James Poirier

La Jolla High School
La Jolla, California

School Profile

School Location and Environment: La Jolla High School is located in La Jolla, California, a suburb about twelve miles north of San Diego. The school is one of twelve high schools in the San Diego Unified School District. Thirty percent of the students are bused in from a predominately Hispanic area of San Diego; an additional 20 percent, who live in La Jolla, use their own transportation to come to school. The school has strong sports and academic programs and was ranked #22 in the March 1998 *Newsweek* magazine report, "The 100 Best Schools in America."

Grades: 9–12

Type: Public high school

Total Enrollment: 1,450 students

Percentage of Minorities: Hispanics comprise 35 percent of the student population; Asian Americans, 10 percent; African Americans, 5 percent; and 5 percent are other, unspecified minorities.

College Record: Sixty percent of the graduating seniors go on to attend four-year colleges; 30 percent attend two-year colleges or trade schools. The number of graduates who choose to attend one of the schools in the University of California system is growing. About 18 graduates go on to Ivy League schools each year.

Overview of Advanced Placement Chemistry

AP Program: La Jolla High School offers two sections of AP Chemistry, which meet five days a week for 55 minutes; there is no extra period for laboratories. Each section usually starts with 30 to 35 students, but many drop the course in the first month. We accept both first and second year chemistry students but demand that they have a strong background in math. Most AP Chemistry students are tenth or eleventh graders who are also in the

second-year algebra or pre-calculus classes. Students of any grade may take AP Chemistry, however, and there are always a few ninth graders who enroll. Interestingly, these freshmen have always scored a 5 on the AP Exam. As a group, the seniors have the worst AP Exam results, averaging an approximately 50 percent pass rate. First-year students generally do better on the exam than second-year students.

La Jolla High School administered nearly 500 AP exams in 1998 with a pass rate of 85 percent. All students who are enrolled in AP Chemistry are required to take the AP Chemistry Exam in May. This is a school rule (at least for the AP science courses) and has been in force for the last five years. The rule is important because it separates those students who are serious about the course from those who are not. Students are responsible for paying their own exam fees and all seem to be able to do so without financial hardship. I have offered to pay the fee in exchange for some lab cleanup work, but no student has ever taken me up on my offer.

AP Class Size: Approximately 50 students in two sections

Teaching Strategies: I use the following strategies when teaching my AP Chemistry course. I believe they are the most important factors to having a successful course.

1. **Create a group spirit** and high esprit de corps, similar to that which develops among members of a sports team.

2. **Encourage students to work together in order to learn.** The class is not split into "those who are" and "those who are not" going to take the AP Exam; everyone is in the same boat. Since each student realizes that he or she *is* going to take the exam, each works hard to understand the material.

3. **Limit lectures to allow plenty of time for other learning activities.** I do not lecture a great deal. After students have read and outlined a chapter, I will spend a day or two lecturing on it, covering the high points of the theory, deriving any important equations, and presenting

demonstrations that are relevant to the topic. I assign a few questions from the back of each chapter but use them only as an introduction to the material. We go over these questions and shortly thereafter I hand out a set of questions taken from old AP Exams. These are the essay and problem-type questions that students can expect to see on the exam in May.

4. **Keep quizzes and tests short,** sometimes even to just one or two questions, so that testing does not take up too much time during the period.

5. **Require each student to present the solution to a problem before the class.** This technique is probably my trademark as a teacher. Each student receives 6-10 old AP Exam questions on the current chapter and is expected to have completed them in two or three days. (Problems often do not contain all the parts of the original exam question; for example, I will only assign those parts that pertain to the chapter we are covering.) In addition, each student is assigned the responsibility of presenting two of the questions on the overhead projector for the entire class. Many students receive the same question, but they do not know upon whom I will call. Students receive points based on the quality of their presentation. I post the detailed solution to each problem in the classroom so they can examine beforehand the problems they do not understand.

   Students often have stage fright when they are first asked to come forward to present the solution. They soon find, however, that the rest of the class is behind them and wants them to succeed. To this end, the class is attentive during the explanation and even tries to help the presenter over the rough spots. My job as teacher is to stand near the back of the room and oversee the process. This involves my knowing when to step in and ask pertinent and probing questions such as, "Could you go over step 3 again? I don't see where you got your answer." I will ask the presenter questions if I feel the class is getting lost. I can tell when this happens because the class usually grows very quiet, as if projecting the plea, "Don't call on me because I don't understand." There are also times when I ask questions because I honestly cannot follow what the presenter is doing.

The seminar-like atmosphere these problem presentation sessions creates is not threatening and makes it easy for students to ask questions. Soon there is a lively give-and-take between the presenter and the class. Lights seem to go on and learning takes place. These sessions are the very heart of how I teach AP Chemistry.

Preparing for the AP Exam: Three weeks before the AP Exam I schedule six review sessions from 7:30-9:00 p.m. in my classroom to go over multiple-choice questions from the 1994 AP Exam. Two Saturdays before the exam we all meet in the morning in the school cafeteria to take the 1989 AP Exam for practice. The following Saturday the same procedure is followed with the 1994 AP Exam. The exams are identical in administration to the actual AP Exam. At the end of both exams I give students the answers and a scoring sheet, which they use to grade their own exam and figure their score. They are shocked by their results on the first exam but are better able to see the areas in which they are weak. The second exam usually shows an improvement in scores since students know where to concentrate their studying.

Students must turn in the scoring sheet on the following Monday and they receive a huge amount of credit. I grade on the curve, so those who do not complete this assignment hurt their grade. Students who cannot make the Saturday sessions must pick up an exam packet from me on Friday, take the three-hour exam at home over the weekend, have the completed scoring sheet signed by a parent, and return the sheet to me on Monday. This system works well and students believe it greatly improves their chances of passing the exam.

There are no lectures, tests, quizzes, or chapter readings following the AP Exam. These two or three weeks are instead devoted to large, involved laboratories that take three to four days each. I expect students to do an excellent job on these investigations and I grade their lab reports carefully. They receive a large number of points for these labs, which gives them a good reason to complete the work. It is important to keep in mind that after the AP Exam students are in no mood for new material and want a break of some sort. These labs provide that break and are a good learning opportunity as well.

Texts

McQuarrie, Donald A., and Peter A. Rock. *General Chemistry.* 3rd ed.

Zumdahl, Steven *Chemistry.* 3rd ed.

Laboratory Manuals

We do not use a lab manual but rather a collection of labs from various sources. These include

Hope College Lab Program. Hope College, Holland, MI.

Masterson, William L., and Emil J. Slowinski. *Chemical Principles in the Laboratory.* 5th ed.

Ehrenkranz, David and John J. Mauch. *Chemistry in Microscale.*

Demonstration Resources

Shakhashiri, Bassam. *Chemical Demonstrations: A Handbook for Teachers of Chemistry.*

Summerlin, Lee R., and James L. Ealy, Jr. *Chemical Demonstrations: A Sourcebook for Teachers*

Course Outline

Note: An asterisk (*) indicates the most important labs.

Unit 1: Calculations and Uncertainty — 1.0 weeks

Dimensional analysis, uncertainty, significant figures

Suggested Experiments

None

Unit 2: Atoms, Molecules, and Ions — 1.5 weeks

Review of formula writing, oxidation states, nomenclature, etc.

Suggested Experiments

Safety in the lab
How to use a balance
How to use equipment

Unit 3: Stoichiometry — 2.5 weeks

Mole, atomic weight, molecular formula, balancing equations, limiters, empirical formulas, percent composition, percent yield, and solution stoichiometry

Suggested Experiments

Empirical formula of copper iodide (Hope College)*
Synthesis of aspirin (Masterton)
Net ionic reactions using microscale (Mauch)*

Unit 4: Gases — 2.0 weeks

Ideal gas law, van der Waal's equation, Avogadro's Law, STP, Dalton's Law, Graham's Law, kinetic theory of gases, etc.

Suggested Experiment

Molecular mass of a volatile liquid (Masterton)*
[Isopropanol works best.]

Unit 5: Thermochemistry — 2.0 weeks

Enthalpy, thermochemical equations, heats of formation, bond energies, heats of reactions, etc.

Suggested Experiment

Calorimetry (Hope College)*
[This covers thermochemistry and solution stoichiometry.]

Unit 6: Atomic Structure and Periodicity — 2.0 weeks

Atomic spectra, Bohr atom, quantum numbers, atomic orbitals, electron configurations, periodic table, trends in the periodic table in terms of physical and chemical properties

Suggested Experiments

Flame test for metals using spectroscopes
[Also, show discharge tubes and how they relate to wavelength. Mention bright line spectra and have students use diffraction gratings to view spectra.]

Unit 7: Chemical Bonding — 3.0 weeks

Lewis structures, ionic bonding, character of bonds, covalent model, octet rule and exceptions, resonance, VSEPR model, and hybridization

Suggested Experiment

VSEPR model building using styrofoam balls and pipe cleaners*

[Students must first make five geometries and be able to distinguish between electron and molecular geometry. It is important that students know this material well for the AP Exam.]

Unit 8: Liquids and Solids — 1.5 weeks

Dipole-dipole interactions, hydrogen bonding, London forces, liquid state, types of solids, metallic bonding, network solids, vapor pressure, change of state, phase diagrams, and specific heat

Suggested Experiment

None

[There are many good demonstrations for this unit's material.]

Unit 9: Properties of Solutions — 2.0 weeks

Electrolytes and nonelectrolytes, molarity, molality, mole fraction, colligative properties, Raoult's Law, Henry's Law, freezing point depression, boiling point elevation, and osmotic pressure

Suggested Experiment

Molecular mass determination by freezing point depression (Masterton)

[There are also many good demonstrations for this unit.]

Unit 10: Chemical Thermodynamics — 2.5 weeks

Gibbs free energy equation, laws of thermodynamics, enthalpy, entropy, free energy, energy and work, exo- and endothermic reactions, and state functions

Suggested Experiments

None

[There are many good demonstrations from a variety of sources for this unit.]

Unit 11: Chemical Kinetics — 2.5 weeks

Reaction kinetics, rate law expressions, order of reactions, rate constant, half-life, activation energy, catalysts, and reaction mechanism

Suggested Experiment

Kinetics of thiosulfate decomposition (Ehrenkranz)

Unit 12: Chemical Equilibria — 2.0 weeks

Laws of mass action, equilibrium expressions, calculations of K and equilibrium concentrations, Le Châtelier's principle, and how equilibrium is shifted by temperature, concentration, etc.

Suggested Experiment

Determination of the equilibrium constant (Hope College)

Unit 13: Acids and Bases — 2.5 weeks

pH, K_a and K_b expressions, titration, degree of ionization, K_w expressions, indicators, equivalence points, Arrhenius, Brønsted-Lowry and Lewis acid theories, and salt hydrolysis

Suggested Experiments

Titration of a solid acid to find its molecular weight (Hope College)

Titration of a diprotic acid (Hope College)*

Unit 14: Electrochemistry — 1.5 weeks

Oxidation and reduction half-cells and equations; electrochemical (voltaic) cells, standard voltages, standard voltages from a table, Nernst equation, Faraday's laws, writing redox equations, and balancing equations in acid/base solutions

Suggested Experiment

Electrolysis of water, identifying electrodes, writing half reactions, etc.*

[This is a lab I created. It uses a nine-volt battery, two pencils sharpened on both ends, and universal solution in water and shows the evolution of hydrogen and oxygen and the ensuing color changes. Students must write the half reactions and the overall reaction and justify each step.]

Unit 15: Nuclear Chemistry — 0.5 week

This unit takes only a few days and includes nuclear equations, half lives, nuclear particle emissions, fission and fusion, and a bit about nuclear reactors.

AP Exam Review — 3.0-4.0 weeks

I emphasize writing net ionic equations, knowing the solubility rules, solving equilibrium problems, and reviewing old AP Exams.

Charles M. Roberts

Oklahoma School of Science and Mathematics
Oklahoma City, Oklahoma

School Profile

School Location and Environment: Oklahoma School of Science and Mathematics is located on a 32-acre campus near the State Capitol complex and the research laboratories and libraries of the Oklahoma Health Center in Oklahoma City, Oklahoma. OSSM was created in 1983 through state legislative action for high school juniors and seniors who are gifted in math and science and are Oklahoma residents. It graduated its first class in 1992. Students must apply for admission to the school and are typically 15 or 16 years old when they are admitted. They receive full tuition, room, and board from the state of Oklahoma and live in dormitories on the campus during the four semesters of their enrollment. OSSM is currently expanding both its facilities and enrollment. Additional information can be obtained by visiting its web site at http://www.ossm.edu.

Grades: 11–12

Type: Two-year residential selective math and science public high school

Total Enrollment: 133 students; the female/male percent ratio is 49/51

Percentage of Minorities: Asian Americans comprise 26 percent of the student population; Native Americans, 10 percent; African Americans, 5 percent; and Hispanics, 2 percent.

College Record: 100% of the graduating seniors attend four-year institutions: approximately 60 percent go to an in-state public or private university (many as Oklahoma Regents Scholars) and 40 percent go to competitive out-of-state public and private universities.

Overview of General Chemistry I and II

AP Program: Oklahoma School of Science and Mathematics offers a college-level general chemistry course that, while not an AP Chemistry course, does cover the topics detailed in the *Course Description* as well as other topics.

General Chemistry I and II are sequential courses that include both lecture and lab components. The lecture period meets three days a week for 50 minutes; a practicum period meets once a week for 50 minutes. Practicums are usually devoted to addressing specific types of quantitative problems currently being discussed in the lectures. The laboratory section meets once a week for three hours. This lab time is occasionally used for additional lectures and problem-solving.

Students must take two semesters of General Chemistry in order to graduate. A student who is selected to take my section of the course has met specific criteria. The student has

- had at least one year of chemistry prior to coming to OSSM
- made A's in his/her previous chemistry course(s)
- been determined by the mathematics faculty to have sufficient math skills (successful completion of Algebra II or higher)

OSSM supports the position of the College Board — that college-level chemistry courses should not be universally taught to students who have not previously had a year of course work in the subject. It has been our experience that first- and second-year students are quite distinguishable from each other. Therefore, we counsel some students to wait to begin the chemistry sequence until their second or third semester.

The sequence of topics covered in the General Chemistry course has been developed over the years to make assimilation of the material as easy as possible for students. We work to lay down basic concepts first and then build up to more advanced levels of understanding. In all instances we try to show how a particular topic relates to any previously covered material. We do require students to memorize many "factoids" and equations in the belief that without quick recall of such material no student can successfully achieve a professional level in any scientific or engineering discipline. To that end, we provide a multipage handout to the incoming students attending the school's summer orientation meetings. The handout lists all of the chemical symbols and names, polyatomic ion formulas, and other information we feel is crucial for students to have memorized in advance. This way they are not confronted with a large amount of new material at the same time they are trying to adapt

to their new environment. Students are informed that they will be tested on the handout during the first week of classes. This procedure has been well received by the students since its inception.

We use various standardized tests that are available from the American Chemical Society (ACS) to evaluate our chemistry program. In addition, we have participated in the preliminary testing for the ACS Standard High School and Honors High School Exam (1996 and 1998 versions) as well as the latest ACS General Chemistry Exam (2000 version), which is subsequently used by many major universities and colleges to test their students. General Chemistry students are not required to take the AP Chemistry Exam, but many do so; typically, 30-40 students (at least 50 percent of the General Chemistry II class) choose to take it. Each year we also give students the opportunity to take the Chemistry Olympiad Regional Exam.

Class Size: 8–12 students

Teaching Philosophy: My goal is to provide a rigorous course taught at the college level that will challenge the gifted and highly motivated students who take it. At the same time, I want my students to enjoy the learning process and feel a thrill each time they make a discovery. I believe that students take their cue from their instructor. Thus, I strive to convey my genuine enthusiasm for the subject. I frequently describe what I do in the classroom as "playing with my kids." Chemistry is a serious, difficult subject, but it is also a great deal of fun. That is the feeling I want students to take with them from my course.

Laboratory Experience: The laboratory experience is one of the chemistry faculty's top priorities because we believe that the best way for students to learn about chemical reactions is to do them in test tubes or flasks, not just read about them in a book. OSSM's chemistry faculty is comprised of David Holder, Fazlur Rahman, Paul Ellgen, and myself (with the assistance of Ann Dell in the Biology Department), all of whom hold Ph.D.'s in either chemistry or biochemistry and are currently active in their fields. Our combined, extensive backgrounds in various types of research laboratory environments enable us to give our students a strong laboratory experience.

Personally, I really enjoy working in the lab with my students and sharing my knowledge of various methods and techniques. I plan 10 to 12 labs each semester and make one of them a Formal Lab Report for which students must submit a computerized report using the format I supply. Whenever possible, I try to do each lab at that point in the semester where it complements the lecture material.

All of the labs are carried out with the standard, full-scale apparatus that is usually associated with general chemistry labs. Students have access to extensive inventories of chemicals, glassware, and various specialized equipment, and two special chemical hoods allow them to safely do reactions that would otherwise not be possible. We expect students to handle the traditional strong acids and bases properly as a part of their lab experience.

Labs are usually done in student groups of two, but some are done in three or four-person groups. It has been my experience that students who are initially very reticent about working with chemicals for fear of being harmed in some way are quite comfortable if they can be part of a team. I emphasize safety at all times and spend the first week in the lab going over all the rules, which we enforce at all times. After completing this session, students sign a "Safety Contract," which I keep on file. I am pleased to report that none of our students has ever had a major injury, and we intend to keep our record intact.

Assignments: Students are expected to turn in their assignments on time, unless extenuating circumstances prevail. Students with prior knowledge of a legitimate conflict must notify their teacher before the assignment's due date. Assignments and exams that are missed due to an excused absence may be made up with no penalty; depending on the circumstances, labs are either to be made up or an alternative form of work is substituted. Assignments, exams, and labs that are missed due to an unexcused absence cannot be made up and a grade of zero (0) is recorded for what was missed. Unexpected delays are dealt with on an individual basis and the final decision as to whether or not to accept late work rests with the teacher.

Assessment Strategies: I use a computerized spreadsheet to record my students' grades, a tool that makes it easy to calculate their final semester grades. The final semester grade is composed of four parts:

1.	Exams (6 per semester)	45 percent
2.	Final Exam	20 percent
3.	Laboratories (10-12 per semester)	20 percent
4.	Homework and Quizzes	15 percent

1. **Exams** — These are designed so that students must demonstrate their mastery of the material in many ways — by answering multiple-choice questions, writing concise concept narratives, and solving problems that may have multiple parts. In order to receive complete credit for a problem, students must clearly show how they arrived at their solution. I encourage them to style their answers in a manner that is consistent with the free-response section of the AP Exam. Multiple-choice questions frequently have the option "none of these" followed by a blank space in which students supply what they believe to be the correct answer. These exams, which last 50 minutes, are intended to challenge students from a time perspective as well as a knowledge perspective. They also help reduce the "intimidation factor;" students learn that if they prepare properly for exams, they can expect to perform well on them.

2. **Final Exam** — Both semesters conclude with a three-hour comprehensive final exam on the material covered that semester; a final exam has 200 possible points. The format of the final exam is very similar to that of the AP Exam. The multiple-choice section given at the end of the second semester is the latest version of the ACS Honors High School Exam. Final exams are written and agreed upon by all of the members of the group who have taught the General Chemistry course that semester (there are usually three of us).

   As part of our ongoing effort to keep students from being so dependent on their graphing calculators to do the most fundamental arithmetic operations, part of the first semester exam is written to be taken without calculators. Our experience has shown that students

who cannot do elementary math calculations in their heads (or with the help of a pencil and paper) will have great difficulty grappling with the complicated mathematics of such topics as empirical formulas, limiting reagent problems, gas laws, kinetics, electrochemistry, and all types of equilibrium problems.

3. **Laboratories** — Our lab manuals are designed so that students can easily tear out and submit the pertinent portion of each lab at the proper time. Each lab experiment is designed to have at least three components that students must complete and submit for evaluation. The first component is the Pre-Lab, which familiarizes students with the conceptual basis of that particular lab. Students complete the Pre-Lab assignment before the start of the lab. Failure to do so can result in a student being prohibited from doing that day's lab; the student is then required to make up the lab during one of the other sections that meets that week.

   The second part of the lab document contains the written instructions and list of equipment needed to carry out the experiments. It is also the place where students record their observations and data while they are doing the lab. This second part and the third part, which is known as the Post-Lab, are usually turned in for teacher evaluation within one week after the completion of the lab. The Post-Lab contains such topics as sources of error as well as additional questions and/or problems for students to answer. Each part of the lab is assigned a numeric value and recorded as a total number (usually between 40 and 60).

4. **Homework and Quizzes** — Homework is assigned for every chapter studied in the text. Each semester, on the first day of class, I give students a list of assignments. They are notified in class at least one week in advance of the date that their homework will be graded. The homework due date is always 48 hours before the next exam is administered. This encourages students not to procrastinate until the night before and then try to cram in enough to pass the exam the next morning.

   In an attempt to manage the volume of paper the homework assignments produce, I have adopted the following strategy. On the due date, I verbally give the correct answers at the beginning of class.

Students are responsible for grading their own work and recording the number wrong (or not attempted) at the top of the first page. All of the papers are then turned in to me for evaluation. If the amount of homework to be graded threatens to consume too much class time, I post the official answer sheets outside my office door and give students the entire day to grade their homework and submit it to me.

Quizzes are most often used to give students the opportunity to show how well they have memorized the material. They are quizzed on such topics as chemical symbols, various nomenclature items, oxidation states, solubility rules, and VSEPR relationships. I always give quizzes at the beginning of class. They may be announced or unannounced, as stated in the syllabus students receive at the beginning of the semester.

Preparing Students for the AP Exam: I begin preparing my students for the AP Chemistry Exam about the last week of March, upon their return from Spring Break. First I hold a three-hour session for those students who have informed the school counselor of their decision to take the AP Chemistry Exam. During this session I go over as many of the details of both parts of the exam as I can cover in the allotted time. I teach students the strategies I have developed for optimizing their performance on this type of exam. I also hold several sessions with students on a voluntary basis in the late afternoon or evening. Students may check out and study any of the review materials in my archives, which include all of the released exams as well as all of the Chemistry Olympiad exams at both the regional and national levels. By the time May rolls around, students have a good idea how they will score on the exam and are able to take it with a relatively relaxed state of mind. Over the years they have tended to do very well on it.

Texts: We have used the third edition of Steven Zumdahl's *Chemistry* as the primary text for General Chemistry I and II since 1993. It will be replaced by the fifth edition in time for the beginning of the 2000-2001 school year. The previously used text, W. L. Masterton and Cecile N. Hurley's *Chemistry: Principles and Reactions*, has been retained for use as a reference because we have found that on many occasions our students have benefited from having access to a different presentation of the material. The sections on analytical chemistry in Chapter 17 in the Masterton text, for example, are much more

informative than what is presented on this subject in the Zumdahl text. Every year we provide students with our own lab manuals authored by Dr. David Holder and myself. These are updated as new experiments are found for inclusion.

Course Design: The two-semester sequence we have developed does not follow that of the Zumdahl text, but rather allows us to move from one topic to another in a logical fashion. The first three units are usually covered in the first semester (although sometimes we do not get to the material on colligative properties in the third unit until the second semester), with the balance being covered in the second semester.

Beginning Unit: Fundamental Ideas

A. Begin with basic concepts of atoms, then introduce molecules and ions
B. Introduce the periodic table and describe major areas on it
C. Introduce the idea that chemistry is a quantitative and a qualitative science
D. Introduce the language analogy* for chemistry (compare it to any foreign language)
E. Introduce nomenclature rules for inorganic compounds
F. Introduce the concept of the mole and stoichiometry
G. Introduce the ideas of balancing chemical reactions of various types

* The **alphabet** of chemistry is made up of the *chemical symbols* that are in the periodic table; **words** are *chemical formulas*. Words are combined into **sentences** called *chemical equations* for which there are rules about proper syntax.

Second Unit: In-depth Studies of Atoms and Molecules

H. Introduce atomic spectroscopy and structure (pre-quantum mechanics)
I. Cover in reasonable depth the quantum mechanical model with its resultant contributions
J. Show how the arrangement of elements in the periodic table is related to these results
K. Cover in reasonable depth the area of ionic bonding
L. Carry out an in-depth study of chemical bonding (covalent type)

Third Unit: Studies of the Three Main States of Matter

M. Carry out in-depth studies of the gas phase, including intermolecular forces
N. Carry out in-depth studies of vapor pressure and phase diagrams
O. Carry out a reasonable level of study of the solid phase
P. Carry out a reasonable level of study on colligative properties of solutions

Fourth Unit: Studies of Thermodynamics and Kinetics

Q. Cover in reasonable depth the concepts of enthalpy and internal energy
R. Cover in reasonable depth the concepts of entropy and Gibbs Free Energy
S. Cover in reasonable depth the concepts associated with the field of chemical kinetics

Fifth Unit: Studies of Chemical Equilibrium

T. Cover in reasonable depth the concepts associated with gas phase equilibria
U. Cover in reasonable depth the concepts associated with weak acids and bases
V. Cover in reasonable depth the concepts associated with buffer systems
W. Cover in reasonable depth the concepts associated with acid-base titrations
X. Cover in reasonable depth the concepts associated with insoluble salt equilibria

Sixth Unit: Concluding Studies

Y. Cover in reasonable depth the concepts of electrochemistry
Z. Cover in reasonable depth (if possible) the areas of coordination compound chemistry, nuclear chemistry, and organic chemistry

Syllabus

Dr. Roberts's Version of an Ancient Chinese Proverb

What I only hear I tend to forget.
What I see I only partially remember.
What I do is the only path to understanding.

It is my intention to make this course as enjoyable a learning experience as possible. I encourage you to be very actively involved in the process of learning as much as possible about the subject of chemistry (and all of the other subjects you are studying). If you encounter difficulty at any time, please do not hesitate to seek my assistance outside of the classroom. It is my desire that all my students succeed to their ultimate level and I will do my part to help.

Dr. Roberts's Honor Code: Students who take my course are expected to conduct themselves with integrity both in and out of the classroom and abide by this Honor Code:

Upon my Honor, I will neither give nor receive inappropriate aid of any kind for any purpose throughout my tenure at OSSM.

I expect complete adherence to the Honor Code by all students at all times! A breach of the code will result in appropriate disciplinary action.

Laboratory Dress Code: During laboratories it is important to wear clothing that will not interfere with the experiments. The first lab period will be devoted to lab safety, which includes proper laboratory attire. Students who come to lab inappropriately dressed or otherwise unprepared will not be allowed to participate in the scheduled lab experiment and will receive a grade of zero (0) for that lab assignment. Remember that lab safety requires each student to prepare for lab *prior to arrival* in order to be organized and efficient during the laboratory period. *Protective eyewear (goggles) will be provided in the lab and must be worn at all times, unless I state otherwise.*

Note on the Practicum Period: I intend to use this one-hour period each week as a time for the group to focus on directed problem-solving using the material currently under discussion. There may be some occasions when I will have to present additional lectures in order to adequately cover the

subject matter. In either case, I believe that if you use this time properly, then your performance on all of the exams in this course will be positively influenced. Please note: *Only chemistry will be done during this period!*

Instructor's Disclaimer: The instructor reserves the right to make any changes to the lecture, exam, or lab schedules that may be necessary due to unexpected circumstances that may arise during the semester. Should any changes be made, a revised schedule will be printed and provided to all students at the earliest possible time. Quizzes, both announced and unannounced, will be given throughout the course at the discretion of the instructor.

General Chemistry I

Fall Semester Lecture and Laboratory Schedule

Week of	Chapters and Topics	Laboratory
Aug. 16	Chapter 1: Chemical Foundations	Lab Safety
	Chapter 2: Atoms, Molecules, and Ions	*ACS Exam*
Aug. 23	Chapters 1 & 2 continued	Lab #1
Aug. 30	Chapter 3: Stoichiometry	Labs #2A/B
	Exam I (Chapters 1 & 2) on Fri.	
Sept. 6	Extended Weekend [students go home for extended weekends]	
	Chapter 3 continued	Recitation
Sept. 13	Chapter 3 concluded	Labs #3 & 4
	Chapter 4: Types of Chemical Reactions and Solution Stoichiometry (sections 4.4-4.7)	
Sept. 20	Chapter 4 continued (sections 4.3 & 4.1)	Lab #5
	Exam II (Chapter 3 & part of Chapter 4) on Fri.	
	End of the First Grading Period	
Sept. 27	Chapter 4 concluded (sections 4.2 & 4.7-4.11)	
	Chapter 7: Atomic Structure and Periodicity	Lab #6
Oct. 4	Extended Weekend	
	Chapter 7 continued (E. M. Radiation —> Quantum Numbers)	Lab #7

Oct. 11	Chapter 7 continued (Electron Configurations) Chapter 7 concluded	Lab #8
Oct. 18	*Exam III* (Chapters 7 & 4) on Wed. Chapter 8: Bonding: General Concepts Chapter 9: Covalent Bonding: Orbitals VSEPR Theory and Valence Bond Theory Localized Electron Model and Hybrid Orbitals Ionic Bonding (Chapter 8 sections & section 7.14)	Recitation
Oct. 25	Chapter 9 continued (Molecular Orbital Theory) *Exam IV* (Chapters 8 & 9) on Fri.	Lab #9
	End of the Second Grading Period	
Nov. 1	Extended Weekend Chapter 5: Gases (sections 5.1 & 5.2) Wed. — Overview of first 5 sections of Chapter 5 Fri. — Chapter 5 continued (Postulates of Kinetic Theory, Real Gases) Chapter 10 (section 10.1, Intermolecular Forces)	Recitation
Nov. 8	Mon. — Chapter 5 continued (sections 5.6 & 5.7) Wed. — Chapter 5 concluding discussions	Lab #10
Nov. 15	*Exam V* (Chapter 5) on Mon. Chapter 10: Liquids and Solids	Recitation
	Nov. 20-28 Thanksgiving Vacation	
Nov. 29	Chapter 10 continued	Lab #11
Dec. 6	Chapter 10 continued (Solids) *Exam VI* (Chapter 10) on Fri.	Recitation Review for Final Exam
Dec. 13-17	*Semester Final Exam* (Chapters 1-5 & 7-10)	No Lab
	Dec. 18-Jan. 4 Winter Holidays (Time for much R & R!!)	

First Semester Laboratory Experiments

1. Safety Contract and Lab Familiarization
2. Basic Techniques and Paper Chromatography
3. Percent Composition/Chemical Formulas
4. Mole Relations in a Chemical Reaction
5. The Copper Cycle
6. Many Colors of Manganese
7. Atomic Radius/Avogadro's Number
8. Atomic Spectrum of Hydrogen
9. Solubility of Ionic Compounds
10. Boyle's Law
11. Colligative Properties

    [In this lab students make ice cream in Ziploc sandwich baggies to study the phenomenon of the depression of the freezing point temperature by the addition of a nonvolatile solute (rock salt) to a solvent (water). Invariably, it also ends up being a celebration of the end of the semester. I tell them it's the only time they'll get to eat their experiment.]

General Chemistry II

Spring Semester Lecture and Laboratory Schedule

Week of	Chapters and Topics	Laboratory
Jan. 5	Chapter 6: Thermochemistry	Safety Review (Fri.)
	Chapter 16: Spontaneity, Entropy, and Free Energy	Lab #1
Jan. 10	Chapter 6 concluded	Safety Review (Mon.)
	Chapter 16 continued	Lab #1
	Chapter 8: Bonding: General Concepts (sections 8.5 & 8.8)	Recitation (Fri.)
Jan. 18	Extended Weekend	
	Chapter 16 concluded	Recitation
Jan. 24	*Exam I* (Chapters 6 & 16) on Mon.	
	Chapter 10 (Vapor Pressure and Phase Diagrams)	Lab #2 (Masterton, Ch. 17)

Jan. 31	Chapter 10 continued	Lab #3
Feb. 7	Chapter 10 concluded Chapter 11: Properties of Solutions (Colligative Properties)	Recitation
Feb. 14	Chapter 11 continued *Exam II* (Chapters 10 & 11)	Lab #4
	End of First Grading Period	
Feb. 23	Extended Weekend Chapter 11 concluded Chapter 12: Chemical Kinetics	Lab #5
Feb. 28	Chapter 12 continued	Lab #6
Mar. 6	Chapter 12 concluded *Exam III* (Chapters 11 & 12)	Recitation
	Mar. 11-19 Spring Break	
Mar. 20	Chapter 13: Chemical Equilibrium (Le Chatelier's Principle)	Recitation AP Workshop
Mar. 22	*International Chemistry Olympiad — Regional Exam*	
Mar. 27	Chapter 13 concluded *Exam IV* (Chapter 13)	Lab #7
Apr. 3	Chapter 14: Acids and Bases	Recitation
	End of Second Grading Period	
Apr. 11	Extended Weekend Chapter 14 continued	Recitation
Apr. 15	*International Chemistry Olympiad — National Exam*	
Apr. 17	Chapter 14 concluded Chapter 15: Applications of Aqueous Equilibria *Exam V* (Chapter 14)	Lab #8

Apr. 25	Extended Weekend Chapter 15 continued	Lab #9 Recitation (Fri.)
May 1	Chapter 15 concluded Chapter 17: Electrochemistry	Ch. 22: Organic Chemistry
May 8	Chapter 17 continued *Exam VI* (Chapter 15)	Lab #10
May 12	Extended Weekend	
May 16	*AP Chemistry Exam* Concluding Comments on the Course *Exam VII* (Chapter 17)	Recitation Lab #11 Review for Final Exam
May 22	*Semester Final Exams* (General Chemistry II final exam will be given on Wed.)	

Second Semester Laboratory Experiments

1. Coffee Cup Calorimetry
2. Qualitative Analysis: Anions
3. Qualitative Analysis: Group I Cations
4. Qualitative Analysis: Group III Cations
5. Colorimetry
6. Kinetics
7. Determination of an Equilibrium
8. Buffer/pH
9. Titration Curves
10. Electrochemistry
11. Colligative Properties

    [This is the same lab we do to celebrate the end of the first semester.]

William R. Robinson

Purdue University
West Lafayette, Indiana

School Profile

Location and Environment: Founded in 1869 as the land grant college of Indiana, Purdue University is a coeducational, state-assisted system. The main campus is located in suburban West Lafayette, 65 miles northwest of Indianapolis and 120 miles southeast of Chicago. The student body, which is primarily residential, consists of 29,700 undergraduates (16,700 men and 13,000 women).

Overview of Chemistry 115/116

Students majoring in science, engineering, and preprofessional programs enroll for two semesters of general chemistry — Chemistry 115 and Chemistry 116. Approximately 4,500 of these students are enrolled in general chemistry each semester, and about 2,500 of them are involved in the two-semester sequence for science and engineering students that is described here. Students are expected to have taken high school chemistry and be prepared to take beginning calculus concurrently with Chemistry 115.

Chemistry 115/116 meets for two lectures (400 students), one recitation section (24 students), and one three-hour laboratory (24 students) every week for 15 weeks. Recitation sections and laboratories are led by teaching assistants. The two courses cover the principles of chemistry with an emphasis on problem solving.

Course Requirements and Grading: Recitation activities, which include concept maps and challenge problems, complement or build on the homework. Concept maps are used to help students connect the variety of terms and concepts that are covered in the course. Challenge problems are similar to the marathon problems developed by James H. Burness (see the *Journal of Chemical Education* 68 [1991]: 919). A brief discussion of both concept maps and challenge problems can be found at the Journal of Chemical Education Internet Conceptional Question and Challenge Problem web site, http://JCHEMED.chem.wisc.edu/JCEWWW/Features/CQandChP/index.html.

Attendance in lab is required in both Chemistry 115 and 116. Students without excused absences who fail to complete three or more laboratories cannot pass the course. Completion of a lab project includes attendance in the laboratory, participation in the laboratory work, and completion and timely submission of a satisfactory laboratory report. Group work is encouraged. Students work in groups during most recitation and laboratory activities.

Homework is assigned but not collected for grading. Students have the first 20 minutes of each recitation to check their work and seek answers to outstanding questions; but they are expected to have finished the homework prior to the recitation so that they can participate in other recitation activities. Graduate instructors are available for additional help during office hours. Quizzes covering the homework are given at the start of the laboratory period following the recitation in which the homework was discussed.

Grades in Chemistry 115/116 are based on a maximum of 1,000 points, which are the total of

- 8 short quizzes at 15 points each
- 11 laboratory projects at 25 points each
- 3 one-hour examinations at 130 points each
- 1 two-hour final examination for 215 points

Students actually have 9 quizzes and 12 laboratories but are allowed to drop their lowest quiz and lowest laboratory scores. Typically, 850 points or more earns an A; 750 points or more, a B; 650 or more, a C; and 550 or more, a D.

Texts

Brown, Theodore L., et al. *Chemistry: The Central Science.* 7th ed.

Gardner, Thomas. *Experimenting with the Internet: A Guide for Chemistry Students.*

Long, Gary L., et al. *Math Review Toolkit.*

Purdue University. *Chemistry 115 Laboratory Manual.*

_____. *Chemistry 116 Laboratory Manual.*

Wilson, Roxy. *Solutions to the Red Exercises in "Chemistry: The Central Science."*

Chemistry 115 (Semester 1)

Lecture Topics

1. **Matter and Measurement** (2 lectures)
   - Matter, its classification and properties
   - Units of measurement
   - Uncertainty in measurement
   - Dimensional analysis

2. **Elements, Molecules, and Ions** (2 lectures)
   - Atomic structure, isotopes, atomic numbers, mass numbers
   - The periodic table
   - Molecules and molecular compounds
   - Ions and ionic compounds
   - Naming inorganic compounds

3. **Stoichiometry: Calculations with Chemical Formulas** (2 lectures)
   - Chemical equations
   - Atomic and molecular weights; the mole
   - Masses of atoms and molecules
   - Empirical formulas from chemical analysis
   - Quantitative information from balanced equations
   - Limiting reagents

4. **Aqueous Reactions and Solution Stoichiometry** (3 lectures)
   - Solution composition and concentration
   - Properties of solutes in solution
   - Solutions of acids, bases, and salts; neutralization
   - Ionic equations
   - Metathesis reactions
   - Solution stoichiometry and chemical analysis

5. Thermochemistry (3 lectures)
The first law of thermodynamics
Enthalpy
Enthalpy changes
Calorimetry
Hess's Law
Enthalpy of formation

6. Electronic Structure of Atoms (2 lectures)
Light and quanta
The Bohr model of the atom and electron energies
Wave behavior of matter
The quantum mechanical model of the atom
Atomic orbitals
Electron configurations

7. Periodic Properties of the Elements (3 lectures)
Atomic sizes
Ionization energies
Electron affinities
Metals, nonmetals, and semimetals
Group trends for Groups 1, 2, 16, 17, and 18

8. Basic Concepts of Chemical Bonding (2 lectures)
Ionic bonding and energetics of ionic bonding
Ionic sizes
Covalent bonding
Lewis structures
Bond polarity and electronegativity
Covalent bond strength
Oxidation numbers and formal charge

9. Molecular Geometry and Bonding Theories (2 lectures)
The VSEPR model of molecular structure
Polarity of molecules
Hybridization
Sigma and pi bonds

10. Gases (3 lectures)

The ideal gas equation
Gas densities and molar masses
Partial pressures
Kinetic-molecular theory
Diffusion and effusion
Real gases

11. Intermolecular Forces, Liquids, and Solids (4 lectures)

Intermolecular forces
Properties of liquids
Phase changes, phase diagrams (H_2O and CO_2)
Vapor pressure
Structures of solids

Laboratory Schedule

Note: Unless stated otherwise, it takes one week to complete one laboratory.

1. Check-in; safety review; features of the laboratory
2. Analysis of a metal carbonate by thermal decomposition
3. Preparation of alum from aluminum
4. Identification of five solutions using physical and chemical properties
5. Preparing and standardizing a basic solution by titration
6. Concentration of acids in commercial sodas
7. Enthalpies of dissolution and reaction
8. Analysis by continuous variation: enthalpies of neutralization reactions
9. Properties of the halogens and halide ions
10. Column chromatography: separation of metal ions
11. A quantitative analysis of the formation of a gas
12. Structures of crystalline solids (a computer experiment)
13. Preparation of luminol

Chemistry 116 (Semester 2)

Lecture Topics

1. **Solutions** (3 lectures)
   - The solution process
   - Expressing concentration
   - Factors affecting solubility
   - Colligative properties

2. **Introduction to Chemical Equilibria** (3 lectures)
   - The concept of equilibrium
   - Reaction quotients and equilibrium constants
   - Homogeneous and heterogeneous equilibria
   - Direction of reaction
   - Calculation of equilibrium concentrations
   - Le Chatelier's Principle

3. **Acid-Base Equilibria** (4 lectures)
   - Dissociation of water and pH
   - Bronsted-Lowry acids and bases
   - Equilibria involving weak acids
   - Equilibria involving weak bases
   - The relationship of K_a and K_b
   - Strengths of acids and bases

4. **Other Aqueous Equilibria** (3 lectures)
   - Buffers
   - pH titrations
   - Common ion equilibria
   - Solubility equilibria
   - Complex ion equilibria
   - Combined equilibria

5. **Coordination Chemistry** (2 lectures)
   - The structures of complexes
   - Isomerism
   - Crystal-field theory
   - Color and magnetism

6. **Kinetics** (3 lectures)
   Reaction rates
   Factors affecting rates
   Differential and integrated rate laws
   Half-life
   Reaction mechanisms

7. **Thermodynamics** (3 lectures)
   Entropy
   Calculation of entropy changes
   Gibbs free energy
   Calculation of free energy changes
   Spontaneous processes
   Free energy and the equilibrium constant

8. **Electrochemistry** (3 lectures)
   Oxidation-reduction reactions
   Voltaic cells and cell potentials
   Cell potential and free energy change
   Effect of concentration of cell potential
   Electrolysis
   Commercial cells
   Corrosion

9. **Nuclear Chemistry** (3 lectures)
   Radioactive decay
   Other nuclear reactions
   Patterns of nuclear stability
   Rates of radioactive decay
   Energy changes associated with nuclear reactions
   Nuclear fission and nuclear fusion

Laboratory Schedule

1. Check-in; computer simulation of the Bausch and Lomb Spectronic 20 (assigned as a take-home project)
2. Spectrophotometric determination of the concentration of Fe^{2+} in a solution
3. Spectrophotometric determination of the amount of colored dye in a mouthwash
4. Determination of the concentration and equilibrium constant of an acid using a pH titration
5. Student design of an experiment to determine the concentration and ionization constant of the weak acid in vinegar
6. Preparation of calcium iodate and standardization of a solution of sodium thiosulfate
7. Determination of the solubility and solubility product of calcium iodate
8. Determining what factors affect the amount of dye that will adhere to the surface of an eggshell
9. Design of a short qualitative analysis scheme and analysis of an unknown (2 weeks)
10. Spectrophotometric determination of the order of the reaction of crystal violet with base
11. Construction of galvanic cells and the effect of concentration on their potential
12. Determination of the enthalpy change, entropy change, and Gibbs free energy change from the temperature dependence of the equilibrium constant for a dissolution