lead to a grade reduction of 15 points for each additional missed day (for example, if you skip class a total of 8 times, you would lose $5 \times 15 = 75$ points). Absence shall not be an excuse for failure to learn information covered in the course examinations. In cases involving extended absences for a good reason (for example hospitalization, emergency at home, etc.) a special arrangement will be made between us as to how to make up the missed material or exams.
# Chemistry 122 Lecture/Homework Schedule

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<thead>
<tr>
<th>Lecture 1-2</th>
<th>Gases</th>
<th>Chapter 10</th>
<th>Due 2/14</th>
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<td>Lecture 3-6</td>
<td>Intermolecular Forces, Liquids and Solids</td>
<td>Chapter 11</td>
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<td>Lecture 7-9</td>
<td>Properties of Solutions</td>
<td>Chapter 13</td>
<td>Due 3/3</td>
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<td>Lecture 11-14</td>
<td>Chemical Kinetics</td>
<td>Chapter 14</td>
<td>Due 3/14</td>
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<td>Lecture 15-18</td>
<td>Chemical Equilibrium</td>
<td>Chapter 15</td>
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<td>Lecture 19-22</td>
<td>Acid-Base Equilibria</td>
<td>Chapter 16</td>
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<td>Aqueous Equilibria II</td>
<td>Chapter 17</td>
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<td>Chemical Thermodynamics</td>
<td>Chapter 19</td>
<td>Due 4/28</td>
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<td>Lecture 30-32</td>
<td>Electrochemistry</td>
<td>Chapter 20</td>
<td>Due 5/5</td>
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<tr>
<td>Lecture 33-34</td>
<td>Nuclear Chemistry</td>
<td>Chapter 21</td>
<td>Due 5/9</td>
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<tr>
<td>Lecture 36-38</td>
<td>Modern Materials/Environmental Chemistry</td>
<td>Chapter 12/18</td>
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<tr>
<td>Final Examination</td>
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<td>Thursday, May 22, 1 PM</td>
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In this course I hope to introduce you to the fundamentals of thermodynamics. The primary text we will use is a very comprehensive and mathematically rigorous physical chemistry textbook (Peter Atkins, *Physical Chemistry, 6th edition*). You probably should spend some time early on in the course re-reading your calculus text (or similar math methods text, which I can suggest other titles), as your mathematics skills are critical for success in this course. We meet Monday, Wednesday and Friday in Room 306 at 10:00 - 11:00 AM. Lab will meet there as well on Tuesday from 3:00 to 6:00 PM. I will hold 8 office hours where I will guarantee normally to be available in my office unless otherwise posted. These will be Monday from 9-10, Wednesday from 9-10, Friday from 9-10, Tuesday from 9-11, Wednesday from 3-4 and Thursday from 9-11. Any other times that my door is open I am available for questions or comments.

The grading policy will be based on the following tentative schedule. You will be required to hand in 9 homework problem sets which will account for 10 points each and due after we finish each chapter (see outline below for dates). Each assignment will be graded based upon completeness more than accuracy. It is imperative that you do the minimum homework assigned, but this is by no means the minimum that should be done to do well in the course. I expect that you will work many additional problems outside of the homework assignments and I will guarantee you will see non-homework problems from the text on the tests. Also, each day in class a student will be randomly selected to present a problem at the board. This should already be completed before class and will be from the current section in Atkins. Any student selected in this fashion who fails to have a problem completed will be docked 5 points for each incident after the first. There will be 7 laboratory assignments worth 25 points each (including an exercise using Maple™ and a literature review exercise). The literature review exercise will consist of a 20 minute oral review of a paper selected from a chemistry journal in the field of thermochemistry or kinetics. For the first experimental laboratory assignment you will turn in a 5-8 page formal laboratory report. The remaining laboratories will be graded based on evaluation of your laboratory notebook and a second oral presentation.

<table>
<thead>
<tr>
<th>Assignment</th>
<th>Points each</th>
<th>Total Points</th>
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<tbody>
<tr>
<td>Homework (12)</td>
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<td>Laboratory Write-ups (7)</td>
<td>30</td>
<td>210</td>
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<td>Midterm Exams (3)</td>
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<td>Final Exam</td>
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<td>250</td>
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<tr>
<td><strong>Grand Total</strong></td>
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<td><strong>1000</strong></td>
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</tbody>
</table>
to the class on the laboratory of your choice the last week of the semester. There will be three one hour long tests each worth 150 points with problems taken primarily from the texts. *The tentative test days will be Wednesday, March 3rd; Monday, March 29th; and Wednesday, April 28th.* There will be a final exam worth 250 points on Thursday, May 20th at 8 a.m. The final will be a cumulative ACS standardized exam on thermochemistry. This means there will be a total of about 965 points. The grading will be such that 91% is an A (910 points), 77% is a B (770 points), 60% is a C (600 points), 50% is a D (500 points). For each midterm exam you will be allowed a single sheet (double sided) with any information on it you like.

The attendance policy shall be that all labs must be completed, including laboratory write-ups and oral exams. Also, it is expected that the student attend all lectures. Up to two days may be missed without excuse, any subsequent absences will lead to a 15 point deduction from your total score for each additional missed day. Absence shall not be an excuse for failure to learn information covered in the course examinations. In cases involving extended absences for a good reason (e.g. hospitalization, emergency at home, etc.) a special arrangement will be made between myself and the student as to how to make up the missed material or exams.

**Thermochemistry—Chemistry 261**

Chapter 0 - Introduction  
February 5th  Matter & Energy  
Section 0.1 – 0.5

Chapter 1 – Properties of Gases  
Exercises 1.3a, 1.8b, 1.14b, 1.27b  
Problems 1.13, 1.17, 1.33, 1.39  
February 8th  The Perfect Gas  
Section 1.1 – 1.3

February 10th, 12th  Optional review session with Teaching Assistant  
Dr. Baltisberger will be at NSF Review panel in Washington, D.C.

Chapter 1 – Properties of Gases (continued)  
February 15th  Real Gases  
Section 1.4 – 1.6

Chapter 2 – The First Law: The Concepts  
Exercises 2.4a, 2.10a, 2.20b, 2.36b  
Problems 2.5, 2.11, 2.14, 2.25  
February 17th  Basic Concepts  
Section 2.1 – 2.2

February 19th  Work and Heat  
February 22nd  Thermochemistry  
Section 2.3 – 2.6

Chapter 3 - The First Law: The Machinery  
Exercises 3.4b, 3.13b  
Problems 3.2, 3.11, 3.26  
February 24th  Second law, Engines, Entropy  
Section 2.7 – 2.9

Chapter 4 – The Second Law: The Concepts  
Exercises 4.5a, 4.15a, 4.20b
Problems 4.6, 4.12, 4.23, 4.30  Due 3/15
February 26th The Direction of Spontaneous Change  4.1 – 4.5

March 1st Optional review session with Teaching Assistant
Dr. Baltisberger will be at Experimental NMR Conference in Orlando, FL

Test 1 Wednesday, March 3rd (keep test copy for Friday) Chapters 0 - 3

March 5th Go over test problems as a group
Dr. Baltisberger will be at Experimental NMR Conference in Orlando, FL

Chapter 4 – The Second Law: The Concepts (continued)
March 8th Concentrating on the System  4.6 – 4.7

Chapter 5 – The Second Law: The Machinery
Exercises  5.3b, 5.11b
Problems  5.2, 5.11, 5.20, 5.29  Due 3/19
March 10th Combining the First and Second Laws  5.1 – 5.3
March 12th Real gases: The Fugacity  5.4 – 5.6

Chapter 6 – Physical Transformations of Pure Substances
Exercises  6.3b, 6.9a
Problems  6.5, 6.13  Due 3/29
March 15th Phase Diagrams  6.1 – 6.3
March 17th Phase Stability  6.4 – 6.7
March 19th The Physical Liquid Surface  6.8 – 6.10
March 22nd – 28th Spring Break (study chapters 1 – 6)

Test 2 Monday, March 29th Chapters 4 - 6

Chapter 7 – Simple Mixtures
Exercises  7.2b, 7.10b, 7.18a
Problems  7.3, 7.10  Due 4/9
March 31st The Thermodynamic Description of Mixtures  7.1 – 7.3
April 2nd The Properties of Solutions  7.4 – 7.5
April 5th Activities  7.6 – 7.7

Chapter 8 – Phase Diagrams
Exercises  8.4a, 8.7b, 8.10a, 8.13b, 8.19b
Problems  8.4, 8.13  Due 4/16
April 7th Phase Rule  8.1 – 8.2
April 9th, 12th Two-component Systems  8.3 – 8.7

Chapter 9 – Chemical Equilibrium
Exercises  9.3b, 9.7b, 9.16a
Problems  9.3, 9.6  Due 4/26
April 14th Spontaneous Reactions  9.1
April 16th Response of Equilibria to Conditions  9.2 – 9.3
April 19th Applications  9.4 – 9.6

Chapter 10 – Equilibrium Electrochemistry
Exercises  10.6a, 10.21a
Problems  10.4, 10.18  Due 4/30
<table>
<thead>
<tr>
<th>Date</th>
<th>Topic</th>
<th>Chapters</th>
</tr>
</thead>
<tbody>
<tr>
<td>April 21st</td>
<td>Thermodynamic Properties of Ions in Solution</td>
<td>10.1 – 10.2</td>
</tr>
<tr>
<td>April 23rd</td>
<td>Electrochemical Cells</td>
<td>10.3 – 10.5</td>
</tr>
<tr>
<td>April 26th</td>
<td>Applications of Standard Potentials</td>
<td>10.6 – 10.9</td>
</tr>
</tbody>
</table>

**Test 3  Wednesday, April 28th**

Chapters 7 - 10

Chapter 24 – Molecules in Motion
- Exercises: 24.7b, 24.13a
- Problems: 24.6, 24.17
- April 30th: Motion in Gases & Liquids
- May 3rd: Diffusion

Chapter 25 – The Rates of Chemical Reactions
- Exercises: 25.5b, 25.13b
- Problems: 25.3, 25.11, 25.18
- May 5th: Empirical Kinetics
- May 7th: Accounting for Rate Laws

Chapter 26 – The Kinetics of Complex Reactions
- Exercises: 26.2b, 26.7a
- Problems: 26.3, 26.9
- May 10th: Chain Reactions
- May 12th: Polymerization & Catalysis

**Final Exam**

Standardized ACS Thermodynamics Exam  Thursday, May 20th, 8 AM
Chemistry Department Oral Communication Evaluation Form

Student's Name_____________________________   Date ____________________

Venue_____________________________   Evaluator ____________________

Each of the following should be rated as being at a distinguished, D, proficient, P, apprentice, A, or novice, N level. The attached form describes these ratings.

Communication Skill Assessment

A. Presence—(voice, pace, eye contact, confidence, body language) ______

B. Use of supplementary material—(chalkboards, handouts, overheads) ______

C. Clarity of talk—(outline, organization, conclusion, appropriate for audience) ______

D. Response to questions— ______

General Comments

Specific Recommendations for Communication Skill Improvement

Technical Assessment

A. Understanding of material ______

B. Explanation of material—(appropriate for level of audience, educational) ______

C. Substance—(technically correct) ______

D. Response to questions ______

General Comments

Specific Recommendations for Improving Technical Content

Overall Rating of Presentation

Distinguished _____   Proficient _____   Apprentice _____   Novice _____
Explanation of Rating Scale

*Distinguished* – The oral communication skills of the student are near perfect. The presentation was well-rehearsed with an exceptionally clear thesis and outline. Appropriate use has been made of supplementary material—writing on the chalkboard or overheads is legible, handouts add significantly to the presentation. Voice projection, the pace of the presentation are fine. Technically, the student has taken the material beyond a mere literature review or research summary by adding additional interpretation or making comparisons not present in the original literature.

*Proficient* – The oral skills of the student are at an acceptable level. Appropriate use has been made of supplementary material—writing on the chalkboard or overheads is legible, handouts add significantly to the presentation. Voice projection, the pace of the presentation are fine. The only minor errors that are present, if any, could be improved through additional practice. NO technical errors are present. The student has presented the reviewed material concisely, accurately, and at an appropriate level for the audience.

*Apprentice* – Key features of oral communication are evident, but capable of additional development. No more than one major flaw is contained in the presentation such as lack of voice projection, poor overhead usage, inappropriate body language, poor quality of supplementary material. The thesis and outline of the talk are obvious. Technically the presentation contains few flaws, however, the material is still not quite understandable at the level of the audience. Understanding could be improved through the use of more appropriate supplementary material, simplification of diagrams and figures, or by spending more time explaining each figure. It is apparent that the student has some understanding of the material.

*Novice* – Essential elements of effective oral communication are not evident. Poor grammar is evident throughout the presentation as shown through poor word choice, sentence structure, and pronunciation problems. No thesis or outline is apparent. Communication aids are not used effectively and are more of a hindrance than a help. The use of a chalkboard, overheads, or other auxiliary material is very awkward. Technically, the report contains numerous scientific errors showing some misunderstanding of the project. The purpose of the research is not evident and it is not presented on a level understandable by the audience.
Sample Syllabus: CHM 113, 1999

Fundamentals of General, Organic and Biological Chemistry—Chemistry 113 A/B

Dr. Jay H. Baltisberger
Science Bldg. Room 101  x6274

In this course I hope to introduce you to the fundamentals of chemistry. This is an introductory course which is only the first step in your science education. The material we cover will not present a complete picture of chemistry, but hopefully will provide you with a basis to learn additional chemistry in other courses and your life once you leave Berea. We will try to give you a brief taste of all the major areas of chemistry from general inorganic topics all the way through biochemistry. Of course along the way some time will be spent on stoichiometry, chemical equations, equilibrium effects, basic organic reactions and biomolecular pathways. What does all this mean to you as a student? Hopefully, it means you will have a better understanding of what makes your car run (combustion reactions), how Crystal Drano works (acid/base chemistry), how your body transfers energy (ATP/ADP), or how a peptide or protein is put together (DNA/Codons).

In this course I hope to introduce you to a range of topics in chemistry including general, organic chemistry and biochemistry. We meet Monday, Wednesday and Friday in Room 101 at 11:00 AM. Laboratory lectures will be given either in room 306 immediately preceding the laboratory in room 313. I will hold 8 office hours where I will guarantee normally to be available in my office unless otherwise posted. These will be MWF 9-10 AM, TR 9-11 AM and W 3-4 PM. Any other times that my door is open I am available for questions or comments. Please stop by if the course is going to quickly or you are generally confused.

The grading policy will be based on the following tentative schedule. You will be required to hand in 12 homework problem sets which will account for 5 points each and due almost once per week. There will probably be 11 laboratory experiments worth 10 points each. You will be required to keep a laboratory notebook which will be collected after the completion of each lab. There will be four one hour long tests each worth 120 points. You will be given unannounced quizzes (20 times throughout the semester) worth 5 points each which will be multiple choice and require you to answer a question about the current material. The test days will be on the Friday March 5th; Monday March 29th; Friday April 16th; and Friday May 7th. There will be a final exam worth 250 points on May 18th at 1 PM. All tests, including the final, will be cumulative. The grading will be such that 92% is an A (920 points minimum), 80% is a B (800 points minimum), 62% is a C (620 points minimum), 55% is a D (550 points minimum) and anything less is an F.
Homework will be graded mostly on the basis of completeness rather than accuracy. These exercises are more a method for me to require you to do problems than to test your knowledge (that is what quizzes and tests are for). The number of problems assigned represents minimum number suggested to do well in the course. If you choose to do fewer, you will lose homework points as well as probably test points. If you choose to do more, you will reap the benefits of much higher test performance in all likelihood.

<table>
<thead>
<tr>
<th>Assignment</th>
<th>Points each</th>
<th>Total Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Homework (12)</td>
<td>5</td>
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<tr>
<td>Laboratory Write-ups (11)</td>
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<td>Midterm Exams (4)</td>
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<td>Quizzes (20)</td>
<td>5</td>
<td>100</td>
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<tr>
<td>Final Exam</td>
<td>250</td>
<td>250</td>
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<tr>
<td><strong>Grand Total</strong></td>
<td></td>
<td><strong>1000</strong></td>
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</tbody>
</table>

Both you and I will be keeping track of your points throughout the semester. At the end of the semester you will turn in a sheet of paper with your current point total listed (excluding the final). If you are within 10 points of the actual total, you will be rewarded with 25 bonus points. If you are within 20 points of the actual total, you will be rewarded with 10 bonus points. If you are more than 20 points of the actual total you will receive no bonus points. This is an exercise that I believe all college students should be able to succeed at and will encourage you to keep records of your progress. This way you will always know where you stand and what you have left to accomplish in the course. I will be happy to help you set up a gradebook for yourself in Excel or Word which you can then use to gain the bonus points.

Office hours will be the other route to gain some bonus points. Each week you may gain up to 3 bonus points by attending office hours and bringing at least one question which goes beyond simply asking a homework problem. These points may not exceed 30 total points for the semester. I am certainly happy to help you with homework during office hours, but I want to reward those who bring questions which ask me about the why and what and not just the mechanics of solving problems. These bonus points will be given to you at the end of an office hour session and will range anywhere from 0 to 3 points, depending on my evaluation of our meetings. Note that you should not expect that coming to office hours each week will guarantee any grade or even specific numbers of bonus points. I expect that attending an office hour should require some preparation if you want to be rewarded with bonus points. BUT, you should also realize that by spending the extra time going beyond the homework you will in all likelihood improve your overall test and quiz performance!
The textbook used for this course is *Chemistry for Today: General, Organic and Biochemistry*, 3rd Ed., by Spencer L. Seager & Michael R. Slabaugh. The laboratory manual is Berea's own and may be found at the college bookstore (once it is printed). In addition you will need a laboratory notebook (bound and lined, do not bring use a spiral bound notebook for laboratory), laboratory splash goggles, laboratory apron (no shorts or sandals permitted in lab), permanent-ink pen, and a scientific calculator (might find at Wal-Mart, etc.) Upper division chemistry majors will offer tutoring (as part of their labor assignments) on some of the evenings in the science library; times and dates will be announced later.

The attendance policy shall be that all labs must be completed, including laboratory write-ups. Also, it is expected that you attend all lectures. Up to two days may be missed without excuse, any subsequent absences will lead to a grade reduction of 15 points for each additional missed day (for example, if you skip class a total of 8 times, you would lose $6 \times 15 = 90$ points). Absence shall not be an excuse for failure to learn information covered in the course examinations. In cases involving extended absences for a good reason (for example hospitalization, emergency at home, etc.) a special arrangement will be made between us as to how to make up the missed material or exams.
### Lecture Schedule

<table>
<thead>
<tr>
<th>Date</th>
<th>Topic</th>
<th>Chapter(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>February 5&lt;sup&gt;th&lt;/sup&gt;</td>
<td>Matter, Measurements, and Calculations</td>
<td>Chapter 1</td>
</tr>
<tr>
<td></td>
<td>Problems 12, 29, 37, 55, 71</td>
<td>Due with Chapter 2 problems</td>
</tr>
<tr>
<td>February 8&lt;sup&gt;th&lt;/sup&gt;</td>
<td>Atoms and Molecules</td>
<td>Chapter 2</td>
</tr>
<tr>
<td></td>
<td>Problems 8, 9, 15, 37, 57</td>
<td>Due February 15&lt;sup&gt;th&lt;/sup&gt;</td>
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<tr>
<td>February 10&lt;sup&gt;th&lt;/sup&gt;</td>
<td>Electronic Structure and the Periodic Law</td>
<td>Chapter 3</td>
</tr>
<tr>
<td></td>
<td>Problems 12, 25, 41, 45</td>
<td>Due with Chapter 4 problems</td>
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<tr>
<td></td>
<td>Guest Lecturer: Larry Blair</td>
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<tr>
<td>February 12&lt;sup&gt;th&lt;/sup&gt;</td>
<td>No lecture or laboratory. Dr. Baltisberger will be in Washington D.C. on NSF review panel. Study chapter 1 and 2 and store up questions!</td>
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<tr>
<td>February 15&lt;sup&gt;th&lt;/sup&gt;, 17&lt;sup&gt;th&lt;/sup&gt;</td>
<td>Forces Between Particles</td>
<td>Chapter 4</td>
</tr>
<tr>
<td></td>
<td>Problems 13, 31, 47, 57, 72</td>
<td>Due February 24&lt;sup&gt;th&lt;/sup&gt;</td>
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<tr>
<td>February 19&lt;sup&gt;th&lt;/sup&gt;</td>
<td>Chemical Reactions</td>
<td>Chapter 5</td>
</tr>
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<td>Problems 3, 11, 25, 35</td>
<td>Due with Chapter 6 problems</td>
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<tr>
<td>February 22&lt;sup&gt;nd&lt;/sup&gt;</td>
<td>The States of Matter</td>
<td>Chapter 6</td>
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<td>Problems 3, 27, 46, 71</td>
<td>Due March 3&lt;sup&gt;rd&lt;/sup&gt;</td>
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<td>February 24&lt;sup&gt;th&lt;/sup&gt;</td>
<td>Solutions and Colloids</td>
<td>Chapter 7</td>
</tr>
<tr>
<td></td>
<td>Problems 5, 17, 25, 49, 73</td>
<td>Due with Chapter 8 problems</td>
</tr>
<tr>
<td>February 26&lt;sup&gt;th&lt;/sup&gt;</td>
<td>Reaction Rates and Equilibrium</td>
<td>Chapter 8</td>
</tr>
<tr>
<td></td>
<td>Problems 2, 7, 15, 31</td>
<td>Due March 10&lt;sup&gt;th&lt;/sup&gt;</td>
</tr>
<tr>
<td>March 1&lt;sup&gt;st&lt;/sup&gt;</td>
<td>No lecture. Dr. Baltisberger will be in Orlando, FL at Experimental NMR Conference from March 1&lt;sup&gt;st&lt;/sup&gt; to March 7&lt;sup&gt;th&lt;/sup&gt;.</td>
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<tr>
<td>March 3&lt;sup&gt;rd&lt;/sup&gt;</td>
<td>Review session (conducted by a Teaching Assistant)</td>
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<tr>
<td>March 5&lt;sup&gt;th&lt;/sup&gt;</td>
<td><strong>Test 1</strong></td>
<td></td>
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<tr>
<td>March 8&lt;sup&gt;th&lt;/sup&gt;, 10&lt;sup&gt;th&lt;/sup&gt;</td>
<td>Review test, Acids, Bases, and Salts</td>
<td>Chapter 9</td>
</tr>
<tr>
<td></td>
<td>Problems 2, 9, 47, 61, 99</td>
<td>Due with Chapter 10 problems</td>
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<tr>
<td>March 12&lt;sup&gt;th&lt;/sup&gt;</td>
<td>Radioactivity and Nuclear Processes</td>
<td>Chapter 10</td>
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<tr>
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<td>Problems 3, 7, 12, 29, 43</td>
<td>Due March 17&lt;sup&gt;th&lt;/sup&gt;</td>
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<tr>
<td>March 15&lt;sup&gt;th&lt;/sup&gt;</td>
<td>Organic Compounds: Alkanes</td>
<td>Chapter 11</td>
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<td>Problems 5, 12, 20, 25, 35</td>
<td>Due with Chapter 12 problems</td>
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<tr>
<td>March 17&lt;sup&gt;th&lt;/sup&gt;</td>
<td>Unsaturated Hydrocarbons</td>
<td>Chapter 12</td>
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<tr>
<td></td>
<td>Problems 3, 23, 43, 68, 73</td>
<td>Due March 29&lt;sup&gt;th&lt;/sup&gt;</td>
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<tr>
<td>March 19&lt;sup&gt;th&lt;/sup&gt;</td>
<td>Alcohols, Phenols, and Ethers</td>
<td>Chapter 13</td>
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<td></td>
<td>Problems 1, 24, 33, 41, 51</td>
<td>Due with Chapter 14 problems</td>
</tr>
<tr>
<td>March 20&lt;sup&gt;th&lt;/sup&gt; – 28&lt;sup&gt;th&lt;/sup&gt;</td>
<td>Spring Break</td>
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<td>March 29&lt;sup&gt;th&lt;/sup&gt;</td>
<td><strong>Test 2</strong></td>
<td>Chapters 1 – 13</td>
</tr>
<tr>
<td>March 31&lt;sup&gt;st&lt;/sup&gt;</td>
<td>Review test, Aldehydes and Ketones</td>
<td>Chapter 14</td>
</tr>
<tr>
<td></td>
<td>Problems 9, 20, 33, 47</td>
<td>Due April 9&lt;sup&gt;th&lt;/sup&gt;</td>
</tr>
<tr>
<td>Date</td>
<td>Topic</td>
<td>Chapter</td>
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<tr>
<td>April 2nd</td>
<td>Carboxylic Acids and Esters (Good Friday, no Lab)</td>
<td>15</td>
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<tr>
<td>April 5th</td>
<td>Amines and Amides</td>
<td>16</td>
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<td>April 7th</td>
<td>Carbohydrates</td>
<td>17</td>
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<tr>
<td>April 9th</td>
<td>Lipids</td>
<td>18</td>
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<tr>
<td>April 12th, 14th</td>
<td>Proteins, Review for test</td>
<td>19</td>
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<tr>
<td>April 16th</td>
<td>Test 3</td>
<td></td>
</tr>
<tr>
<td>April 19th, 21st</td>
<td>Review Test, Enzymes</td>
<td>20</td>
</tr>
<tr>
<td>April 23rd</td>
<td>Nucleic Acids and Protein Synthesis</td>
<td>21</td>
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<tr>
<td>April 26th</td>
<td>Nutrition and Energy for Life</td>
<td>22</td>
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<tr>
<td>April 28th</td>
<td>Carbohydrate Metabolism</td>
<td>23</td>
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<tr>
<td>April 30th, May 3rd</td>
<td>Lipid and Amino Acid Metabolism</td>
<td>24</td>
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<tr>
<td>May 5th</td>
<td>Body Fluids</td>
<td>25</td>
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<tr>
<td>May 6th</td>
<td>Alexander Pines – Chemistry Department Seminar</td>
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<tr>
<td>May 7th</td>
<td>Test 4</td>
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<tr>
<td>May 10th</td>
<td>Review test, Body Fluids</td>
<td>25</td>
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<td>May 12th</td>
<td>Review Session, Course Evaluation</td>
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<tr>
<td>May 18th</td>
<td>Final Exam</td>
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### Tentative Laboratory Sessions

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<th>Lab</th>
<th>Description</th>
<th>Date</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Check-in, Safety, Determination of Density</td>
<td>Feb. 5&lt;sup&gt;th&lt;/sup&gt;</td>
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<tr>
<td></td>
<td>Lab canceled (Dr. Baltisberger in Washington D.C.)</td>
<td>Feb. 12th</td>
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<tr>
<td>2</td>
<td>Evidence of Chemical Reactions</td>
<td>Feb. 19th</td>
</tr>
<tr>
<td>3</td>
<td>Le Châtelier’s Principle</td>
<td>Feb. 26th</td>
</tr>
<tr>
<td>4</td>
<td>Hydronium Ions</td>
<td>Mar. 5&lt;sup&gt;th&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Dr. Baltisberger will be out of town this day.</td>
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<tr>
<td>5</td>
<td>Acid-Base Titration</td>
<td>Mar. 12th</td>
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<tr>
<td>6</td>
<td>Organic Chemistry</td>
<td>Mar. 19&lt;sup&gt;th&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Spring Break</td>
<td>Mar. 26th</td>
</tr>
<tr>
<td></td>
<td>Good Friday</td>
<td>April 2nd</td>
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<tr>
<td>7</td>
<td>Organic Chemistry</td>
<td>April 9th</td>
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<tr>
<td>8</td>
<td>Molecular Models</td>
<td>April 16th</td>
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<tr>
<td>9</td>
<td>Biochemistry - Carbohydrates</td>
<td>April 23rd</td>
</tr>
<tr>
<td>10</td>
<td>Proteins</td>
<td>April 30th</td>
</tr>
<tr>
<td>11</td>
<td>Enzymes and Blood, Check out</td>
<td>May 7th</td>
</tr>
</tbody>
</table>
Sample Syllabus: CHM 113, 1994

Fundamentals of General, Organic and Biological Chemistry - Chemistry 113

Dr. Jay H. Baltisberger
Science Bldg. Room 101  x6274

In this course I hope to introduce you to a range of topics in chemistry including general, organic chemistry and biochemistry. We meet Monday, Wednesday and Friday in Room 101 at 11:00 AM. Laboratory lectures will be given either in room 101 or 106 immediately preceding the lab. I will hold 8 office hours where I will guarantee normally to be available in my office unless otherwise posted. These will be M-F 9-10 AM and T-Th 10-11 & 1-2 PM. Any other times that my door is open I am available for questions or comments. Please stop by if the course is going to quickly or you are generally confused.

The grading policy will be based on the following tentative schedule. You will be required to hand in 12 homework problem sets which will account for 10 points each and due almost once per week. There will probably be 11 laboratory experiments worth 10 points each. You will be required to keep a laboratory notebook which will be collected after the completion of each lab. There will be four one hour long tests each worth 100 points. The tentative test days will be on the Mondays of February 21st, March 14th, April 11th and May 2nd. There will be a final exam worth 250 points on May 18th at 1 PM. Normally all tests including the final will be cumulative. The grading will be such that 85% is an A, 72% is a B, 60% is a C, 50% is a D and anything less is an F. The book used for this course is Elements of General and Biological Chemistry, 8th Ed., by John R. Holum.

The attendance policy shall be that all labs must be completed, including laboratory write-ups and notebooks. Also, it is expected that the student attend all lectures. Up to four days may be missed without excuse, any subsequent absences will lead to a 1/3 letter grade reduction for each four missed days. Absence shall not be an excuse for failure to learn information covered in the course examinations. In cases involving extended absences for a good reason (e.g. hospitalization, emergency at home, etc.) a special arrangement will be made between myself and the student as to how to make up the missed material or exams.
# Lecture Schedule

<table>
<thead>
<tr>
<th>Lecture 1-2</th>
<th>Goals, Methods and Measurements</th>
<th>Chapter 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lecture 3-4</td>
<td>The Nature of Matter: The Atomic Theory</td>
<td>Chapter 2</td>
</tr>
<tr>
<td>Lecture 5-6</td>
<td>The Nature of Matter: Compounds and Bonds</td>
<td>Chapter 3</td>
</tr>
<tr>
<td>Lecture 7-8</td>
<td>Chemical Reactions: Equations and Mass Relationships</td>
<td>Chapter 4</td>
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</tbody>
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**Test 1**

<table>
<thead>
<tr>
<th>Lecture 10-12</th>
<th>Water, Solutions, and Colloids</th>
<th>Chapter 6</th>
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<tbody>
<tr>
<td>Lecture 13-14</td>
<td>Acids, Bases, and Salts</td>
<td>Chapter 7</td>
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<tr>
<td>Lecture 15-16</td>
<td>Acidity: Detection, Control, Measurement</td>
<td>Chapter 8</td>
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<tr>
<td>Lecture 17</td>
<td>Introduction to Organic Chemistry</td>
<td>Chapter 9</td>
</tr>
</tbody>
</table>

**Test 2**

| Lecture 19 | Introduction to Organic Chemistry | Chapter 9 |
| Lecture 20 | Hydrocarbons | Chapter 10 |
| Lecture 21 | Alcohols, Thioalcohols, Ethers, and Amines | Chapter 11 |
| Lecture 21 | Aldehydes and Ketones | Chapter 12 |
| Lecture 22 | Carboxylic Acids and Their Derivatives | Chapter 13 |
| Lecture 23-24 | Carbohydrates | Chapter 14 |
| Lecture 25-26 | Lipids | Chapter 15 |

**Test 3**

| Lecture 28-29 | Proteins | Chapter 16 |
| Lecture 30-31 | Enzymes | Chapter 17 |
| Lecture 32-33 | Extracellular Fluids of the Body | Chapter 18 |
| Lecture 34-35 | Molecular Basis of Energy for Living | Chapter 19 |

**Test 4**

| Lecture 37-38 | Metabolism and Molecular Building | Chapter 20 |
| Lecture 39-40 | Nucleic Acids | Chapter 21 |

**Final Exam**

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>Test 1</td>
<td>February 21st</td>
<td></td>
</tr>
<tr>
<td>Test 2</td>
<td>March 14th</td>
<td></td>
</tr>
<tr>
<td>Test 3</td>
<td>April 11th</td>
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<tr>
<td>Test 4</td>
<td>May 2nd</td>
<td></td>
</tr>
<tr>
<td></td>
<td>May 18th</td>
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## Laboratory Sessions

<table>
<thead>
<tr>
<th>Lab</th>
<th>Topic</th>
<th>Date</th>
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<tbody>
<tr>
<td>1</td>
<td>Check-in, Safety, Determination of Density</td>
<td>Feb. 4</td>
</tr>
<tr>
<td>2</td>
<td>Evidence of Chemical Reactions</td>
<td>Feb. 11</td>
</tr>
<tr>
<td>3</td>
<td>Le Châtelier's Principle</td>
<td>Feb. 18</td>
</tr>
<tr>
<td>4</td>
<td>Hydronium Ions</td>
<td>Feb. 25</td>
</tr>
<tr>
<td>5</td>
<td>Acid-Base Titration</td>
<td>March 4</td>
</tr>
<tr>
<td>6</td>
<td>Organic Chemistry</td>
<td>March 11</td>
</tr>
<tr>
<td>7</td>
<td>Organic Chemistry</td>
<td>March 18</td>
</tr>
<tr>
<td></td>
<td>Good Friday</td>
<td>April 1</td>
</tr>
<tr>
<td>8</td>
<td>Biochemistry - Carbohydrates</td>
<td>April 8</td>
</tr>
<tr>
<td>9</td>
<td>Proteins</td>
<td>April 15</td>
</tr>
<tr>
<td>10</td>
<td>Enzymes and Blood</td>
<td>April 22</td>
</tr>
<tr>
<td>11</td>
<td>Metabolism and Nucleic Acids</td>
<td>April 29</td>
</tr>
<tr>
<td>12</td>
<td>Check-out</td>
<td>May 6</td>
</tr>
</tbody>
</table>
Appendix C: Sample Tests

The following tests are taken from some of the courses I teach. I think it is important to see how different the formats are for each course. Unlike syllabi, which should contain roughly the same information for all of my courses, the tests are individually tailored for each course. I have spent a lot of time carefully refining the way I write my multiple-choice questions for various courses so that they have the same “feel” as multiple-choice questions on standardized exams. Care is taken to ensure that for tests which are to be worked on the given paper have the correct space for each question. For my upper division courses, you will notice that I include many more choices as well as allow students to work on as much paper as they feel is needed. I think this is a very important element that students learn to give me the amount of work they feel is correct rather than what fits in the space provided. In addition for the upper division courses, the number of essay questions is increased. An example of an answer key is also included for an upper division course, where students need a longer period of time to digest the answers and “figure-out” the problems they missed. The natural science exam is included as an example of the kind of tests used in that course. This format was chosen by the instructors of the past and has been used in a fairly rigid manner. One consistency throughout my tests is an attempt to have a professional appearance (rather than something sloppy or hand written). I believe that by making the test appear well written the students will respect them more and take greater care in the performance of that exam.
Multiple Choice Questions (6 points each). Circle the single best answer for each question.

1. How many significant digits does \(8.020 \times 10^{-5}\) have?
   (A) 1 (B) 2 (C) 3 (D) 4 (E) 5

2. How many valence electrons does a neutral \(\text{N}\) atom have?
   (A) 14 (B) 3 (C) 5 (D) 6 (E) 7

3. Which of the following is a sulfite ion?
   (A) \(\text{SO}_2\) (B) \(\text{SO}_3^{2-}\) (C) \(\text{SO}_4^{2-}\) (D) \(\text{CO}_3^{2-}\) (E) \(\text{PO}_3^{2-}\)

4. A compound \(X\) has a MW of 150.0 amu. Calculate the number of moles of \(X\) in 5.00 g of \(X\).
   (A) 0.0333 (B) 0.0621 (C) 0.200 (D) 5.00 (E) 30.0

5. Which of the following will not exhibit hydrogen bonding?
   (A) \(\text{CH}_3\text{OH}\) (B) \(\text{H}_2\text{O}\) (C) \(\text{NH}_2\text{CH}_3\) (D) \(\text{HF}\) (E) \(\text{CH}_4\)

6. Which of the following is insoluble in water?
   (A) \(\text{NaOH}\) (B) \(\text{HNO}_3\) (C) \(\text{AgNO}_3\) (D) \(\text{FePO}_4\) (E) \(\text{BaCl}_2\)

7. What is the \(\text{pH}\) of a solution which has \([\text{OH}^-]\) = \(1.0 \times 10^{-13}\)?
   (A) 7.00 (B) 1.00 (C) 2.00 (D) 13.00 (E) 14.00

8. Which of the following functional groups is most characteristic of thiols?
   (A) \(\text{C} = \text{C}\) (B) \(\text{R} - \text{OH}\) (C) \(\text{R} - \text{O} - \text{R}\) (D) \(\text{–SH}\) (E) \(\text{–NH}_2\)

9. Which of the following is 3-heptene?
   (A) \(\text{CH}_3\text{CH} = \text{CHCH}_2\text{CH}_2\text{CH}_3\) (B) \(\text{CH}_3\text{CH}_2\text{CH} = \text{CHCH}_2\text{CH}_2\text{CH}_3\)
   (C) \(\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3\) (D) \(\text{CH}_2 = \text{CHCH}_2\text{CH}_2\text{CH}_3\)
   (E) \(\text{CH}_3\text{CH}_2\text{CH}_2 = \text{CHCH}_2\text{CH}_2\text{CH}_3\)

10. What is produced when propanol (\(\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}\)) dehydrated?
    (A) \(\text{CH}_3\text{CH}_2\text{CH}_3\text{OH}_2\) (B) \(\text{CH}_3\text{CH} = \text{CH}_2\) (C) \(\text{CH}_3\text{CH}_2\text{CO}_2\text{H}\)
     (D) \(\text{CH}_3\text{CH}_2\text{CH}_3\) (E) \(\text{CH}_3\text{CH}_2\text{CHOCH}_2\text{CH}_2\text{CH}_2\text{OH}\)
11. What is produced when an aldehyde is oxidized completely?
   (A) alkene  (B) alcohol  (C) amide  (D) ketone  (E) carboxylic acid

12. Which of the following is a monosaccharide?
   (A) starch  (B) ethanol  (C) glucose  (D) sucrose  (E) acetone

13. Which of the following are not elements/properties of most triacylglycerol molecules.
   (A) phosphate  (B) glycerol  (C) fatty acids  (D) ester linkage  (E) saponifiable

14. Which of the following is a non-polar sidechain amino acid?
   (A) tyrosine  (B) aspartic acid  (C) serine  (D) cysteine  (E) glycine

15. What base pairs with adenine in RNA?
   (A) adenine  (B) thymine  (C) guanine  (D) cytosine  (E) uracil

16. How many nucleotides make up a codon?
   (A) 1  (B) 2  (C) 3  (D) 4  (E) 5

17. Give the electron configuration for K⁺ and C. (10 points)

18. Calculate the concentration (in Molarity) of a solution prepared by dissolving 0.3215 g of Ba(C₂H₂O₂)₂ in 100.0 mL of distilled water. What will be the resulting concentration (in Molarity) if 10.0 mL of this solution are diluted to 1000.0 mL? (20 points)
19. Write the RNA sequence formed when the following strand of DNA is transcribed for peptide synthesis. (10 points)

\[ \text{3'} \quad \text{GTAACAAACCGTGTGAACG} \quad \text{5'} \]

20. Describe using words and generalized reactions how inhibitors are used to regulate enzyme activity. (10 points)

21. Describe using words and pictures the structure of a DNA double helix. (10 points)
22. Name the following ionic compounds and describe their solubility as soluble or insoluble in water. (16 points)

<table>
<thead>
<tr>
<th>Compound</th>
<th>Name</th>
<th>Solubility</th>
</tr>
</thead>
<tbody>
<tr>
<td>KNO₃</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ba(OH)₂</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(NH₄)₃PO₄</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PbCl₂</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

23. Write the structure of the major product when 1-propyl thiol is oxidized and give the name(s) of functional group(s) in the product molecule. (10 points)

\[
\text{CH}_3\text{CH}_2\text{CH}_2\text{SH} + [\text{O}] \rightarrow ?
\]

24. Draw a molecule which both an alkyn e and an amide. (15 points)

25. Describe in words and reactions how the carbonate buffer can maintain pH = 7. (10 points)
26. Draw three different structural isomers of C₆H₁₃N (including at least one cyclic molecule and one branched non-cyclic molecule). (15 points)

27. Draw a steroid ring system (without substitutions or multiple bonds). (5 points)

28. Balance the following equation and then write the net ionic equations. (18 points)

\[ \text{Mg(NO}_3\text{)}_2 \text{ (aq) + NaClO (aq) } \rightarrow \]

\[ \text{NH}_4\text{Cl (aq) + Pb(NO}_3\text{)}_2 \text{ (aq) } \rightarrow \]
Multiple Choice Questions: Circle the single best answer. No penalty for guessing.

1. Which SI unit indicates $10^{-3}$ grams? (4 points)
   A) mg    B) cg    C) mg      D) kg      E) Mg

2. Do the following arithmetic with correct significant figures: (4 points)
   \[ 863 \times (1255 - (3.45 \times 10^8)) \]
   A) 761511    B) 7.6151x10^5    C) 7.615x10^5    D) 7.62x10^5    E) 7.6x10^5

3. What element has 12 neutrons, 10 protons and 10 electrons? (4 points)
   A) $^{12}$B    B) $^{10}$C    C) $^{22}$Ne    D) $^{22}$He    E) $^{22}$Ti

4. What is the name of the ClO$_4^-$ anion? (4 points)
   A) chlorate    B) chlorite    C) perchlorate    D) hypochlorite    E) chloride

5. How many moles are 44.0 g of CO$_2$? (4 points)
   A) 1.00    B) 2.00    C) 3.00    D) 44.0    E) 1940

6. A compound is made of only H, C and N. This compound has 3.73% by mass hydrogen, 44.44
   % by mass carbon and 51.83 % nitrogen. What is the empirical formula of this compound?
   (4 points)
   A) H$_4$C$_{44}$N$_{52}$    B) HC$_{11}$N$_{13}$    C) H$_4$CN    D) HC$_2$N    E) HCN

7. Write the balanced chemical equation for the reaction of C$_6$H$_{10}$ with O$_2$ to produce H$_2$O and
   CO$_2$. Calculate the mass of CO$_2$ produced when 4.305 g of C$_6$H$_{10}$ is reacted in excess oxygen.
   (10 points)
8. Write out two additional atomic symbols which are isotopes of $^{132}$Cs. (6 points)

9. Name the following ionic compounds. (4 points each)

- Ca(NO$_2$)$_2$
- H$_2$CO$_3$
- Na$_2$SO$_4$
- Mg$_3$N$_2$

10. Write the empirical formula for the following compounds. (4 points each)

- iron (II) bromate
- lithium phosphate
- aluminum oxide
- ammonium chloride

11. A Morgan silver dollar has a mass of 26.73 g. By law it was required to contain 90.0 % by mass silver, with the remainder being copper. When the coin was minted in the late 1800’s, silver was worth $1.18 per troy ounce (31.1 g). At this price, what was the value of the silver in the silver dollar? (8 points)
12. Only two isotopes of boron occur naturally: $^{10}$B (mass = 10.013 amu; abundance 19.78%) and $^{11}$B (mass = 11.009 amu; abundance 80.22%). Calculate the average atomic mass (weight) of boron. (15 points)

13. Balance the following two chemical equations. (10 points)

\[ \text{____ Na}_3\text{PO}_4 (aq) + \text{____ FeSO}_4 (aq) \rightarrow \text{____ Fe}_3(\text{PO}_4)_2 (s) + \text{____ Na}_2\text{SO}_4 (aq) \]

\[ \text{____ C}_8\text{H}_{15}\text{OH} (s) + \text{____ O}_2 (l) \rightarrow \text{____ CO}_2 (g) + \text{____ H}_2\text{O} (l) \]

14. Balance the following equation and calculate the amount of Cu which could be produced by reacting 5.00 g of Cu$_2$O and 15.00 g of CO. (15 points)

\[ \text{____ Cu}_2\text{O} (s) + \text{____ CO} (g) \rightarrow \text{____ Cu} (s) + \text{____ CO}_2 (g) \]
Sample Tests: 1997 CHM 122 Test #2

Name: ____________________________  Test 2
100 points  Chemistry 122A
Dr. Jay H. Baltisberger  April 9, 1997

SHOW ALL CALCULATIONS & USE PROPER SIGNIFICANT FIGURES AND UNITS

\[ pV = nRT \]

\[ R = 0.08206 \text{ L atm mol}^{-1} \text{ K}^{-1} = 8.3145 \text{ J mol}^{-1} \text{ K}^{-1} \]

pH Definition: \[ pH = - \log [H^+] \]
Autoionization Constant for Water: \[ K_w = 1.0 \times 10^{-14} \]

Multiple Choice Questions: Circle the single best answer. No penalty for guessing.

1. What is the reaction rate order for the following rate law? (4 points)
   \[ \text{Rate} = k \left[ N_2 \right] \left[ O_2 \right] \left[ CO_2 \right] \]
   A) 0th order  B) 1st order  C) 2nd order  D) 3rd order  E) 4th order

2. In a second order reaction \( A \rightarrow B \), if the concentration of \( A \) is doubled, what happens to the reaction rate at that moment? (4 points)
   A) rate goes up by a factor of 4  B) rate goes down by a factor of 4  C) rate is unchanged
   D) rate goes up by a factor of 2  E) rate goes down by a factor of 2

3. What is the expression for the equilibrium constant for the unbalanced reaction below? (4 points)
   \[ 2 \text{ SO}_3 (g) \leftrightharpoons \text{ SO}_2 (g) + \text{ O}_2 (g) \]
   A) \( K = \frac{P_{SO_2}}{P_{SO_3} P_{O_2}} \)
   B) \( K = 2 \frac{P_{SO_3}}{P_{SO_2} P_{O_2}} \)
   C) \( K = \frac{P_{SO_2} P_{O_2}}{P_{SO_3}} \)
   D) \( K = \frac{P^2_{SO_2} P_{O_2}}{P^2_{SO_3}} \)
   E) \( K = \frac{P_{SO_2}^2 P_{O_2}}{P_{SO_3}^2} \)

4. Which acid has the strongest conjugate base? (4 points)
   A) HCl  B) HNO₃  C) NaHSO₄  D) H₂SO₄  E) HClO₄

5. What is the somewhat basic pH of a 0.010 M solution of Na₂SO₃ if \( K_B = 1.6 \times 10^{-7} \). (4 points)
   A) 4.40  B) 6.80  C) 7.20  D) 9.60  E) 11.60
6. Calculate the pH of a somewhat acidic 0.10 M NaHCO₃ solution (for HCO₃⁻, \( K_a = 5.6 \times 10^{-11} \)). (12 points)

7. Give the empirical formula or name the following ionic compounds. Indicate the solubility for each. (8 points)

<table>
<thead>
<tr>
<th>Compound</th>
<th>Solubility</th>
</tr>
</thead>
<tbody>
<tr>
<td>molybdenum (IV) chloride</td>
<td>soluble/insoluble</td>
</tr>
<tr>
<td>((\text{NH}_4)_2\text{SO}_3)</td>
<td></td>
</tr>
</tbody>
</table>

8. A mixture of CH₄ and H₂O is passed over a catalyst at 850 K. The emerging gas is collected in a 5.00 L flask and is found to contain 9.62 g CO, 4.60 g H₂, 41.0 g CH₄ and 42.4 g H₂O. Assuming equilibrium has been reached, calculate \( K_c \) for the reaction. (15 points)

\[
\text{H}_2\text{O} \ (g) \ + \ \text{CH}_4 \ (g) \ \rightarrow \ 3 \ \text{H}_2 \ (g) \ + \ \text{CO} \ (g)
\]

9. A solution of 0.050 M KHCrO₄ and 0.050 M K₂CrO₄ has a pH of 6.30. Calculate the \( K_a \) for HCrO₄⁻. (10 points)
10. Consider the aqueous reaction between \( \text{HgCl}_2 \) and \( \text{Na}_2\text{C}_2\text{O}_4 \). The initial rate was measured under various conditions given below. Derive a rate law and rate constants for this reaction. (15 points)

\[
2 \text{HgCl}_2 (aq) + \text{Na}_2\text{C}_2\text{O}_4 (aq) \rightarrow 2 \text{NaCl} (aq) + 2 \text{CO}_2 (g) + \text{Hg}_2\text{Cl}_2 (s)
\]

<table>
<thead>
<tr>
<th>Expt. #</th>
<th>[HgCl(_2)] (M)</th>
<th>[Na(_2\text{C}_2\text{O}_4)] (M)</th>
<th>Rate (M/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.105</td>
<td>0.15</td>
<td>1.8x10(^{-5})</td>
</tr>
<tr>
<td>2</td>
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<td>0.30</td>
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<tr>
<td>3</td>
<td>0.052</td>
<td>0.30</td>
<td>3.5x10(^{-5})</td>
</tr>
<tr>
<td>4</td>
<td>0.052</td>
<td>0.15</td>
<td>8.9x10(^{-6})</td>
</tr>
</tbody>
</table>

11. Write the four bases \( \text{ClO}^- \), \( \text{ClO}_2^- \), \( \text{ClO}_3^- \) and \( \text{ClO}_4^- \) in order of strongest to weakest base and explain your reasoning. (10 points)

12. At 1285 °C, \( K_p = 0.133 \) for the \( \text{Br}_2 (g) \rightleftharpoons 2 \text{Br (g)} \) dissociation reaction. Calculate the equilibrium partial pressures in a flask at 1285 °C and 1.00 atm containing only \( \text{Br}_2 \) and \( \text{Br} \) vapor. HINT: Set up equilibrium expression in terms of \( P_{\text{Br}_2} \) and \( P_{\text{Br}} \) and substitute for one using the total pressure equation, \( P_{\text{Br}_2} + P_{\text{Br}} = 1.00 \text{ atm.} \) (10 points)
Sample Tests: 1998 CHM 362 (formerly 262) Test #3

Examination 3 - Chemistry 262

November 18, 1998

Name: ____________________________

Dr. Jay H. Baltisberger

Please answer 3 of 4 questions, showing all calculations - 35 points each, 105 total.

• In your own words, describe how the Born-Oppenheimer approximation is used to simplify the quantum mechanical calculations for a BeH₂ molecule.

• Draw a pictorial representation of a $\sigma_u$, $\pi_u$, $\pi_g$ and $\sigma_g$ molecular orbital. Which of these in general is lower in energy? Which of these in general is higher in energy? Explain.

• Write out the complete secular determinant used to solve for the energies and coefficients of the molecular orbitals for HF (use the H1s, F1s, F2s, F2pₓ, F2pᵧ and F2pₜ orbitals as a basis set). Describe the meaning of each $\alpha$, $\beta$ and S term in the determinant. Describe a reasonable approximation for which terms may be safely ignored in such a calculation.

• For each species NF, NF⁺, and NF⁻, use the MO method to A) write the valence-electron configuration; B) find the bond order; C) decide whether the species is paramagnetic.

BONUS TIME (10 points)

5. In homonuclear diatomic molecules, all $u$ MOs are anti-bonding, true or false? Explain.
Choose five of the following seven problems for 30 points each:

1. The table to the right gives the break and halt temperatures found in the cooling curves of two metals A and B. Construct a phase diagram (using graph paper or other accurate means of plotting) consistent with the data of these curves. Label the regions of the diagram, stating what phases and substances are present. Give the probable formulae of any compounds that form.

<table>
<thead>
<tr>
<th>Mole fraction B</th>
<th>Break (°C)</th>
<th>First halt (°C)</th>
<th>Second halt (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
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<td></td>
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</tr>
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<td>0.40</td>
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<td>700</td>
<td>400</td>
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<tr>
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<td>750</td>
<td>700</td>
<td>400</td>
</tr>
<tr>
<td>0.60</td>
<td>670</td>
<td>400</td>
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<tr>
<td>0.70</td>
<td>550</td>
<td>400</td>
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<tr>
<td>0.80</td>
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<td>400</td>
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<tr>
<td>0.90</td>
<td>450</td>
<td>400</td>
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<tr>
<td>1.00</td>
<td></td>
<td>500</td>
<td></td>
</tr>
</tbody>
</table>

SEE ATTACHED SHEETS (left off for space reasons)

2. Draw the phase diagram (using graph paper or other accurate means of plotting) for the Mg/Cu system given that Mg melts at 648 °C; Cu melts at 1080°C; intermetallic compounds MgCu$_2$ and Mg$_2$Cu melt at 800°C and 580°C respectively. Eutectics of 10, 33 and 65 mass percent Mg composition melt at 690°C, 560°C and 380°C respectively. A sample of Mg/Cu alloy containing 25 mass percent Mg is prepared in a crucible heated to 800°C in an inert atmosphere. Describe what will be observed if the melt is cooled slowly to room temperature. Specify composition and relative abundances of each phase at each point in time and sketch the cooling curve.

SEE ATTACHED SHEETS

3. It is found that the boiling point of a binary solution of A and B with mole fraction A, $x_A = 0.6589$, is 88°C. At this temperature the vapour pressures of pure A and B are 957 and 379.5 torr, respectively. Is this solution ideal? What is the initial (before solution has boiled away) composition of the vapour above this solution.

   For ideal solution, $V.P. = P_A^* x_A + P_B^* x_B = (957 \text{ torr}) (0.6589) + (379.5 \text{ torr}) (0.3411) = 760.0 \text{ torr}$. This is the V.P. at the normal boiling point, therefore the solution must be ideal (definition of normal boiling point is temperature where vapor pressure is 760 torr). This vapor will have a composition of $x_A = (957 \text{ torr}) (0.6589) / [(957 \text{ torr}) (0.6589) + (379.5 \text{ torr}) (0.3411)] = 0.8297$, indicating the vapor is rich in A as expected.

4. The vapour pressure of a 500.0 g sample of benzene was 400 torr at 60.6°C, but it fell to 386 torr when 19.0 g of an unknown involatile organic compound was dissolved. Calculate the molar mass of this compound.
Using Raoult’s law, \( P_A = 386 \text{ torr} = P_A^* x_A \). Thus \( x_A = 0.965 \), implying that \( x_B = 0.035 = \frac{(19.0 \text{ g} / \text{MW}_B)}{[(19.0 \text{ g} / \text{MW}_B) + (500.0 \text{ g} / 78.1128 \text{ g mol}^{-1})]} \). We may solve this for \( \text{MW}_B = 81.839 \text{ g mol}^{-1} \).

5. At 25°C and 1 atm, a 0.5000 mol/kg solution of NaCl in water has partial molar volumes of 18.63 cm³/mol and 18.062 cm³/mol for the NaCl and water respectively. Find the volume at 25°C and 1 atm of a solution prepared by dissolving 0.2500 mol of NaCl in 0.5000 kg of water.

Using formula for partial molar volumes \( V = V_A,m n_A + V_B,m n_B = (18.63 \text{ cm}^3 \text{ mol}^{-1}) (0.2500 \text{ mol}) + (18.062 \text{ cm}^3 \text{ mol}^{-1}) (500 \text{ g} / 18.015 \text{ g mol}^{-1}) = 505.96 \text{ cm}^3 \). The mass of this solution is \( (0.2500 \text{ mol})(58.443 \text{ g mol}^{-1}) + 500.0 \text{ g} = 514.61 \text{ g} \), giving a density of 0.983 g cm⁻³. Note that the water actually loses density as the sodium and chloride ions break up the hydrogen bonding network.


The condition for ideal solutions is for the two molecules to be so similar in size, shape and molecular interactions that mixing A with B will give A-A interactions which are nearly identical to A-B and B-B interactions. Normally this is not the case, but for systems like Benzene-Toluene, the interactions are similar enough to call the solution nearly ideal. In the case of optical isomers, the structures are merely mirror images of one another, thereby having identical interactions, size and shape. The only way to separate these molecules is using some sort of chiral separation scheme, since the interactions are so similar. Given this, I would define this mixture as nearly perfectly ideal.

7. In which solution would water have a lower activity (A) 0.0300 m NaCl, (B) 0.0200 m MgCl₂, or (C) 0.0300 m MgO (assuming all are fully dissolved and none undergo ion pairing).

You can use the Davies equation to calculate the activity coefficients for each of these solutions, or you can note that in all cases, the total number of ions in solution is identical. Given that the activity of the solvent (water) is basically related to the vapor pressure of the water, you can ask, which solution will bind water most tightly, preventing the molecules from escaping the solution at the liquid/gas interface? Certainly the answer is the ions with the highest charge (MgO) which will bind very strongly to the exiting water molecules, dragging down the net activity of both the solute and the solvent. Thus answer (C) is the correct choice.
Sample Tests: 1995 GSTR 232 Test #2

Name: ___________________________ Test 2
Section: ___________________________ October 10, 1995
75 points Natural Science GSTR 232

Instructions: Answer 15 of the 18 questions. Circle the three questions that you do not want graded. If you do not circle three questions then only the first 15 questions will be graded. Each question will be worth five points (5 x 15 = 75 total points).

\[ E = m c^2, \quad c = 3.0 \times 10^8 \text{ m/s}, \quad 1 \text{ J} = 1 \text{ kg m}^2 / \text{s}^2, \quad h = 6.626 \times 10^{-34} \text{ J s}, \quad \lambda = h / m v, \quad m \Delta v \Delta x > h / 2 \pi, \]

\[ N = N_0 e^{-\lambda \tau} = N_0 \left( \frac{1}{2} \right)^{\frac{\tau}{\tau_{1/2}}} \text{ where } \tau = t_{1/2} \]

1. Write a balanced nuclear reaction for the alpha decay, \( ^2_4 \alpha \), of an Einsteinium-252 nucleus, \( ^{252}_{99} \text{Es} \).

2. Write a balanced nuclear reaction for the beta decay, \( ^{0}_1 \beta \), of a Neon-22 nucleus, \( ^{22}_{10} \text{Ne} \).

3. The half-life of Bismuth-210, \( ^{210}_{83} \text{Bi} \), is 5 days. How many grams would remain after 15 days if you began with 1000 g of Bismuth-210 (show all work)?
   A) 333 g  B) 250 g  C) 167 g  D) 125 g  E) 12.5 g

4. A Uranium-235 (U) is struck by a neutron and fissions into Rubidium-93 (Rb) and Cesium-139 (Cs) and additional neutrons. Write a balanced nuclear reaction.
5. Normally the carbon in our atmosphere is 100 parts $^{14}\text{C}$ per 10,000 parts $^{12}\text{C}$. Recently an archeologist dug up a pot containing mustard seeds. They were found to have 25 parts $^{14}\text{C}$ per 10,000 parts $^{12}\text{C}$. What is the age of these seeds (show all work) assuming the half-life of $^{14}\text{C}$ is 5700 years?

6. Write the complete atomic symbol for and calculate the number of neutrons, protons and electrons in a single atom of Aluminum-27 (Al). In what way would the nucleus of an Aluminum-28 isotope differ from this one?

7. Suppose 10.000 kg of Uranium (U) in a nuclear power plant decays via a fission reaction. If 0.002 kg of mass is converted to energy, how much energy is released (show your work)?

   A) 2.0 J  
   B) $6.0 \times 10^8$ J  
   C) $18.0 \times 10^8$ J  
   D) $1.80 \times 10^{17}$ J  
   E) $1.80 \times 10^{14}$ J

8. Why can’t we see the quantum mechanical effects of a man walking?
9. Describe how the Rutherford experiment with gold foil and alpha particles provided evidence to contradict the Thomson model of the atom.

10. An atom of iron (mass = $10^{-25}$ kg) travels at a speed of 20.0 m/sec with an uncertainty of ±0.1 m/sec. What is the minimum uncertainty in its position?

11. Given the mass of the electron as $9.1 \times 10^{-31}$ kg and its velocity of $1 \times 10^{-6}$ m/sec, find its de Broglie wavelength. Is this wavelength measurable?
12. Use both pictures and word to describe the bonding in a formaldehyde molecule with the formula CH₂O, where carbon is located as the central atom of the molecule.

13. Draw 3 different molecules (using stick bonding pictures shown in lecture, e.g. O=C=O), each containing exactly 4 carbon, 1 oxygen and 10 hydrogen atoms (there are more than 3 possible correct structures which can be drawn with the C₄H₁₀O formula).

14. Explain why a Cl₂ molecule is chemically more stable than a Ne₂ molecule (which doesn’t even exist in nature!)

15. Write out the number of valence electrons present in neutral Na, Cl, Ar, S and P atoms.
16. List two properties of radon which make it a potential long term health problem.

17. Draw the standing wave of an electron in the $n = 3$ orbit of a hydrogen atom.

18. In the Bohr atomic model, using only the orbit $n = 1$ and $n = 2$, fill in the correct answers in the following sentence:

A photon is absorbed by the atom as an electron moves from the _______ orbit to the _______ orbit while a photon is emitted by the atom as an electron moves from the _______ orbit to the _______ orbit. Of these two orbits, the _______ orbit is of higher energy.
Appendix D: Scholarly Writing

The following list of journal articles which have been written/published while I was a member of the Berea College faculty. These appear at the end of the file as separate individual documents.

Journal of the American Chemical Society, 118, 7209-7214 (1996)
Submitted J. Phys. Chem. includes student authors (see highlighted names)
Appendix E: Sample Grant Proposal

I have written a number of grant proposals of which a reasonable fraction have been funded. The included proposal for the PRF was one that required 3 resubmissions to finally achieve funding but represents how I have a true tenacity when it comes to getting an agency to award me a grant.

1995 Petroleum Research Foundation proposal ($20,000), funded.

Abstract

We propose to study how the physical properties of phosphate based glasses are connected to bond-angle and chain-length distributions found in these glasses. These microscopic features will be examined using solid-state nuclear magnetic resonance (NMR) techniques, providing chemical shift tensors which can be converted into structural information using correlations derived from both experiments and ab initio calculations. This will be accomplished by utilizing the NMR techniques of magic-angle spinning (MAS) and magic-angle hopping (MAH) to extract chemical shift tensors from both previously studied and new systems within the crystalline and non-crystalline metaphosphate classes. These results will be used to determine microscopic structure which will then be correlated with macroscopic properties relating to both sample composition and preparation. In particular, we would like to look at the effect of composition on bond-angle distributions and examine correlations between these distributions and the ionic conductivity in these glasses. These experiments represent new and exciting applications of existing techniques to a fundamental class of materials; we would ultimately apply these to other phosphorus-chalcogenide glasses which exhibit even higher ionic conductivities. Currently there are only a small number research groups using these types of NMR experiments to study glasses and few publications exist which utilize two-dimensional (2D) NMR to examine amorphous solids. The proposed research will involve undergraduate research assistants who will work on all aspects of this research, including running NMR experiments and interpreting the results, providing a vital element for their chemical education.

Introduction

Glasses are technologically important in an enormous range of applications because of their diverse optical, transport and structural properties. The type of application is primarily determined by the
physical properties of each glass which in turn are governed by the composition and preparation of that
glass.[1] Phosphate glasses may function as photoconductors, solid electrolytes and low-frequency
waveguides with the element phosphorus playing the important role of glass former in these materials.[2, 3] In the last decade the use of NMR to study glasses has grown substantially,[4] in particular, $^{31}$P
MAS NMR has proven quite effective in these systems[5-8] because of its moderate dipolar coupling,
large isotropic chemical shift range and large chemical shift anisotropies. Until only recently NMR has
been utilized primarily in simple one-dimensional MAS experiments, which yield limited information.
While historically MAS has been used to study glasses, new NMR techniques such as MAH[9-11] can
provide penetrating information about the local bonding in $^{31}$P containing systems. The proposed re-
search will use these recently developed 2D experiments (MAH in particular) to give significant im-
provements in the understanding of glass structure. The previous application of these sorts of 2D ex-
periments, such as dynamic-angle spinning,[12] have shown enormous potential for the study of
glasses.[13]

The types of questions we will address concern short and medium range structure present in
phosphate glasses. Other than NMR, structurally sensitive experiments are somewhat limited in appl-
cation to amorphous materials. X-ray diffraction relies on the existence of long range translational
order and x-ray scattering involves deconvoluting multi-atomic correlation functions. Other spectro-
scopic techniques such as UV and IR spectroscopy rarely give significant insight into local environ-
mental differences. NMR, however, is a localized technique that has the capacity to probe the micro-
scopic environment at each individual site in an amorphous material. We hope to convert these measured
NMR parameters into structural information (e.g. bond-angle, ring-size or chain-length distributions)
using ab initio calculations (specifically Gaussian94). This structural information will be correlated with
both chemical composition and sample preparation, and ultimately with physical properties. Additionally,
the information would be invaluable to help test, clarify and improve existing molecular modeling and
dynamics calculations.

**Experimental**

Initially, we intend to study phosphate ($P_2O_5$) based glasses and their alkali metal network modi-
fications in the metaphosphate and orthophosphate classes. To gain a better understanding of the local
and medium range structures present in these glass systems, we will also study a number of crystalline
systems of similar composition which will provide an empirical basis for the interpretation of NMR data
on glasses. To some degree, the large database of $^{31}$P chemical shift information which already exists
will allow us to quickly direct our research efforts to the more interesting amorphous samples. All crys-
talline and glassy samples will be synthesized from high purity materials using standard techniques.
This involves heating the finely ground mixtures significantly above the melting temperatures (usually around 1000° C) and cooling in a controlled fashion. For samples where the starting materials, such as P₂O₅, may vaporize and change sample composition, a vacuum sealed approach will be used. Amorphous and crystalline alkaline metaphosphate (with the empirical formula LiₓNaᵧK₁₋ₓ₋ᵧPO₃ where 0 ≤ x + y ≤ 1) samples were prepared in this fashion already by undergraduate research assistants at Berea College during the summer of 1994. A variety of quenching techniques were explored and a “splat” cooling technique (pouring the liquid sample onto a cold copper plate and quickly pressing flat with a second plate) proved most effective. Powder X-ray diffraction was used to determine both phase and crystallinity information and NMR experiments were conducted at the Ohio State University (OSU) looking at the ³¹P nuclei in these samples. In addition, I am spending time this summer at OSU (with the Grandinetti group) and Stanford University (with the Stebbins group) doing both NMR experiments as well as learning valuable sample preparation skills. In the future, other NMR active nuclei (e.g., ²⁹Si, ²³Na or ⁷Li) will be studied using both the traditional solid-state NMR technique of MAS and the new MAH experiment for structural characterization of a sample. These NMR experiments will be carried out at the University of Kentucky (UK) using a MAS probe to be purchased this summer with a recently awarded Research Corporation Cottrell grant and ultimately at Berea College once we have suitable instrumentation. In addition, some of this work will continue to be conducted at OSU in the laboratory of Dr. P. J. Grandinetti as this has proven to be a valuable collaboration in this area as well. Finally, the interpretation of the NMR parameters will be aided using a variety of simulation and ab initio calculation programs which will be performed on the computers at Berea College. In all cases, undergraduate research assistants will be involved in the preparation and characterization (including running NMR experiments) of samples as well as the simulation of spectra.

**MAS and MAH NMR**

MAS is a NMR experiment which gives high resolution isotropic spectra for ³¹P sites by averaging the chemical shift anisotropy and homonuclear dipolar interactions. These types of spectra are useful because the isotropic chemical shift is related directly to coordination and bonding environment.[7] By performing multiple-pulse experiments in conjunction with sample rotation, a variety of 2D experiments will be performed that correlate isotropic shifts with anisotropic lineshapes (MAT, MAH).[10, 11, 14] MAH is a 2D NMR experiment in which a sample is effectively moved through three orthogonal directions providing anisotropic averaging using a conventional MAS probe.[10, 11] This produces sideband free isotropic spectra correlated with anisotropic spinning sideband patterns, which will work well for ³¹P where the chemical shift anisotropies are quite large. This method is superior to similar correlation experiments, since there will be little dipolar broadening in the either di-
mension since the sample may be continuously spun about the magic-angle at rates of 1 to 5 kHz and still generate a large number of spinning sidebands. The data collected in this fashion will also be pure-absorptive phase without necessitating unusual sample reorientation methods, in contrast to most of the other techniques such as VACS Y[15]. From our work at OSU it appears that for particularly favorable systems, MAS alone may be used to gain anisotropic information. We have observed that the MAS spectra of the metaphosphates are inhomogeneously broadened by a distribution of chemical shifts. Therefore, a modified Herzfeld and Berger spinning sideband analysis[16] of a single 1D MAS spectrum can generate complete tensor distribution information for a material.

**Computer Calculations**

All the proposed experiments rely on the creation and application of computer code to simulate the NMR spectra and extracted parameters. New desktop workstations makes the simulation of NMR lineshapes and calculation of electric field gradients and chemical shift information from ab initio molecular orbital programs quite feasible at Berea College. In fact within the next year we will be setting up a UNIX workstation with this software in the science building at Berea College. In addition, undergraduate research assistants can make immediate contributions to these projects by becoming involved in computer programming without extensive NMR experience. By combining computer simulations with experimental data, we will be able to interpret the NMR spectra of glasses with greater reliability and accuracy. This is important in the quantization of structural parameters in glasses from chemical shift tensors. Specifically, we will explore the effect of changing the O–P–O bond angles or the effect of chain length on the chemical shift tensor using ab initio calculations on small molecular fragments of alkali rich metaphosphates. I have already begun to use Gaussian94 to study the silicon and oxygen environments in silicate glasses this summer at OSU and will use this experience to apply the same techniques to phosphate glasses.

**Conclusions**

In this study, we will investigate the structural order and disorder in a variety of glasses using NMR as a probe at the microscopic level. Specifically, we will obtain quantitative information about distributions of bond angles and other structural features which will be compared with macroscopic properties.[2] It is hoped that the fundamental understanding of the formation of short and medium range order on a microscopic level will help to describe these macroscopic properties. In particular, we will address how this microscopic structure affects the mechanism of ionic conduction and evaluate why specific chemical changes lead to reduction or enhancement of this conductivity. This structural information will be an invaluable aid when engineering glasses to achieve more predictable and possibly useful physical properties.
These research projects will be of the type which may be successfully completed by an undergraduate student. Each element in this research project is relatively straightforward to perform and can lead to significant results. While most of this work will be conducted in the chemistry department at Berea College, experiments requiring equipment we do not have will be carried out at larger nearby universities, giving the undergraduates the opportunity to be involved in a large scale research environment. This would involve taking students to a school such as UK or OSU (as was done the summer of 1994 and 1995) for part of the summer research program to do experiments such as DTA, TGA, XRD and high-field NMR. Overall, this research should not be in direct competition with any of the major research labs and will in fact be in collaboration with the Grandinetti group at OSU (see attached letter). Finally, the equipment purchased for this research will be used to supplement the physical chemistry and instrumental analysis laboratories at Berea College by bringing FT NMR within the grasp of our students.

References

Appendix F:  Sample Committee Submission

One area I am particularly proud of is my attempts to improve the governance structure and college catalog at Berea College so that the experience of both faculty and students may be streamlined and improved. One example was the work to disband the SLOC which was successful. Another example included here is the proposal to add independent majors to the college catalog. This is still a work in progress as the proposal was tabled.

**1998 Independent majors proposal to APC, currently tabled.**

**BEREA COLLEGE**

**CURRICULUM REVISION PROPOSAL**

**PROPOSAL:**

I propose that we add a new section to the Berea College catalog entitled “Interdisciplinary Majors”. This section would provide a listing and description of majors which fall in-between those currently offered by individual departments. This would allow standardization of majors that normally are required to go through the “independent major” rubric. Initially we propose that the interdisciplinary major of neuroscience be created. Other interdisciplinary majors can follow as individuals and departments develop them within the guidelines below. Each major will be attached to one or more departments and will be reviewed each time such a department conducts a self-study. Each major will have one or more faculty advisors who will act as advisors for those students in one of these interdisciplinary majors. This advisor will act as a liaison between departments involved in an interdisciplinary major. These majors will not be used as arguments to add additional regular term courses or hire additional faculty. Short-term courses may be taught to help round out interdisciplinary majors but standard short-term limits of no more than two course from a major will apply. All interdisciplinary majors must be constructed using courses available in the current catalog and must be put together so that students have a high probability of finishing within the four year college graduation requirement.

**CATALOG DESCRIPTION:** (text to be inserted right before independent major section, text in italics is indicated for information purposes only and is not to go into the catalog.)

**INTERDISCIPLINARY MAJORS**

A student who wishes to pursue a major which falls between the various academic departments at Berea College may elect to declare either an Interdisciplinary Major or an Independent Major (see next section). Interdisciplinary majors are standing majors which have an affiliated faculty advisor and have specifically designed guidelines. Currently, we offer an interdisciplinary major in the field of neuroscience. Students declare an interdisciplinary major at the same time as a regular major. All interdisciplinary majors require a minimum of 2.5 GPA and completion of at least 4 credits of course work within that major program prior to admission (unless specifically mandated by a particular interdisciplinary major). The approval of the interdisciplinary major advisor is required before a student may be officially accepted into a given major. The standard rule of 21 credits outside of a major shall be accounted for by 21 credits from departments not directly affiliated with the major. The interdisciplinary advisor for that major will act as this students advisor for the remainder of his or her time at Berea College. The course requirements for each major are given below:
Neuroscience (affiliated with Biology and Psychology departments):
Biology 110, 113, 240; Psychology 100, 205, 212; Chemistry 121, 122, 221, 222, 223;
Physics 115 & 116; participate in at least one summer research project in a neuroscience-
related lab (on- or off-campus); choose one of Biology 220, 231 or 286 (must be an evolu-
tion special topics course); choose one of Psychology 207, 208, 211, 214; choose either Bi-
ology 292 or Psychology 206 & 224. Recommended electives: one or two neuroscience-
related short-term courses as available. Computer science courses and additional courses in
math (120, 130) and philosophy (112). A foreign language is also required through the sec-
ond level to meet the culture area requirement. Biology 110 and Psychology 100 must be
completed with 2.5 GPA or higher (minimum grades of C–) to be admitted to the major.

(FYI, these courses are Modern Biology, Zoology, Molecular and Cell Biology, General
Psychology, Statistics for Psychology, Physiological Psychology, General Chemistry I & II,
Organic Chemistry I & II, Biochemistry, General Physics I & II, Comparative Vertebrate
Anatomy, Developmental Biology, Evolution, Principles of Learning, Cognitive Psychology,
Abnormal Psychology, Ethology, Biology Seminar, Research Methods, Senior Research)

RATIONALE: The need for interdisciplinary study has been discussed previously in “Being and Be-
coming”, publications from the National Research Council, National Science Foundation and by groups
such as Project Kaleidoscope. The time is right for Berea to expand its educational boundaries to em-
brace interdisciplinary work. The current “Independent Major” section of the catalog is certainly a valid
route to earning a major which falls between the cracks, but it is not highly visible. In fact, a student
must declare an independent major before accumulating 15 credits, otherwise they have to move their
proposal through two committees rather than one. The number of hurdles and obstacles that this pre-
sents (at least in the eye of a student) as well as the relative obscurity of this section of the catalog means
that fewer students are able to pursue independent majors than might wish to. Also, majors such as bio-
chemistry, earth sciences, applied mathematics and others might be amongst the majors students are
looking for in a college but sense Berea to be lacking. The proposal attempts to put together a single
new interdisciplinary major which may be completed without adding any new courses or hiring new
faculty (and provides a framework for adding new interdisciplinary majors such as biochemistry, com-
munications, environmental science, etc.). The need for faculty specifically in the named area is not a
major problem. Since these are essentially pre-approved independent majors, they do not really fall out-
side existing structures, merely providing a more visible and simplified access to them. These majors
will be reviewed on a regular basis (via departmental self studies) so that course content can be evaluated
as well as number of majors and success of interdisciplinary major program. I propose that these
changes be made as soon as possible (next two years) and be reviewed by APC at the end of that time.
There should be no additional financial cost affiliated with these programs since all courses are already a
part of the college. There may be a shift in distribution of majors (some pre-medical students in chem-
istry and biology may change to biochemistry, if such a major were created to replace the current inde-
pendent major) but I expect no overall reduction in any departmental program.

The issue of the 21 courses outside major discipline is one which is addressed via the departmental
affiliations of each major. Since these are all approximately 14-15 courses in length, this requirement
would seem to indicate a need for 35-36 total credits? I think the answer lies in defining the statement
“outside major discipline”. My answer would be to define this in terms of affiliated departments. For
neuroscience, any biology and psychology courses would count as major discipline courses, whereas
the chemistry and physics courses would be counted as “outside” the major discipline. The basic idea
of the outside courses is to make a student more well rounded, I assume. I think the interdisciplinary
majors can achieve this well-rounded academic portfolio almost by default.

As to the question of whether these majors are “valid”, and do they really meet a real world need and expectation, my answer to this is found by looking at our majors already in the catalog. Currently, most of the natural science majors at Berea College have fewer courses than a similar major found at a large institution. So we are not covering the same volume of material by default. Yet, it is not breadth that defines the quality of a major, just because physics does not offer a course on fluid mechanics or chemistry on polymers does not mean these are failings. Students who go on to graduate school can
take these sorts of courses there with the preparation they are being given here at Berea. Students who
go on to industry will be taught there what they need to know. So I think the additional liberal arts
courses our students take fill a more important void than additional courses in the major. With this as a
reference, the interdisciplinary majors also will not be fully comprehensive. They will cover substantial
material from the fields of relevance and prepare a student adequately to proceed to graduate school,
professional school or industrial positions.

SUBMITTED BY: Jay Baltisberger, Assistant Professor of Chemistry with consultation of other fac-
ulty members.
Appendix G: Natural Science Lecture Notes

I have included two examples of lecture notes that I have prepared for the natural science course. These represent my attempts to push the boundaries of the course and to teach more of the "how the universe works" rather than the conventional lectures delivered by some instructors. There is a great deal of inertia in the course to retain the traditional lectures and in fact many faculty teach with essentially the same notes for more than 7 years. In particular, the comments that these status-quo oriented faculty members have about these lecture notes have been rather unsupportive, using words such as "glib" to describe them. It is within this atmosphere that these were developed and because of this atmosphere that I look forward to the new format for the course. The examples included are: 1998 GSTR 232 Lecture 8 (Where does the energy come from?) and 1998 GSTR 232 Lecture 9 (Why don’t we just burn water?)
Sample Lecture Notes: 1998 GSTR 232 Lecture 8

Lecture 8 — Where does the energy come from?
The Nuclear Atom  Spring 1998

Reading Assignment: Lecture notes and Chapter 11 & 14 (Trefil & Hazen, pages 256-282, 324-327). For additional information on the ultimate structure of the nucleus, Chapter 12 (pages 281-301) gives good descriptions of quarks and leptons.

Objectives: After listening to the lecture, reading through the notes and assignment from the textbook, attending the class discussions, and performing the assigned exercises, you should be able to do the following:

1. Use the mass/energy conversion equation: $E = mc^2$
2. Understand a nuclear decay curve, the concept of half-lives and radioactive decay.
3. Define belt of stability, critical mass, alpha, beta, gamma decay modes, isotope, atomic number, atomic mass (mass number).
5. Understand the relative sizes and charges of protons, electrons and neutrons.
6. Describe the conservation laws used in balancing nuclear reactions.

Assignment #8 (to be completed before the next recitation section for review and discussion)

8A. Use the periodic table to identify the element, atomic number, mass number and electrical charge of the following combinations:
   - 8 protons, 8 neutrons, 10 electrons
   - 8 protons, 9 neutrons, 10 electrons
   - 9 protons, 8 neutrons, 10 electrons
   - 8 protons, 8 neutrons, 9 electrons

8B. Imagine a collection of 1000 uranium-238 atoms sealed in a box at the formation of the Earth, 4.3 billion years ago. Use the uranium-238 decay chain to predict some of the things you will find in the box if opened today.

8C. Discussion: Can nuclear radiation escape from a nuclear power plant? If so, how?

8D. What is nuclear waste? Why is it a serious problem for society?

8E. What is the product of the alpha decay of $^{245}\text{Pu}$? What is the positron emission product from $^8\text{Be}$?
Introduction

We learned about energy (kinetic, potential, waves, heat and nuclear among the various forms) in lecture 6. In this lecture we will discuss the nucleus in greater detail and ultimately address the question of “where does energy really come from?” The short answer to this question, as we will learn, is that energy comes from the nucleus of atoms where nuclear reactions (e.g. fission and fusion) are the principal source that powers the sun and the earth (aside from the energy stored in chemical bonds). The longer answer of where the energy came from that started the sun is one we will leave until later in the course when we discuss the Big Bang.

Nuclear Atomic Structure

Sean Smith told you about the nature of the electronic atom, tracing the development of nuclear and electronic structure beginning with Dalton through Thomson and Rutherford. Ultimately we arrived at the Bohr model with a tiny nucleus containing the positive charge and most of the mass and a cloud of electrons circling this nucleus in circular orbits. This picture is not the most modern theoretical model for the atom, but it is satisfactory for this course. Looking at the nucleus, we can begin the process of dissecting this smallest of all entities (see pages 259-261 in the text). In the figure below we see the layers of a molecule stripped away at into smaller and smaller units. In general, each nucleus contains protons and neutrons held together in a volume of space approximately $10^{-15}$ meters in diameter. As Sean described in his previous lecture, protons (often represented $p$ or $^1_p$) have a mass of 1.007 amu (atomic mass units, 1 amu = $1.6606 \times 10^{-27}$ kg) which is nearly 2000 times larger than the mass of an electron ($5.485 \times 10^{-4}$ amu, sometimes represented $^0_e$ or $^0_{-e}$). The proton is the carrier of positive charge in atoms, with each proton having a +1 charge (1.602x10^{-19} coulombs) which is exactly opposite and equal to that of an electron. Neutrons (represented normally as n or $^0_n$ on the other hand are about as massive as a proton (1.008 amu) but possess no charge. You might ask, what exactly holds a nucleus together? As an example, consider a carbon-12 nucleus (this is a notation we will describe more completely in a moment), which has 6 protons and normally 6 neutrons. These twelve subatomic particles (or...
nucleons) are held together by a force which is called the “strong force” which is much more powerful than the coulombic force of repulsion between the positively charged protons (see page 262 in the text). The neutrons feel no coulombic force, but feel this same attractive strong force that holds the protons together. Because the strong force is so potent at holding nucleons (protons and neutrons) together, splitting a nucleus into smaller pieces requires an enormous amount of energy (and can also release an enormous quantity of energy, as we shall soon discover).

Let us return to the notation carbon-12 for a moment. The name (and chemical reactivity) of any element is determined by the number of protons (which is of course equal to the number of electrons in a neutral atom). As an example, a carbon-12 atom has 6 protons; in fact, all carbon atoms will have 6 protons (and the number of protons is called the atomic number for this reason). You might remember that the periodic table itself is arranged by the atomic number (or equivalently by number of electrons) of each element. The reasons for this arrangement will be discussed further in the next lecture. As an aside, the importance of atomic number on periodicity was partially realized by a young researcher named Henry Moseley whose career studying the interaction of X-rays and atoms (including the prediction of the existence of three new elements before their discovery) in Rutherford’s laboratory was cut short by WWI. What about the number in the name, carbon-12? This is the mass number and it indicates the total number of protons plus neutrons. Since protons and neutrons both have an approximate mass of 1 amu (and electrons have negligible mass), the mass number will represent the total mass of an atom (in amu). When you look at a periodic table, you might notice that the masses are not integers, but rather decimal numbers. There are two reasons for this, the first of which relates to the slight mass difference between neutrons and protons and the mass lost when they are bound together into a nucleus. The second relates to the fact that for most elements, multiple types of each element are found and these different types are referred to as isotopes!

Isotopes are defined as atoms of a given element with differing mass numbers. Examples include $^{235}\text{U}$, $^{238}\text{U}$ and $^{239}\text{U}$ (all isotopes of uranium) or $^{12}\text{C}$, $^{13}\text{C}$ and $^{14}\text{C}$ (all isotopes of carbon) and isotopes may be found for virtually every element on the periodic table. The $^{12}\text{C}$ notation here is different from the carbon-12 notation, but they are fully equivalent. The former will be used primarily due to its more compact form, but in the public media, you may encounter either of these notations (note that sometimes the lower number is left off, since the atomic symbol implicitly determines this). What exactly makes isotopes different? The answer is that isotopes differ only by the number of neutrons. For $^{12}\text{C}$ there are 6 neutrons in the nucleus and for $^{14}\text{C}$ there are 8 neutrons in the nucleus. As we shall see
in the following sections of the lecture, the differing numbers of protons and neutrons have different energetic stability. Ultimately, there are shells and shapes for given numbers of nucleons, in analogy with what we see in electronic models (discussion of this to continue in lecture 9). These shells help determine which nuclei are more stable than others. For instance, \(^{12}\text{C}\) is a highly stable form of the carbon nucleus which (for all practical purposes) never undergoes nuclear decay (see next section or pages 262-266 of the text). For \(^{14}\text{C}\), the arrangement of neutrons and protons is non-ideal and the nucleus will disintegrate over time. In fact, the disintegration of \(^{14}\text{C}\) nuclei is used today to date objects from 500 to 50,000 years old! This field of radioactive dating is a topic we will discuss in greater detail later in this lecture and will be the cornerstone of the discussion of geology and the age of the earth!

So what about the electrons in this picture of an atom (see page 257 for more discussion of this topic)? We will focus on electrons in lectures 9 and 10 where we will learn how they control all of the chemical bonding interactions between atoms. But for now, we will focus on the nucleus and learn how to use the energy stored therein to power the stars, the earth and to provide tools which benefit human-kind in the fields of space exploration, medicine and even electrical power generation!

Returning back to the nucleus, we can look deeper into the protons and neutrons. Is this the smallest particle into which matter may be divided? The answer is both yes and no. Certainly, in the last 25 years, we have learned that protons and neutrons are composed of quarks (which are even smaller particles, see the earlier figure of atomic and nuclear structure) but at this point, it appears quarks are confined to the nucleus and cannot be isolated. I hesitate to say that it is impossible to isolate quarks, but merely that no experiment or active theory indicates a method to achieve this separation. There are six flavors of quarks (up, down, top, bottom, charm and strange) but this is going beyond the scope of this course. If you are interested, you should read the material in Chapter 12 of the text for further information about the sub-structure of nucleons!

**Nuclear Chemistry**

The figure above shows the relationship between stability of a nucleus and the number of protons and neutrons. Notice that for the most part, atoms will have a few more neutrons than protons. This is particularly true of the larger atoms, which require additional neutrons to act to separate the multitude
of protons from one another (because the protons repel one another electrostatically). The isotopes marked with small dots indicate stable nuclei, while the shaded region is generally indicative of long lived isotopes (where long lived may be from a few microseconds to millions of years). Once you leave this belt of stability, you find that there are no stable isotopes and nuclei tend to decay in times which are fantastically short. Now we have mentioned already that atoms can decay or disintegrate, but what exactly does this mean? The discovery of radioactive decay occurred in the early part of this century by researchers such as Madam Marie Curie. I will not go into any detail other than to state that she was a singularly important figure as a pioneer in nuclear chemistry and a woman who ultimately won two Nobel prizes (one in chemistry in 1911 and one in physics in 1903) for her extraordinary research. Ultimately, as additional researchers looked at the problem of radioactive decay, it became apparent that there are primarily three types of decay (as well as the various nuclear reactions we will discuss). These processes are referred to as alpha (which is just the emission of a $^4_2$He nucleus, sometimes written as $^4_2\alpha$), beta (in which either an electron, $^0_\cdot\beta^-$, or positron, $^0_\cdot\beta^+$, is emitted), and gamma (emission of a high energy photon of light) decay (for more information read pages 262-266). Each of these decay modes is operational in very distinct regions of the isotope chart on the preceding page. Any isotope lying above the belt of stability tends to decay via a beta (electron) emission mode. Any atom below the diagonal line (the 1:1 line on the figure, indicating equal numbers of neutrons and protons) will invariably decay by either capturing an electron or emitting a beta particle (positron, $^0_\cdot\beta^+$). Finally, atoms lying above the diagonal, but below the belt of stability (and generally with fairly large mass) will undergo alpha decay. The figure above shows how each decay mode will change the position of an initial parent isotope (the nucleus you start with) into a daughter nucleus (the nucleus you end up with). Below are examples of balanced nuclear equations for each of the three major decay modes.

\[
\begin{align*}
^{235}_{92}\text{U} & \rightarrow ^{231}_{90}\text{Th} + ^4_2\alpha \\
^{14}_{6}\text{C} & \rightarrow ^{14}_{7}\text{N} + ^0_{-1}\beta^- + ^0_0\nu \\
^{29}_{15}\text{P} & \rightarrow ^{29}_{14}\text{Si} + ^0_{\cdot\cdot}\beta^+ + ^0_0\nu \\
^{231}_{90}\text{Th}^* & \rightarrow ^{231}_{90}\text{Th} + ^0_0\gamma
\end{align*}
\]

(alpha decay)  
(beta decay)  
(positron decay)  
(gamma decay)
Two other decay modes which are commonly observed are shown below. The example of neutron capture is common only in situations where there is a substantial number of neutrons around, while the electron capture offers a slightly different mechanism than that of positron decay to achieve essentially the same result.

\[
\text{\^{14}N} + \text{\,^{0}n} \rightarrow \text{\^{14}C} + \text{\,^{1}e} \quad \text{(neutron capture)}
\]

\[
\text{\,^{14}N} + \text{\,^{1}e} \rightarrow \text{\,^{14}C} + \text{\,^{0}e} \quad \text{(electron capture)}
\]

For the three basic decay modes (alpha, beta and gamma) there is a time value called the “half-life” which describes how quickly each reaction will occur (see page 269). This is the value of time in which 1/2 of the parent nuclei you started with will have decayed. We have already seen exponential growth (when discussing the energy crisis) and now we observe the phenomenon of exponential decay. Mathematically we may express this process using the equation below:

\[
N(t) = N_0 \times \left(\frac{1}{2}\right)^{t/\tau}
\]

Where \(N_0\) is the number of parent nuclei present at \(t = 0\) (where \(t\) is time) and \(\tau\) is the half-life of the nucleus in question. If you graph this equation for 10.0 g of \(^{90}\text{Sr}\) (which has a \(\tau = 29\) years) you arrive at the chart given below. On this graph we can see that after about 29 years, we will have only 5.0 g of \(^{90}\text{Sr}\) left. Waiting another 29 years (58 years total) we observe only 2.5 g of the parent nucleus remaining. This trend will continue on for a long time with the number of parent nuclei continually shrinking, until the last nucleus finally disintegrates. The curve is a fit through the five data points with an exponential decay of the form given in the preceding equation. As a secondary thought, what would you predict the primary daughter nucleus to be from this decay mechanism? We answer this by looking at a periodic table and observing that the most stable form of strontium has a mass of 88 amu. This indicates that \(^{90}\text{Sr}\) has too many neutrons and therefore lies above the belt of stability. For this parent, the primary decay mechanism is expected to be beta emission, following the equation below:
\[ ^{90}\text{Sr} \rightarrow ^{90}\text{Y} + ^{0}_{−1}\beta^- + ^{0}_{0}\gamma \]  

(beta decay)

The Yttrium nucleus produced is also radioactive (lying above the belt of stability still) and will decay with a half-life of 64 hours via a beta emission to \(^{90}\text{Zr}\).

Other important reactions include the decay of uranium (primarily found as \(^{238}\text{U}\)) in nature) and carbon in the form of \(^{14}\text{C}\). In particular, \(^{14}\text{C}\) has a half-life of 5730 years, which turns out to be very convenient for archaeological studies. Since this half-life is so long, \(^{14}\text{C}\) does not remain around for geological time scales (millions to billions of years), but rather is refreshed via the carbon cycle in our atmosphere. The point that \(^{14}\text{C}\) may enter the carbon cycle is in the upper atmosphere where the cosmic ray proton flux causes random nitrogen nuclei (found in \(^{14}\text{N}_2\) gas) to undergo a nuclear reaction in which a proton is converted to a neutron, producing \(^{14}\text{N}\). Assuming our atmosphere has not changed substantially in the last 50,000 years, it can be assumed that this reaction has maintained a relatively constant level (aside from quantifiable changes due to fluctuations in cosmic ray flux) of \(^{14}\text{C}\) in the upper atmosphere (which filters down to the rest of the earth via the carbon cycle). Since all living organisms either breathe in \(\text{CO}_2\) or eat things that breathe in \(\text{CO}_2\), it is relatively straightforward to assume that the amounts of \(^{14}\text{C}\) found in the molecules of a living plant or animal (or derived product) will be constant until the time of death. From that moment forward, no new carbon will enter the organism and the \(^{14}\text{C}\) will begin its 5730 year half-life decay! What this says is that in 5730 years, the percentage of \(^{14}\text{C}\) relative to \(^{12}\text{C}\) will decrease by a factor of two! The mathematics are actually quite easy to follow, once you see a simple example. A living organism has 15.3 \(^{14}\text{C}\) disintegrations per gram per second due to normal atmospheric levels of \(^{14}\text{C}\) found in that organism. If we find an ancient piece of cloth which has 3.8 \(^{14}\text{C}\) disintegrations per gram of carbon per second, we may calculate the age using the half-life equation.

\[
N(t) = 3.8 = N_0 \left( \frac{1}{2} \right)^t = 15.3 \left( \frac{1}{2} \right)^{5730\text{yrs}}
\]

This equation may be rearranged and solved for the time to arrive at:

\[
\frac{1}{4} = \left( \frac{1}{2} \right)^{5730\text{yrs}} \implies t = 2 \times 5730\text{yrs} = 11460\text{yrs}.
\]

Thus we can surmise that the piece of cloth was made by some very early human civilization. In general this method of dating will work accurately back to about 50,000 years. This represents nearly 10 half-
lives, at which point the amount of radioactive carbon will have been reduced by a factor of about 1000. However, all is not lost in the quest to determine the date of still older objects, since for the most part, there exist other nuclear decay process which can be used to chart the age of many ancient artifacts.

Turning our attention to uranium, we can see the decay of $^{238}_{92}U$ and its daughter nuclei in the graph above. Notice that since this is a very heavy nucleus, the primary decay mode is via alpha decay (which reduces the atomic number by two and the number of neutrons by two). If you look to the lower left corner you will observe that the final product in this sequence is $^{206}_{82}Pb$. Along the way, we pass through one of the more famous daughter nuclei in the media today, radon! More will be mentioned of this decay chain later in the lecture, but for now you should note that the half-lives range from the nearly 4.5 billion years for $^{238}_{92}U$ to sub milliseconds for $^{214}_{82}Po$. The final decay mode to be mentioned is the gamma decay, which is simply the emission of a high-energy photon of light. Gamma-rays continually strike the earth from the multitude of nuclear reactions occurring beyond our solar system, but never reach the earth’s surface. Those seen on the surface are from radioactive decay of local nuclear species (such as the uranium decay chain). In general, almost any nuclear reaction will be accompanied by a gamma decay to release any excess energy.

The next topic on our high speed tour of nuclear chemistry is nuclear reactions. As a starting point, we can look at the first nuclear reaction you ever observed, the sun.
Fusion Energy

The sun continually feeds the earth with energy. This energy is what keeps the planet warm, the plants growing and the water cycle running smoothly (evaporation is heat driven) among other effects. This energy does not appear from the void, but instead must come from somewhere (remember conservation of energy). Ultimately, this energy comes from fusing nuclei together—not just forming chemical bonds, but rather forcing the nuclei to come so close that they form a new nucleus. This is a process known as fusion and is what leads to the formation of atoms heavier than hydrogen. Some of the most basic nuclear reactions which occur deep inside a star are indicated below (the figure above (a-c) illustrates graphically reactions 1-3 respectively):

\[
\begin{align*}
{^1}_1\text{H} + {^1}_1\text{H} &\rightarrow {^2}_2\text{H} + {^0}_1\beta^+ + {^0}_0\nu \quad (1) \\
{^1}_1\text{H} + {^3}_2\text{He} &\rightarrow {^3}_2\text{He} + {^0}_0\gamma \quad (2) \\
{^3}_2\text{He} + {^3}_2\text{He} &\rightarrow {^4}_2\text{He} + 2 {^1}_1\text{H} \quad (3) \\
{^2}_2\text{H} + {^1}_1\text{H} &\rightarrow {^2}_2\text{He} + {^1}_0\text{n}. \quad (4)
\end{align*}
\]

There are a few items listed in these reactions which may appear unfamiliar. The first is the \( {^0}_1\beta^+ \) which represents a beta particle (alternatively an anti-electron or positron). We have already encountered this particle, along with a \( {^-}_1\beta^- \) which is just another notation to indicate an electron, sometimes called a “beta particle”, which has a large amount of energy and has been emitted from an active nucleus. In the earliest stages of our universe, this first reaction was the only reaction which could occur, since no heavy isotopes existed (note that \( {^1}_1\text{H} \) is nothing more than a proton and an electron)! You might ask, if we collide two protons at very high energy, can we make a \( {^2}_2\text{He} \) nucleus? The answer is not entirely trivial, but it basically amounts to NO! The strong force is capable of holding protons together, but only in the presence of neutrons. Thus, in a primordial universe the first baby-steps of nuclear chemistry must be the formation of deuterium \( (\text{^2}_1\text{H}) \) from hydrogen. This requires the conversion of a proton into a neutron which may be written as follows:
This nuclear reaction suggests why we get a positron formed in the fusion of two hydrogen nuclei in reaction (1). The third product ($^0\nu$) is called a neutrino. Neutrinos have no rest mass and no charge; neutrinos are thus nearly impossible to detect. You might wonder why it is even in the equation in the first place? The answer to this lies in the conservation laws of nuclear physics. The first conservation law we used (without telling you) is the conservation of mass-energy. We basically required that the total mass-energy of the reactants be equal to that of the products (and due to Einstein, this is effectively a conservation of energy restatement)! The second conservation law was that of conservation of charge. On the left side of equation (1) we have a total of two $^1\text{H}$ nuclei (which carry a +2 total charge). On the right we have a $^2\text{H}$ and a $^1\beta^+$ which each carry +1 charge for a total of +2. The neutrino has no charge, as mentioned earlier. Other similar conservation laws lead to the requirement of neutrino formation in this reaction.

Let us focus on reactions (2) and (4) for now, for these involve more normal nuclear particles! If you look up the rest masses of each of these nucleons in a book (such as *Table of Isotopes* or *Atomic Data and Nuclear Data Tables*) you will discover that the masses are as follows:

<table>
<thead>
<tr>
<th>Nucleon</th>
<th>Mass (amu)</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>1.008665</td>
</tr>
<tr>
<td>$^1\text{H}$</td>
<td>1.007825</td>
</tr>
<tr>
<td>$^2\text{H}$</td>
<td>2.014102</td>
</tr>
<tr>
<td>$^3\text{H}$</td>
<td>3.016049</td>
</tr>
<tr>
<td>$^3\text{He}$</td>
<td>3.016029</td>
</tr>
<tr>
<td>$^4\text{He}$</td>
<td>4.002603</td>
</tr>
</tbody>
</table>

Now looking at reaction (2) what we can calculate is that the total mass of the reactants is 1.007825 + 2.014102 amu = 3.021927 amu, while the mass of the product is 3.016029 amu. Note that in this reaction, we have lost 0.005898 amu. This does not represent on the outset a very large amount of mass, considering this is only $9.7608 \times 10^{-30}$ kg (a very small quantity). BUT if we return to the equation of Einstein and calculate the amount of energy this represents, then we can see the following:

$$\Delta E_{(2)} = \Delta m \, c^2 = (9.794x10^{-30} \text{ kg}) (2.9979 \times 10^8 \text{ m/s})^2 = 8.802 \times 10^{-13} \text{ J}.$$ 

Now this might represent a very small amount of energy, but this is on a per atom basis. Suppose we fuse 1.007825 g of $^1\text{H}$ and 2.014102 g of $^2\text{H}$? Then we will produce 3.016049 g of 3H and the energy released will be:
\[ \Delta E_{(2)} = \Delta m \, c^2 = (0.005898 \text{ g})(1 \text{ kg/} 1000 \text{ g})(2.9979 \times 10^8 \text{ m/s})^2 = 5.301 \times 10^{11} \text{ J}. \]

If you remember from lecture 6, a rolling semi-truck carries about \(3.8 \times 10^7\) J. You can see that the fusion of a mere 3 grams of hydrogen can eventually the same amount of energy that is carried by over 10,000 semi-trucks! This demonstrates the power of the nucleus over conventional energy sources. If you turn to the sun, which has the mass of over a million earths, then you can begin to appreciate the total nuclear energy stored therein. A similar calculation for reaction (1) will show:

\[\Delta m_{(3)} = 0.01888 \text{ amu} = 3.135 \times 10^{-29} \text{ kg} \]

\[\Delta E_{(3)} = \Delta m \, c^2 = (3.135 \times 10^{-29} \text{ kg})(2.9979 \times 10^8 \text{ m/s})^2 = 2.818 \times 10^{-12} \text{ J}.\]

This represents a factor of almost 4 more energy released per reaction than in reaction (1). This is one of the most energetically favorable reactions which can occur and is one of the reactions which helps power our own sun (and other stars as well)! Fusion itself will not stop once \(^3\text{He}\) or \(^4\text{He}\) is reached, because with the gravitational forces present inside a star, additional reactions can occur. One example might be:

\[\frac{4}{2}\text{He} + \frac{4}{2}\text{He} + \frac{4}{2}\text{He} \rightarrow \frac{12}{6}\text{C} .\tag{5}\]

In this reaction, three helium nuclei (with two protons each, for a total of six protons) are fused to form a single carbon-12 nucleus. Even this can release a great deal of energy:

\[\Delta m_{(5)} = 0.007809 \text{ amu} = 1.300 \times 10^{-29} \text{ kg} \]

\[\Delta E_{(5)} = \Delta m \, c^2 = (1.300 \times 10^{-29} \text{ kg})(2.9979 \times 10^8 \text{ m/s})^2 = 1.169 \times 10^{-12} \text{ J}.\]

As you get to larger and larger nuclei (with more protons and neutrons) you will find that the energy gain on a per nucleon basis becomes less and less. Comparing reactions (2), (3) and (5) we can see that these involve 3, 5 and 12 nucleons (protons + neutrons) respectively. Scaling the reaction energies by these factors gives:

\[\Delta E_{(2)} = 8.802 \times 10^{-13} \text{ J} / 3 \text{ nucleons} = 2.934 \times 10^{-13} \text{ J/nucleon}.\]

\[\Delta E_{(3)} = 2.818 \times 10^{-12} \text{ J} / 5 \text{ nucleons} = 5.636 \times 10^{-13} \text{ J/nucleon}.\]

\[\Delta E_{(3)} = 1.169 \times 10^{-12} \text{ J} / 12 \text{ nucleons} = 9.74 \times 10^{-13} \text{ J/nucleon}.\]

In fact, once you approach \(^{56}\text{Fe}\) , you cannot emit energy by fusing nuclei any more. The only way to fuse atoms into nuclei larger than iron is to add energy to a reaction. This can only occur in a situation where a great deal of free energy is liberated, such as in a supernova. In fact, every heavy atom found on
earth today, is a result of a supernova sometime earlier in the history of our universe! We will discuss fusion more once we return to nuclear power and humankind. For now, we can leave the sun glowing in the sky, releasing the many millions of Joules of energy in the form of radiation and high-energy particles to our solar system.

**Fission/Decay Energy**

The planet is continually being heated from the inside, as evidenced by the plate tectonics (we’ll learn about this in later lectures) and the volcanic activity which occasionally breaks through the cold crust so violently (Mt. St. Helens, Montessorat). Ultimately, the source of this energy is the nuclear decay chains (see page 273) of heavy nuclei such as uranium. The amount of energy released by the uranium decay chain is actually quite enormous. When this reaction occurs inside a planet (such as our Earth) there is nowhere for this energy to go except into the rocks at the core and from there up into the mantle. We may not see enormous quantities of radiation at the surface, but in the interior of or planet, a nuclear reactor churns continuously (the surface reactions release energy to the solar system before we see it)! As was mentioned in the first chemistry lecture on energy, Lord Kelvin attempted to predict the age of the Earth based upon conservation of energy arguments. His failure was in the lack of knowledge of the nuclear energy locked inside our planet in the form of dispersed heavy nuclei. Today, people are beginning to turn more eyes towards geothermal energy sources, most of which ultimately either tap into the nuclear energy stored inside the earth or the flux of light coming from our sun. In the end, nuclear power (fission, fusion, geothermal, solar, etc.) really is the **only** route we can go to solve the long-term energy crisis!

**Nuclear Energy for Humankind**

Looking back to the notes from lecture 6 you will recall that fission power has been slowly growing over the last 40 years and in the next 40 years may slowly displace coal and gas as a primary energy source (already has in some countries). Currently, when we talk about nuclear energy we normally mean the fission reactors which effectively “burn” $^{235}\text{U}$ as a fuel. The groundwork for this type of power plant was laid in the 40’s by some of the greatest scientists who ever gathered in one location. They were brought together in the Manhattan Project to build the atomic bomb (shown to the right)! Inside a simple atomic bomb are two pieces of uranium (primarily the $^{235}\text{U}$ isotope) separated by distance. When the two pieces of uranium are brought together under appropriate conditions (a chemical explosion), a chain reaction starts and the bomb explodes. What is the heart of this chain reaction?
Neutrons! The reactions below represent two possibilities from the immense number of reactions that actually do occur inside an exploding mass of uranium.

\[
{_{92}^{235}U} + {_{0}^{1}n} \rightarrow {_{96}^{142}Ba} + {_{36}^{91}Kr} + 3{_{0}^{1}n} \quad (6)
\]

\[
{_{92}^{235}U} + {_{0}^{1}n} \rightarrow {_{37}^{93}Rb} + {_{55}^{141}Cs} + 2{_{0}^{1}n} \quad (7)
\]

These are by no means the only possible reactions. The reason we cannot pin down the reaction which occurs with any more accuracy stems from the mechanism by which the reaction occurs. The picture below shows a neutron striking a uranium nucleus. The initial response of the nucleus is to deform slightly. This is the step which determines what the reaction products will be. As you might guess, the neutron effectively cuts the uranium nucleus into two pieces of differing (and not necessarily identical from reaction to reaction) size. Depending upon the exact fission reaction which occurs, anywhere from one to three or more neutrons will be ejected. If these neutrons strike additional uranium nuclei they liberate yet more neutrons, driving an exponentially growing reaction. The primary difficulty in building an atomic bomb becomes one of maintaining the uranium in a confined space as a critical mass for a time sufficient to release the enormous amount of energy observed at Nagasaki and Hiroshima. Fortunately for mankind, this requirement makes building an atomic bomb rather difficult and makes it impossible for a nuclear fission power plant to actually blow up in an atomic blast. Now a concept which has been mentioned multiple times in this section is critical mass. What exactly is a critical mass of uranium?
A critical mass is defined as the amount of material needed so that the fast moving fission neutrons may strike another uranium atom before they leave the mass of uranium. If you only have a small number of uranium atoms, then once the first few atoms divide, the resulting neutrons will not strike anything and the reaction will terminate. This reaction may be restarted by injecting additional neutrons from an outside source, but it is impossible for a sub-critical mass to spontaneously undergo a chain reaction. If we collect enough uranium into one location, then it is possible to achieve a “critical mass” at which point the probably of neutrons escaping the material is small enough to allow for a continuous chain reaction. The figure on the previous page is designed to illustrate this point. Note that the right-hand uranium core is indeed critical, since the neutrons are striking additional parent nuclei before escaping the material.

So you might ask, what good is a critical mass? The answer lies in the design and construction of a nuclear power plant. The above figure shows a fission power plant and identifies the important components in such a plant. Just as in any power plant (except for some of the solar and hydroelectric plants), the key to electrical power is the production of steam. In most power plants, the steam lines are a sealed and closed system which is heated to boiling by the energy source but is cooled back to room temperature using an external coolant, such as a lake, river, ocean or even an air cooling tower. This
steam is used to turn a generator. Inside the core of a fission power plant, we have rods filled with pellets of enriched uranium which are separated by some sort of moderator (examples include water, graphite, and sodium metal). The role of the moderator is to slow neutrons down from the fission reaction so that they have a greater probability of striking another uranium atom before leaving the core (and being lost in the walls of the reactor). In all cases, removal of the controlling moderator has the effect of stopping the reaction, since the neutrons will escape before establishing and maintaining a chain reaction. There are really only two sources of pollution which are generated by a nuclear power plant. First, the water being heated needs to be cooled. Any time you release heat to the outside world without converting it into work, you inevitably will lead to undesirable energy pollution. Secondly, you generate nuclear waste. This waste takes the form of radioactive material which are daughter nuclei from the fission reaction. This waste represents a major disposal issue which is the focus of current debate. No final solution has been reached, but a variety of competing disposal schemes are being developed to ultimately solve this problem intelligently.

**Other Applications of Nuclear Chemistry**

Of course there are other applications of nuclear chemistry in the real world. We have seen the headlines which talk about cold fusion (a failure in science due to researchers skipping the key peer review step). This looks to not be a viable energy source, but it did raise additional interest in new ideas about nuclear reactions. Fusion energy itself remains a topic of major research efforts in America. Again, the problem is not completely solved, but researchers have been able to start and sustain fusion reactions using a variety of designs. The major hurdle is winning the energy battle and improving the efficiency of these plants. Radiation makes its power felt in a variety of medical applications too numerous to describe here today. Radon gas (which is an end product of the uranium decay chain) remains a problem in some areas. Finally, spacecraft are powered using nuclear reactions. This has not gone without criticism (recall the Cassini launch of last year). All in all, nuclear chemistry plays a very big role in society and truly does answer the question of “where does the energy come from”!
Reading Assignment: Lecture notes and Chapter 7 & 9 and Chapter 8 optionally (Trefil & Hazen, pages 179-231).

Objectives: After listening to the lecture, reading through the notes, attending the class discussions, and performing the assigned exercises, you should be able to do the following:

1. Describe the Bohr model of the atom, including numbers of electrons in each orbit, explaining how these values lead to the octet rule used in Lewis dot structures.
2. Describe why electrons are the dominant concern in chemical reactions.
3. Describe the three types of bonding approaches used by atoms to achieve full Bohr orbits.
4. Draw Lewis dot structures and predicting the central atom using metal/non-metal arguments.
5. Balance simple chemical equations.

Assignment #9 (to be completed before the next recitation section for review and discussion)

9A. Give the electron configuration for the following atoms and predict how they normally achieve a stable electron configuration through bonding: Na, Al, C, F.

9B. Draw the Lewis dot structures for H₂O, SCN⁻, HNO₃, O₃, HCCH.

9C. Write a balanced chemical reaction for:
   1) The combustion of acetylene (HCCH) in the presence of excess oxygen (O₂) to produce water (H₂O) and carbon dioxide (CO₂).
   2) The precipitation of lead sulfate (PbSO₄) by mixing solutions of lead nitrate (Pb(NO₃)₂) with sodium sulfate (Na₂SO₄).

9D. Describe the bonding in the following substances: graphite (C), sand (SiO₂), sodium chloride (NaCl), nitrogen gas (N₂), copper metal (Cu), copper sulfate (CuSO₄).
In the previous lecture we learned about nuclear energy and how this source of energy ultimately drives our world. Today, we will be pursuing the real world usage of energy and in particular chemical bonding. Even though nuclear energy (either directly or indirectly) provides us with most of the energy we encounter, it is the chemical energy which we mostly use on a daily basis. This energy might take the form of the candy bar we eat or the petroleum we burn to heat our homes and run our cars. Ultimately, the question of energy in the real world relates to chemical bonding (see page 168). We learned two lectures ago about the Bohr model of the atom. In this model the electrons travel in little circular orbits about the nucleus. This is strictly not correct and if you want to learn more about a better model, you can start by reading the chapter on quantum mechanics in your text (chapter 8). This is a substantial can of worms, so to speak, and is an unnecessary complication for discussing chemical bonding. Thus, today we will be looking at chemical bonding and begin to answer questions that we face in the real world like, “why is diamond harder than coal (both are basically carbon)?” or “why does water boil at 100˚ C while nitrogen boils at -196˚ C?” or even “why can’t we just burn water for fuel?” These are important physical questions which determine characteristics the world around us. Note that in these questions the “why” is not a question of purpose but one of cause and effect. In science, of course, the question of purpose (divine or otherwise) is never to be answered! In the case of chemical bonding, we touch a topic that literally touches our lives every single moment (the air you breath, the seat you sit on, the soda you drink....) To do this, we need to return to basic ideas about what an atom is and how it is put together.

Previously we saw and read about the development of atomic theory beginning with the earliest civilizations, going through Dalton, Thomson, Rutherford and ultimately Bohr. Now what is it that
makes the Bohr model useful? The Bohr model does place the electrons in specific ORBITS. The rule for populating these orbits is called the Pauli Exclusionary rule and states that no two electrons may be located in the same orbit. There are individual shells which are numbered from one to seven (normally, though even higher values are allowed). This shell number corresponds with the “principle quantum number” derived from a full quantum mechanical treatment (review pages 169 and 180-181 in Trefil & Hazen). The first shell can hold only two electrons, the second and third can hold eight, the fourth and fifth can hold eighteen, and the sixth and seventh can hold thirty two electrons. The larger quantum numbers signify increasingly larger orbital radii and thus the larger occupancy limits.

<table>
<thead>
<tr>
<th>Shell Number</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Maximum Occupancy</strong></td>
<td>2</td>
<td>8</td>
<td>8</td>
<td>18</td>
<td>18</td>
<td>32</td>
<td>32</td>
</tr>
<tr>
<td><strong>Valence Electrons</strong></td>
<td>2</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
</tbody>
</table>

Notice I have distinguished the maximum occupancy and valence electrons in this table. It is important to consider that not all orbits are identical. Even though we describe the atom as having only seven orbital shells, each shell itself is subdivided in the full quantum mechanical model. Thus not all electrons in a given shell are identical and some will be closer to the nucleus than others. This is the primary distinction between valence and other electrons; as we will discover, really only the outermost electrons matter and this means the valence electrons.
Let us think about a sodium (Na) and a lithium (Li) atom. The sodium atom (with a +11 nuclear charge) will have a configuration of 2 electrons in the inner shell, 8 in the second and 1 in the third. If the ten inner shell electrons hide the central +11 charge from the outer shell electrons then the outermost third shell electron will view the nucleus as having +1 charge. In the case of a lithium atom (with a +3 nuclear charge), which has a configuration of 2 electrons in the 1st shell, 1 electron in the 2nd, the outer electron again behaves as if the nucleus was +1. Both lithium and sodium have only 1 outer electron. What about others? Potassium (K), Rubidium (Rb), Cesium (Cs), and Francium (Fr) also have this same property! Notice on a periodic table these atoms all lie in the same column or family (see periodic table shown earlier, this idea of periodicity was discussed earlier in lecture 7 or the text beginning on page 179 in Hazen & Trefil). It was noted in the 1800’s that all metals from the alkali metal family formed $\text{M}_2\text{O}$ compounds with oxygen (Na$_2$O, K$_2$O, Li$_2$O, etc.) Also, these elements all reacted with water identically (producing a metal hydroxide, hydrogen gas and excess heat). Similar periodic (but different) properties could be found in other columns (families) such as the carbon (IV A), halogen (VII A) and chalcogenide (VI A) families. This is really where the definition of “valence electrons” arises, since these outer electrons are exposed and hidden from the binding nuclear charge by inner electrons. Note that within a family, the valence electrons will be in increasingly larger orbits. The chemical and physical properties are thus not expected to be identical but they will have distinct similarities within a given family.

A particularly unique family is the noble gases in which each member has valence shell which is completely filled. Helium has two valence electrons in the 1st shell, Neon has eight valence electrons in the 2nd shell, Argon has eight valence electrons in the 3rd, and so on. These gases are particularly remarkable in that very few chemical compounds exist which incorporate a noble gas. For a very long time these atoms were referred to as the “inert” gases for this reason.

Why is it that outer electrons seem to matter as far as chemical properties are concerned? Think for a moment about bringing two atoms together. What parts of the two atoms interact first? Of course, the answer is the valence electrons, regardless of what atoms you speak of. It is the interaction between valence electrons which produces the variety of chemical bonds we will be discussing today. Remember for a moment the description of noble gases as nearly inert. Why would these be inert when an atom such as oxygen (with only two fewer valence electrons) will react with almost anything? The answer lies in completely filled shells: all noble gases except helium have eight valence electrons and have no interest in acquiring additional electrons. To form a chemical bond, the outer shell electrons of the two inter-
acting atoms will by necessity interact with one another. A filled shell renders a neutral atom nearly im-
pervious to any additional interactions (though this is not perfect and this leads ultimately to chemical
reactions). Thus the periodic table really shows us all we need to know about the chemical properties as
regarding electron configurations. The fundamental rule we see from the noble gases is that the concept
of a filled valence shell (octet rule) is highly desirable in an atom.

Now in what manner may an atom achieve the stable octet configuration? There are basically
three ways an atom can achieve a valence octet (discussion extended on page 205 of our text). One
method is to give away some electrons. This is a good solution for atoms which have only a few valence
electrons. Another method is to steal electrons from other atoms. This is a good method if an atom has a
nearly complete octet at the start. The final and most interesting method is to share electrons. This is the
method preferred by the carbon family and ultimately leads to the massive diversity of molecules which
make up our world.

The first case is relatively straight forward and common to most of the metals (left side of the
periodic table). That is atoms give away electrons to atoms who want them, leaving them with a smaller
but more stable number of electrons. Just how many electrons would an atom give away? The answer is
just enough electrons to leave it with an octet surrounding the nucleus in the valence shell (read further
on page 206 of the text). Lets look at an example of a single sodium atom which is atomic number 11
and thus has 11 protons and 11 electrons. The figure on the next page shows an electron being lost (to
what?) from a sodium atom. The final state (on the right) has lost one electron leaving the 2nd shell with
8 electrons (a complete octet). The sodium in this form is referred to as a sodium ion (cation) or Na⁺. 
This is highly stable (it is essentially a neon atom with a +11 rather than +10 nucleus), especially when
in the presence of a negative ion. Remember for a moment the theme of this lecture, which is “why
don’t we just burn water” and apply that question to the formation of cations. Note that in the formation
of a cation, an electron is being removed from an atom. This means separating a negative and positive
charge spatially and this always will cost energy (energy must be added to the atom to pry loose the
electron). Even though the final product is highly stable, you need a driving force of energy to produce a
cation. A fundamental question to ask is from where this energy arise. One possibility is the formation
of anions described next (read page 207 in the text).
The second method of achieving stable valence octets is stealing electrons! The following figure shows the initial electron configuration for a fluorine atom (with +9 nuclear charge, two inner 1st shell and seven outer 2nd shell electrons). By gaining a single electron the valence shell achieves a stable octet. Where would this electron come from and conversely (from previous method) where would the sodium electron go to? The answer lies in charge balance, that is when a fluorine gains an electron to become F\(^-\) (an anion) that electron must have come from some other atom such as a sodium going to Na\(^+\). Note that the formation of an anion is a process which generally will release energy (since the negative electron is moved closer to a positive nucleus). When this energy released is large enough to balance the cost of forming a cation, ions can be formed. Assuming these atoms are close enough to swap electrons, they are also close enough to pull on each other via electric forces. Thus the birth of an IONIC COMPOUND. An example of this would be sodium fluoride (from above, NaF) or the more familiar sodium chloride (NaCl). Other ionic compounds are things such as magnesium oxide (MgO) or calcium chloride (CaCl\(_2\)). What you might be noticing about these names and formulas is that they seem to involve an element from the left side of the periodic table (a metal) combined with one from the right (a non-metal). Also you might notice that it is not always a simple 1:1 ratio. The CaCl\(_2\) formula indicates that for every one calcium ion there are two chloride ions. Why is it this way? Why not one calcium per three chloride ions? The answer to this question lies again in the octet rule. Atoms in group VIIA (the halogen family) are all one electron fewer than the noble gas family (VIIIA).
Thus, all halogens have one basic desire, to acquire an extra electron! Looking back at the alkali metals in column IA, we see they all desire to lose an electron to become +1 charged and thus have the stable noble-gas octet configuration. Other families follow the same basic approach; the alkaline earth elements (IIA) desire a +2 charge, the oxygen family (VIA) want a −2 charge, the nitrogen family (VA) want −3 charge and so on. The only confusion creeps into the picture when we talk about atoms such as iron (Fe) or copper (Cu) or other transition metals (groups IB to VIIIB). These sometimes adopt multiple stable configurations by moving electrons from the inner orbits up to outer valence orbits. You will not be expected to predict whether copper is going to be Cu⁺ or Cu²⁺.

In the final octet completion scheme we discussed the concept of sharing electrons (described on pages 208-209 in the text). The atoms most likely to do this are small and in need of many electrons. The best example of this is carbon (C) which has only four valence electrons. It could try to steal four more electrons to become C⁴⁻ or lose four electrons to become C⁴⁺ but both of these options leave the resulting ion with an extreme charge. Very rarely will an ion ever have a charge greater than about ±3, let alone ±4, so how can a carbon or other middle family atoms share electrons and achieve octet stability?

Let us look at one of the simplest of all cases, that of hydrogen gas (see figure below). Each hydrogen atom has but a single proton and electron. To complete a stable valence shell both atoms desire two electrons total in the 1st shell. To solve this problem, the basic model to imagine is that of two atoms coming together. As the orbits begin to overlap the electrons get confused as to which atom they are attached to and begin to move about both orbits (perhaps in a figure eight shape). Both atoms see the two electrons moving about them and thus feel secure (thinking that they each have a full outer shell). Note that neither atom completely “owns” either electron at this point, but rather they are sharing them. This is called a single bond by chemists, representing a single pair of shared electrons. Thus is born the simples of all molecules, H₂. Again, looking at energy, we may ask what is gained here by sharing electrons? The key lies in looking at what each electron now “sees”. In effect, each electron “sees” two protons (separated by about 1 Å) and feels the electrical pull of these positive charges. In general, energy
is released when an electron moves into a region of greater electrical attraction (closer to the positive charges) and thus the formation of a bond is an energetically favorable process.

A similar example is that of an oxygen molecule, $O_2$. These atoms each have 8 protons and electrons with 6 valence shell electrons. In the figure below, only the valence electrons (2nd shell) are shown for clarity. As the two oxygen atoms come together, just as with the hydrogen molecule, the electrons begin to mutually orbit the oxygen atoms. The net effect is that the oxygen atoms share two pairs of electrons; this is called a double bond. Again, this process is one which is energetically favorable and creates a molecule which is far more stable than simple oxygen atoms.

Within this framework of shared electron (or covalent) bonding, atoms will always attempt to achieve an octet configuration. For carbon (C) this means sharing its 4 electron with partners to the extent that it has 8 total electrons. An example of this is CH$_4$ (shown on the next page, note each hydrogen has one and the carbon four valence electrons.) Each carbon shares two electrons with each of the hydrogen atoms to create four carbon-hydrogen single bonds. Similar molecular drawings may be made of NH$_3$, H$_2$O, CO$_2$ and others, but drawing all these circles gets tedious. The approach I will describe momentarily is called a Lewis dot structure notation, named suitably after G.N. Lewis of UC Berkeley who was the first to formalize this notation (way back about 1900.) Before we discuss this formalism for covalent bonds, we need to look at the final covalent sharing mechanism.

The idea of a metallic bond, like covalent bonding, involves the sharing of electrons to complete octets on atoms (see page 208 in the text). This idea of sharing is taken to the extreme in metallic bonding with electrons shared by all the atoms in a single crystalline piece. To understand what am I speaking of, imagine a chunk of sodium metal. Suppose there are 100 atoms in the single crystalline piece. How many valence electrons are there? That answer is simple, 100 valence electrons (at one per sodium atom). Now imagine if these electrons are a free flowing sea of electrons surrounding not one or two sodium atoms but all 100 atoms. Essentially all the atoms are rendered stable by spreading all of the electrons over all the atoms. This form of covalent bonding is commonly found only in the metals (left side of periodic table) and results in the metallic properties we know (conductivity, malleability, reflection, etc.) Non-metals (atoms on the right side of the periodic table) almost never form these metallic
bonds. Non-metallic solids such as graphite, diamond, sulfur and others are primarily molecular (covalent) solids.

\[
\begin{align*}
\text{CO}_2 & :O::C::\ddot{\text{O}}: \\
\text{O}_2 & :O::\dddot{\text{O}}: \\
\text{N}_2 & :N::N: \\
\text{CH}_4 & \text{H}:\text{C}::\dddot{\text{H}}: \\
\text{HCN} & \text{H}:\text{C}::\dddot{\text{N}}: \\
\text{H}_2 & \dddot{\text{H}}:
\end{align*}
\]

We now return to the important Lewis dot notation for molecules. In this notation all valence electrons are shown as dots. A bond will be represented by a pair of dots. Some examples are given below for CO\textsubscript{2}, O\textsubscript{2}, N\textsubscript{2}, CH\textsubscript{4} and HCN. It is critical to note that only valence electrons are shown and that bonding geometry (shape of the molecule) is not indicated by electron positions. The fundamental rules may be summarized as follows:

- First, count total valence electrons for each atom (for CO\textsubscript{2} there are 4+6+6 = 16). For every positive charge (if a cation) reduce the electron count by one, conversely for every negative charge (if an anion), increase electron count by one (for CO\textsubscript{3}\textsuperscript{2–} there are 4+6+6+6+2 = 24).
- Second, locate the most metallic atom (to the left and down on the periodic table) at the center of the molecule. Distribute other atoms around this central atom.
- Third, place single bonds between each atom and the central atom.
- Fourth, complete octets around each atom by adding pairs of non-bonding electrons.
- Fifth, count the number of electrons you have currently drawn and reduce total back to correct total (from first step) by forming multiple bonds.

Once you start counting electrons in the various molecules it becomes clear that nitrogen (N) seems to normally need 3 bonds, carbon (C) wants 4, oxygen (O) wants 2, hydrogen (H) wants 1. Others of importance include sulfur (S) which wants 2 bonds (imagine that, with sulfur directly under oxygen) and the halogens (F, Cl, Br, I) which all want 1 bond. Using these simple bonding rules it is possible to construct molecular bonding pictures for virtually any molecule I could throw at you. The next lecture will deal with the diverse range of chemical formulas and bonding patterns found in nature in the form of organic molecules.

We return now to look at energy and chemical bonds (more on page 218 in the text). Certainly the formation of ionic and covalent bonds can be used to change atoms into molecules and thereby release energy (falling down the long energy stairwell, so to speak). In general, all things in nature tend to go to the lowest energy state (rocks fall down not up). Yet this does not give the full picture. Chemistry is a dynamic subject in which atoms rearrange to form different molecules with a great deal of diversity.
and function. Our bodies rely on the conversion of glucose and oxygen into carbon dioxide and water to provide energy to run our biochemical machines. Our cars rely on the reaction of gasoline with oxygen to produce carbon dioxide and water, again to produce energy to move us from point A to point B. Essentially, while almost any bonding arrangement will reduce the energy of a system of atoms, there will almost always be a specific arrangement which is lowest in energy. It is towards this arrangement of atoms that most chemical reactions steadily move towards, bouncing down the energy staircase. We will begin to discuss some of the diversity of chemical reactions in the next lecture.

I told you diamond is harder than coal (or quartz or any of a large number of solids). We haven’t completely answered the “why” behind that question. What kind of bonding occurs in diamond? It is pure carbon and each carbon wants to form 4 bonds. The result is a molecular framework where each carbon is surrounded by 4 other covalently bonded carbon atoms. This structure is particularly sturdy for a variety of reasons; first, the carbon-carbon single bond is moderately strong. Second, the packing of the carbon atoms in a tetrahedral array is highly favorable and energetically very stable. Finally, if you want to break any of the carbon bonds, you end up breaking many bonds! By analogy, think of a seam holding two pieces of cloth together, it is easy to break a single stitch but to rip the entire seam apart takes far more energy. In diamond, you cannot easily fragment off even a small number of carbon atoms (the energy cost is just too high). Compare this with ice, where the H₂O molecules which make up the solid structure are not bonded to one other strongly. In this structure, a single H₂O may be removed without significantly changing the bonding. Thus covalent bonds are the glue that holds a diamond lattice together and gives it such high strength.

What is left of this lecture? Merely to mop up some details we haven’t considered. The final topic of today is chemical reactions (which we will study extensively next lecture.) We already have been writing chemical reactions, probably without thinking about it. Consider the statement “sodium metal and chlorine gas react to form sodium chloride solid.” What does it really tell us? It states in words what the following equation does in symbols:

\[ 2 \text{Na (s)} + \text{Cl}_2 (g) \rightarrow 2 \text{NaCl (s)}. \]

The equation is a balanced statement telling us that two sodium atoms react with one chlorine gas molecule to give two ionic sodium chloride molecules (actually the NaCl is not a single molecule but an empirical formula representing an ionic lattice.) The atoms on the left are called reactants and on the right the products. It is critical in all chemical equations that we balance both numbers of atoms as well as
charge. Note that there are two sodium atoms in the reactant mixture and two in the product. As well there are two chlorine reactant and product atoms. Chemical equations are to science the equivalent of accounting to business. We must keep track of all important information and present it in a manner which is clear and concise. Actually this is no different than balancing the nuclear reaction equations we learned in lecture six.

Let’s do a few more examples and call it a day. What is the balanced chemical reaction between aluminum and chloride to produce aluminum chloride? First, Al is a solid and Cl₂ is a gas. Second, aluminum chloride is AlCl₃ which is an ionic solid. Writing the equation:

\[ 2 \text{Al} (s) + 3 \text{Cl}_2 (g) \rightarrow 2 \text{AlCl}_3 (s) \]

What is this telling us? It states that two aluminum atoms combine with three chlorine gas molecules to produce two aluminum chloride molecules.

What about the reaction of Na and H₂O to give NaOH and H₂? This is a reaction which is obviously quite exothermic (if you use a large enough chunk of Na it will actually explode the H₂ gas).

\[ 2 \text{Na} (s) + 2 \text{H}_2\text{O} (l) \rightarrow 2 \text{NaOH} (aq) + \text{H}_2 (g) \]

Why do we care about writing chemical equations, anyhow? I can probably give you a multitude of reasons, primarily from the perspective of cooking! Why do you want a recipe book in the kitchen? You could just as easily throw the flour and eggs together randomly and hope to get the food you want? Chemicals are the same, in that we want the correct quantities to produce what we need (be it aspirin or motor oil). It is important in an automobile to have the mixture of oxygen and gasoline appropriate to achieve the proper rate of combustion. In the plastics industry, the chemical mixtures are carefully engineered to produce the properties that are needed in the materials. The silica based glasses used in windows and containers are all modified by small amounts of metal oxides to achieve the physical properties desired. Containers need to be strong, yet easily molded (lower melting point); windows need to be stable over long periods of time (better not be water soluble!) Other information provided by writing chemical equations is that they may be used to estimate energies and reaction rates (see page 228 in the text). How is the ozone hole forming? How quickly will the battery run out of power? These are questions that writing balanced chemical equations helps answer. The chemical equation is not the final stage in chemistry but is really just part of the language used by chemists. At our next lecture, we will study
another language of chemistry, that of organic chemistry and put the atoms together into far larger molecule such as proteins and nucleic acids.

- Additional chemical equation balancing problems to be studied at your leisure:
  
  \[
  \text{Al (s)} + \text{Fe}_2\text{O}_3 (s) \rightarrow \text{Al}_2\text{O}_3 (s) + \text{Fe (s)}
  \]
  
  \[
  \text{N}_2 (g) + \text{O}_2 (g) \rightarrow \text{N}_2\text{O (g)}
  \]
  
  \[
  \text{Ca (s)} + \text{H}_2\text{O (l)} \rightarrow \text{Ca(OH)}_2 (aq) + \text{H}_2 (g)
  \]
  
  \[
  \text{C}_3\text{H}_7\text{OH (l)} + \text{O}_2 (g) \rightarrow \text{CO}_2 (g) + \text{H}_2\text{O (l)}
  \]
  
  \[
  \text{KMnO}_4 (aq) + \text{KNO}_2 (aq) + \text{H}_2\text{O (l)} \rightarrow \text{MnO}_2 (s) + \text{KNO}_3 (aq) + \text{KOH (aq)}.
  \]

- Additional molecules to practice Lewis dot structure drawing:
  
  \[
  \text{CO, ClO}^-, \text{CH}_3\text{Cl, NO}_2^-, \text{ICl}
  \]
Appendix H: Berea College Chemistry Department WWW pages

Samples from our web pages I have written, included at end of this document. Complete site found starting at http://207.168.194.200/~jhb/chemistry.html.
Appendix I: Communication Across Campus IV Report

This report documents my efforts in working with the CAC group. It includes many comments duplicated in the narrative for this tenure evaluation report.

CAC Report

Jay Baltisberger

4/15/97

Chemistry Teaching Techniques
and Other Related Projects

Introduction

The format for teaching chemistry courses has traditionally been the standard lecture with limited involvement by the students in the actual classroom experience. Active learning by students has primarily come from the laboratory component of these courses. The main reasons for this probably stems from the intrinsic difficulty in reaching the “cutting edge” of knowledge in a field as developed as chemistry. Even in upper division courses, students address few real problems which have not already been solved. Under these circumstances it is difficult at best to inspire students to actively participate in the learning process. I have attempted to improve my chemistry courses (CHM 261 & CHM 262, physical chemistry; CHM 121 & CHM 122, general chemistry; CHM 113, nursing chemistry, and GSTR 232, natural science) through the introduction of techniques borrowed from my colleagues in the humanities which promote active learning. The successes and failures of these techniques in my courses is partially documented, though complete data analysis will not be completed until January 1998.

General Chemistry

In the general chemistry sequence two major changes were attempted. Both changes were designed to encourage students to prepare for class actively. The primary goal was to give incentive to read the chapter assignments prior to each lecture and be accountable for this reading. Unlike a small discussion section in a writing course, the larger general chemistry section is not conducive to student discussion. We have a very specific quantity of material which must be covered and we do not have time to arbitrarily wander down dead-end academic roadways. While student lead discussions can be quite fruitful
in some other introductory courses, in general chemistry the students lack the fundamental knowledge to really push their fellow classmates and extend the knowledge of their peers. In addition the large size precludes most students from having the opportunity to participate extensively. I adopted a more primitive but relatively effective tool of daily quizzes. This entailed a short multiple choice problem designed to be answered without extensive calculation but requiring knowledge of the current lecture material. The goal was first to encourage reading ahead and second to pinpoint specific problems which we can answer over the course of the lectures. In addition, these questions are used (often in identical form) as the basis for portions of the midterm exams (each test had 5 multiple-choice questions worth 20 points of 100 total). Students see these same sorts of questions when facing the standardized exams given at the conclusion of each course sequence as well as on tests such as the MCAT (Medical College Aptitude Text) or GRE (Graduate Record Exam).

The second change involved daily journal requirements. This basically was designed to encourage a better study style than most students had learned from high school. Because most students in general chemistry are freshman who have never previously been academically challenged heavily in their lives, the concept of using a journal to improve classroom and examination preparation was probably a bit mysterious to them. Basically, students were required to turn in a minimum of one page each week from a duplicate entry journal which detailed the times, dates and material studied for every day that week. Students were encouraged to go beyond the simple bookkeeping to include notes (for example recopying lecture notes, transcribing or interpreting book reading or listing formulas) as well as problems. In particular, I encouraged students to use the journal every time they opened their general chemistry textbook. While this utilization of journals is quite powerful, most students did not proceed beyond the minimum journal requirements. Grades were given each week and constituted about five percent of the total class grade. Unfortunately, since my minimum requirements were relatively easy to achieve (and rewarded students with 70% to 80% of the available points) many students choose not to do anything extra with their journals. I think the idea of using journals has a great deal of potential but is difficult to implement due to the massive grading requirements as well as the general apathy of the students. Ironically, the ones who worked hardest on their journals were often students who didn’t need the extra help. Finally, one common factor observed in many of these journals was the poor decisions made in terms of time management by many students. Often times students would proudly tell me they worked on general chemistry for 2-6 hours in a given week in which there were 3 hours of lecture and 3 hours of laboratory work for the course. Many faculty would agree that a 1:1 ratio of in-class to out-of-class time is proba-
bly not sufficient to achieve optimal performance, and unfortunately most of these students demonstrated that was true.

Physical Chemistry

The physical chemistry courses are designed for Junior and Senior chemistry majors. In general, they in general are much smaller in size (between 5 and 20 students) and are at a much higher difficulty level than general chemistry. These course tend to build upon the concepts learned in general chemistry and other chemistry courses. Students discover very quickly that very few problems in physical chemistry can be solved by the simple “plug-and-chug” approach favored in general chemistry. In addition, many of the results are difficult to visualize (for example, calculating \( \frac{\partial S}{\partial T} \) or other derivative functions). A number of techniques have been attempted to improve the learning environment in physical chemistry. The first of these was the idea of having a student do a “problem-of-the-day” in front of the class, the second involved allowing the students greater control over the laboratory portion of the course and a third method attempted more group projects and grading.

The “problem-of-the-day” approach was derived from a methodology discussed in small group setting with Ed McCormack, which he used in his business classes. In his approach, each day the discussion might be lead by two students chosen at random from a hat. In the application to physical chemistry, I select student names at random each day. I use a weighted average approach so that students who have successfully completed a problem have a lower probability of being drawn. The student who is drawn each day is responsible to produce a problem on the board related to the current lecture material which is taken from the problems in our textbook. Alternatively the student may select a similar problem from other textbooks which are available in the library. If a student fails to have a prepared solution, this student is penalized by an increased probability (by an amount equivalent to losing one problem of the day) and the next name on the list is used. If more than four names fail to have finished problems then a volunteer is selected. I prefer to not select volunteers as these tend to be the same students over and over (those who are always prepared.) Some students have a lot of difficulties being prepared and thus tend to fall to higher and higher probability. In practice, this ultimately forces these students to bring worked problems to class. I have not had to penalize students more than one or two times in general. There are no points affiliated with the problem of the day and students face no pressure for getting right or wrong answers. If errors are detected, we talk through them and fix them in class. Many times the students choose some of the easier problems and thus the exercise is not particularly valuable, but other times they choose very insightful problems which stimulate discussion and answer difficulties students may
have had. I have not found a consistent method for attracting students to the later variety of problems. This exercise tends to use a moderate amount of class time (probably 10 minutes per 50 minute lecture) and thus is questionable in terms of the time value. In general these courses are already very difficult to finish all the material on a standard syllabus in the allotted time and this sort of technique certainly can slow down the material. The big advantages seem to be the extra preparation students spend before classes.

The second technique of student control of laboratory experiments has been more successful than the “problem-of-the-day” technique. What I basically have done is allowed students greater flexibility in choosing their laboratory assignments. This is initially accomplished at the beginning of each semester by requiring the students to read the Journal of Chemical Education and select a physical chemistry experiment (there is usually about one every other monthly issue that is appropriate.) Students then present the experiment to the class in pairs in an oral presentation with a “proposal” format. That is to say, the pairs are attempting to “sell” their lab experiment to the class. Once all proposals have been presented, we vote as a class as to which experiments we wish to pursue. In addition, previous “working” laboratory experiments are added to the available list of experiments. No more than two or three new experiments will be attempted on any given semester (due to the difficulty in building new apparatus and uncertainty in success). On the whole we have created about four or five new labs in the physical chemistry courses which I have added to the “working” list. These experiments tend to be innovative and fun for the students, with such topics as “Photophysics in a Disco” and “Liquid-Liquid Phase Diagrams” added to the successful experiment list over the last year. On the whole, the physical chemistry laboratories are meant to only sample a tiny portion of the massive number of physical chemistry possibilities. As such, choosing different laboratory experiments each year does not adversely affect the students since there is no single lab which I would consider “essential” to continuing success in chemistry.

The final methodology employed was the idea of increased numbers of group projects. Essentially, chemistry is a group science in that almost all research and laboratory work done in the real world is performed by teams rather than individuals. In this regard, students need to recognize the importance of and participate in group experiences. The kinds of group activities that are involved in physical chemistry revolved primarily around laboratory experiments in the past. Most often the students work in groups of three or four while performing the experiments as well as writing up formal laboratory reports in groups. In addition, while not formally graded in groups, homework assignments are routinely solved
in a group setting by the students outside of class. I have attempted to add more in-class group projects in the form of in-class exams which are solved in a group format. One student nicknamed this a “communist” style of examination with rather derogatory implications. A similar project I attempted was to have a “communist” style take-home exam. In both cases, a few students felt that they had to work harder than they normally would have and were irritated that they got the same grade as their peers. These students preferred to stand on their own merits and not share grades with other students. Some of the weaker students seemed to enjoy the interaction as well as the improved grades. On the whole these new attempts to engage the students in more group activity have not been well received and are not something I recommend.

In conclusion, of all the modifications implemented in physical chemistry, the most successful were those involving the students in the selection of laboratory assignments. The students greatly appreciate all efforts to hand the controls over to them. The “problem-of-the-day” has been continued this year and has had limited success. I think my mind is still wavering on the educational value relative to the time required for this exercise. Finally, the idea of group grading, while useful for laboratory and homework assignments, seems less useful and poorly received in the form of examinations.

Nursing Chemistry

In the nursing chemistry course, some of the same modifications tried in the general chemistry course were applied here, including daily quizzes and journal entries. Again, the results are similar to those in general chemistry. The journals tended to be used mostly as a bookkeeping notebook saying “I studied 3 hours on....” and not really a notebook to record questions about reading and lectures. Few students seem able, at least at this level, to use the journal effectively as a study tool. They tend to view it as something that needs to be a well-written and polished final result rather than something that is a work in progress intended to aid them. They tend to focus on the time details more than the real questions. In terms of the quizzes, I feel that the daily quizzes help the students learn in a similar fashion to the learning which has occurred in general chemistry. Nursing students cover very similar material (at least in the first half of the course) and arrive with weaker backgrounds usually. As such, the quizzes give the students a basis to help study for exams and to prepare ultimately for the standardized exams they will take throughout their careers. The other innovation in nursing chemistry comes from using the world-wide web (WWW) as a means to help students monitor grades in the course. Each student was assigned a secret individual code which could be used to access their own grades as well as the grades of the course as a whole. The WWW published gradebook gave them percentages and ideas about how
they stood in the course (estimating current grade). The students used this resource some, but it was difficult to keep the gradebook current as the tools I used for putting the information on the web were probably not sufficiently advanced to make the task easy. I think the future of this type of open gradebook approach is growing as more web tools are developed. This is more than just a simple easy route to checking grades though, since it frees the students from having to wander in and face me one-on-one. If they feel ashamed, perhaps it provides them a way to see the whole picture without feeling embarrassed. I am not sure that this is a positive side-effect, since students feeling this way maybe should be visiting me on a more regular basis. On the other hand, any method to encourage students to take an interest in their performance cannot be all bad. On the whole, I think this technique is very promising but just not something I am ready to do on a regular basis yet.

**Natural Science**

Natural science is a course required of all students at Berea College and is generally feared, hated or loved. Few seem to leave this course without some strong feelings, some positive and some negative. Two major changes I have been working towards in this course involve changing the content and changing the format. This is a team taught course, so the opportunity to institute effective change is somewhat limited and rather slow to happen. Still, I feel my comments have been heard and taken seriously by the senior faculty members involved in the course and in fact I was given the opportunity to teach this course (along with Megan Morgan-Carr and Eric Pearson) in the summer of 1996. In the smaller summer school setting we tried some ideas out which were new relative to the format as taught in the spring and fall terms normally. One of the ideas was the abolition of the lecture notes and requirement that students actually read the textbook. A second involved adding a large number of “laboratory” experiments to replace some of the traditional discussion sections. Finally we tried to add a little fun and relevancy by showing some different evening movies to help remind students of the role of scientists in the public eye. These changes seemed to be well received by the students, though I am not sure we can document a specific change in overall happiness with the course or in terms of total information retention. I think that natural science, like all courses, should be continuously evaluated and changed as the students attitudes and abilities shift from year to year and decade to decade.

**Chemistry Seminar**

Our chemistry seminar course has traditionally been a capstone course to allow us to evaluate the relative preparation of a graduating senior to successfully read a current journal article and present it in-
telligently in front of their peers. The writing and speaking components have focused on the lead article extensively with presentation format and literature references being of high concern. I have recently added a concept I learned about from Ed McCormack and Tom Boyd involving interviewing as a means of evaluating the preparation of our seniors. In the spring of 1997 we added the requirement that each senior turn in a final-draft resume and complete a mock interview with myself (the course instructor). In this interview I have the opportunity to ask questions about the student’s chemistry background which may not be rehearsed as might be the case of the senior seminar. In addition, the interview provides us an opportunity to track where our students are headed after graduation both long and short term. Finally, I have used these sessions as a chance to try to tune up any presentation problems a student may have. If they include something on their resume, they should be prepared to discuss it intelligently and to some degree of depth. I have tried to illustrate the kinds of questions a student may encounter from a prospective employer evaluating a resume. I think it is a relatively low stress and high productivity meeting that lasts no longer than 30 minutes and allows the students to really ask some questions they might not have had the opportunity to previously. On the whole, the students who have undergone this evaluation seem to appreciate it. Again, the time commitment is small and the potential benefit is well worth the energy it takes to achieve it.

**Interdisciplinary Majors**

I have been working the last five months on the development of a proposal that the college include in the catalog interdisciplinary majors, specifically in the areas of biochemistry, chemical physics, earth science and others. This idea stems from discussions I have had with other faculty from other institutions through my Project Kaleidoscope connections. Many students these days seem interested in the hot topics and our traditional majors do not always carry the flash that maybe “biochemistry”, “applied computer science”, “chemical physics” or “polymer chemistry” might have. The ideas about interdisciplinary majors are not new and in fact the current college strategic plans seem to point us in that direction. As well, many of the national organizations (National Science Foundation among them) have been suggesting similar ideas. This is one proposal, however, that I will not be able to complete entirely on my own, so I view my work in this area more as a dialogue facilitator. I opened this dialogue at the fall science faculty retreat and felt that some were open to these ideas. As in all things there are a diversity of ideas and problems that need to be dealt with before any such proposal becomes a reality, but I think that it is a good project for me to be involved in and pushing forward as best I can.
Conclusions

In conclusion, the CAC4 project has been very rewarding personally. I feel I have learned a great deal by talking with my colleagues in other departments and these ideas have been translated into real applications in the classroom. Many of the readings and other materials were highly useful (I would especially recommend the Classroom Assessment Techniques by Angelo and Cross.) I plan to continue analysis of the materials I collected over the various courses I have tried new ideas. The net result will probably be additional experiments followed by more refinement. I am not sure it is productive to necessarily try to “reinvent” any given idea, but it certainly doesn’t hurt for me to tax my intellect occasionally and challenge traditions. Even if traditional techniques prove to be superior, insights learned in new ideas can always be translated back into useful applications.
Appendix J: Berea College Evaluations: Looking at the Numbers

The course evaluations (IEQs) given at Berea College are extremely helpful to instructors as individuals in that they provide an anonymous feedback which is standardized from course to course and which is consistently applied from semester to semester. When I get these at the end of a term, I spend a great deal of time trying to find insights that I may use to improve my courses in the future. Certainly when the numbers are below the college average or indicate a particular area that needs work, I try to think of ways to improve that area. Yet, often the measures that I have adopted do not seem to produce direct correlations with IEQ numbers. This has been disturbing for me and I have spent time talking with other chemistry faculty about this fact. This has led me to use the number but not to put blind faith in them. In regards to tenure evaluation, I hope it is seen that I do pay attention to the IEQ’s but that these do not drive my teaching. When we look at these evaluations then in response to asking about teaching excellence, I believe that we need to be very careful in using these numbers to either indict or applaud an instructor. The IEQ evaluations have limitations and should not be applied as a tool to compare different instructors. There are too many variables for which these evaluations fail to account. In general, it is well known that there are a variety of factors which can directly affect the numerical ratings (as well as the kinds of favorable/unfavorable comments made in the written section). First among these of course is grading; students will generally like an instructor who has "given them a break". This does not mean they necessarily like to be given high grades for no work, but if they think that you were a bit lenient and helped "push" them over the edge with some generosity, then it is certainly reciprocated on the evaluations. Second, the age of the students filling out the evaluations matters. Freshmen have very different expectations for a class than do upper-classpeople. It is common for freshman to want extensive out of class review sessions, study sheets, lecture handouts, dropped tests and other
teaching tools that are more high school than college. These are tools that responsible (upper level) students do not need to succeed in a course. When presented with classes with mixed populations, you will always have some who are unhappy with the teaching style. This will certainly also appear in the numerical rankings on the IEQs. Third, the timing of the in-course evaluations can directly affect the scores. If you give evaluations the day after a tough test you will see worse marks than if you give them the day after some easy lecture or other assignment that makes the students feel more positive. An example might be on the day of evaluations to cancel class for the rest of the period so that students may spend more time evaluating the course. This may be a bit of a cynical view, but I believe that these are true. Finally, the size of the class itself will affect how the students perceive a course. There is little chance for even the most wonderful class experience given to a class of 120 to compete with an intimate small group discussion section of 15 students. The feeling of personal attention and caring that a student gets from the small class is going to affect the relative scoring of these courses.

Given the wide range of factors outside of teaching excellence that affect the course evaluations we must consider that the numbers themselves really do have some sort of error bars. Not just an error which represents the standard deviation of the population and gives some idea of the distribution, but errors that come from asking "if this evaluation were repeated, how many students would change their answers on a given question?" These errors are very difficult to predict but even a conservative prediction that some fraction of the class would randomly rate a given question higher or lower by one point will potentially produce a different class average while retaining a similar standard deviation. Does this imply that the averages produced on these IEQs are wrong? No, but rather it implies that they cannot be accepted as strictly representational. Given the range
of errors which can be produced and given the range of in class evaluation conditions, the fact that most faculty members are within one standard deviation of the college mean is not surprising. Now when an evaluation score goes substantially outside of the normal range, then we may begin to ask is this an indication that there is a problem. But to use these numbers for any purpose other than rough qualitative evaluation is not just improper, it is truly unfair.

This leaves us asking how to look at the IEQs with a degree of fairness. First, I would suggest it is absolutely critical to compare apples to apples and not oranges. This means comparing courses of comparable size, comparable difficulty, comparable material rather than comparing numbers to the college mean. In addition it means looking closely at differences to try to see if they truly are different or are merely a result of random outside factors. On the whole, the IEQs are useful but should not be held up as the standard measure of excellence. Similar comments could also be made about the alumni surveys if they are to be used as a numerical measure rather than an additional source of information.

The table below summarizes some of the statistical information I hoped to convey with the preceding discussion.

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In this table we have two different sample sizes (one with 20 the other with 30 students) answering a general question on a five point scale. The <N> represents the "true" average which is the
weighted mean of the probabilities that a given student will answer a given value. The $\sigma_N$ represents the standard deviation of this probability distribution. The $n_i$'s are the outcome using a random number generator to pull out 20 or 30 responses from the probability distribution. The $<n>$ and $\sigma$ columns are the mean and standard deviation of these six different distributions for a given "true" average. It is clear that on the average the $<N>$ and $<n>$ are very similar. It is also true that it is more difficult to get averages above rather than below the true average due to the fact that all $<N>$ are greater than 2.5 and thus all suffer from the "wall" of the top score of 5. It is also clear that for a given $<N>$ there can be substantial deviation for a given class evaluation (certainly ±0.4 is not unheard of). So in the end what does this all mean when applied to our IEQ forms? I believe that there is valuable content in these questionaires when read intelligently. The written comments given by the students are the single most important element, but the numbers themselves have information. Care should be taken to not say “Wow, that change I made really improved this area” if you see an isolated jump of +0.5 to a given question. Now if this jump seems to remain year after year, then it may be real, but given the large number of variables affecting a given score, it may go back down from time to time. Does this indicate that the change really didn’t work? I would hold that the answer is not clear from the numbers. If the written comments indicate that the students appreciate that change, then I’d say it was good, if they seem to complain about it, then it might not be (though student complaints alone are not the only voice to be heard in evaluating change in a course). My conclusion about the numbers on the IEQ forms is that they should not be used as a strict judge of people or courses but instead be used as a guide to try to help us make meaningful changes. If an area shows a weakness, then I say by all means try to improve it, but do not do so only for the IEQ number nor assume that the numbers will improve automatically even if the course does.