**Chemistry**

**Program Mission**

**Step1: Department/Program Mission (Due May 15, 2009)**

The mission of the chemistry department is to provide an outstanding undergraduate education in the chemical sciences and an active intellectual community within the liberal arts tradition. Our goal is to equip students with the critical skills and understanding that will enable them to pursue careers in the chemical and medical sciences, as well as to create an informed citizenry that will serve as leaders in the societal discussion of science and technology. We believe that chemistry serves as a key partner in the increasingly interdisciplinary nature of science. To achieve these goals, we utilize an active pedagogical approach, which emphasizes the process of scientific discovery, the ever-changing body of scientific knowledge, and student-faculty interactions. We believe it is essential that students experience the process of scientific investigation, in the laboratory, the classroom, and through the unique mentoring relationship that develops through collaborative student-faculty research. We emphasize the integral nature of chemistry in our society, both as an endeavor that betters our lives and as a way of understanding and exploring our world.

**Step 2: List goals/outcomes (Due May 15, 2009)**

The curriculum in the Chemistry major is mostly vertical, where one course prepares a student for the next course in the sequence. This is particularly true of Chemistry 121, a course designed to prepare students for organic chemistry; Chemistry 211 and 212. A high percentage of the students who successfully complete 121 should be successful in Chemistry 211. To that end we have identified a number of learning goals students should have mastery of at the completion of Chemistry 121. Likewise we have identified learning goals for our Chemistry 211 and 212 courses. We have generated an assessment tool given to our graduates that is administered at graduation, 2 years and 5 years post graduation. We also have identified an expanded Learning Goal that will assess our continued emphasis on research in the curriculum.

**Learning Goal 1 – Content Knowledge: Key Concepts of Chemistry 121**

The student will have mastered key concepts of stoichiometry, equilibrium, atomic and molecular structure and acid – base chemistry prior their entry into Chemistry 211.

**Learning Goal 2 – Content Knowledge: Key Concepts of Chemistry 211/212.**

The student will have mastered the key concepts of chemical bonding, organic nomenclature, stereochemistry, structure determination using NMR and IR Spectroscopy, specific organic chemical reactions and mechanisms, upon completion of chemistry 211 and 212.

**Learning Goal 3 – Research , Critical Thinking and Communication Skills**

Our graduates will demonstrate a basic understanding of how to do research: to use the chemical literature, to identify a problem, to design and carry out experiments, to analyze and present research results, to keep a professional laboratory notebook and to write professional reports.

**Learning Goal 4 – Content Knowledge: Core Chemistry**

Our graduates will have obtained knowledge of the basic core of chemistry and the professional skill set needed to be successful in postgraduate chemical endeavors. This would include graduate school in chemistry, professional employment as chemists, medical school, or other graduate programs with significant chemistry content.

**Step 3: Identify program components (Due May 15, 2009)**

*Required courses, elective courses,out-of-classroom or other experiences that are designed to achieve each educational objective. NOTE: Every class will not, nor is it expected to,achieve each outcome. The goal is to get an even distribution of experiences that achieve the outcomes.*

**121** **Structure and Equilibrium** **(1)** **Fall, Spring: Learning Objective : 1, 3 and 4**
Basic principles of stoichiometry, atomic and molecular structure, and chemical equilibria, including the study of weak acids and bases in aqueous solution. Proficiency in algebra is expected. Lecture and laboratory. *Staff.*

**123** **Inorganic Chemistry: Introduction** **(1)** **Spring: Learning Objective : 3 and 4**
Prerequisite: Chemistry 121 or permission of instructor. A systematic introduction to the chemistry of the elements; concepts include electrochemistry, solubility and complex ion equilibria. Lecture and laboratory. *Staff.*

**206** **Chemical Analysis** **(1)** **Fall, Spring: Learning Objective : 3 and 4**

Prerequisite: Chemistry 121. Chemistry 123 is recommended. Laboratory course emphasizing the collection, analysis and interpretation of quantitative data, using both traditional and instrumental techniques. *Bieler, Lewis, Metz.*

**211** **Organic Chemistry: Structure, Stability and Mechanism** **(1)** **Fall: Learning Objective : 2, 3 and 4**
Prerequisite: Chemistry 121.
An integrated two-semester introduction to the chemistry of carbon-based molecules--the molecules of life. The structure and stability of carbon compounds, including: nomenclature, physical properties, spectroscopic properties, stereoisomerism and acid-base properties. The physical and mechanistic understanding of organic chemical reactions, focusing on: substitution, addition, elimination and rearrangement reactions. Laboratory involves techniques of synthesis and purification. *French, Harris, McCaffrey.*

**212** **Organic Chemistry: Mechanism and Synthesis** **(1)** **Spring: Learning Objective : 2, 3 and 4**
Prerequisite: Chemistry 211.
A continued survey of the mechanisms and reactions of organic molecules focusing on aromatic and carbonyl compounds, and the application of organic reactions toward organic synthesis. Laboratory involves team-designed organic syntheses of biologically relevant molecules and/or synthetic methodology. *French, Harris, McCaffrey.*

**288** **Selected Topics** **(1/2)** **Fall or Spring: Learning Objective : 3 and 4**
Prerequisite: Chemistry 121. *Staff.*

**301** **Chemical Energetics and Kinetics** **(1)** **Fall: Learning Objective : 4**
Prerequisites: Chemistry 123 or 211 and Math 141 or equivalent.
An exploration of the basic thermodynamic and kinetic principles that govern the outcome of all chemical reactions and physical processes. Primary emphasis is placed upon macroscopic chemical thermodynamics with applications to solutions, colligative properties and phase equilibria. Additional topics include kinetic molecular theory; the experimental basis for determining reaction rates, rate laws and rate constants; the relationship of rate laws to reaction mechanisms; and the effect of temperature change on the rate constant. *Bieler, Lewis.*

**321** **Advanced Synthesis Laboratory** **(1/2)** **Spring: Learning Objective : 3 and 4**
Prerequisites: Chemistry 206 and 212.
An exploration of advanced methods of chemical synthesis techniques in both organic and inorganic chemistry. Emphasis is placed on analysis of the synthetic products for purity and qualitative identification, using FT-NMR, FTIR, ultraviolet and visible spectroscopy. Further identification and analysis is done using HPLC, GC/MS, gas chromatography and LC/MS. Two four-hour laboratories per week. *Bethune, French, Harris, McCaffrey.*

**323** **Advanced Laboratory: Biochemistry** **(1)** **Fall: Learning Objective : 3 and 4**
Prerequisite: Chemistry 206, 337.
The study of biochemical laboratory techniques, including enzyme purification and kinetics; gel exclusion, ion exchange; agarose gel electrophoresis; isolation of nucleic acids; and a special student-designed project. *Rohlman.*

**327** **Advanced Physical and Analytical Chemistry Laboratory** **(1/2)** **Spring: Learning Objective : 3 and 4**
Prerequisite: Chemistry 206 and 301. Prerequisite or corequisite: Chemistry 340.
An exploration of various areas of physical chemistry and advanced problems in analytical chemistry including thermodynamics, kinetics, spectroscopy, x-ray diffraction and quantum mechanics. In carrying out these experiments, students use UV/Vis, fluorescence, ICP, IR, and x-ray fluorescence spectrometers and gain experience with electroanalytical methods, vacuum lines, lasers and x-ray diffraction. Two four-hour laboratories per week. *Bieler, Lewis, Metz.*

**337** **Biochemistry** **(1)** **Spring: Learning Objective : 4**
Prerequisite: Chemistry 211 or permission of instructor.
An in-depth study of biochemical structure, catalysis, metabolism and cellular regulation. Understanding living systems through molecular and chemical models. Areas of emphasis include macromolecular structure, enzyme mechanisms and kinetics, metabolic mechanisms and regulation, genomics, and proteomics. Same as Biology 337. *Rohlman.*

**340** **Physical Chemistry** **(1)** **Spring: Learning Objective : 4**
Prerequisite: Permission of instructor. Normally a student is expected to have completed Chemistry 121, 123, 211, 212, 206 and 301 as well as 2 units of calculus and 2 units of physics. The microscopic or molecular basis for chemistry. Among the topics covered are the use of Schrodinger wave mechanics to examine the energies of atoms and molecules, including structure and chemical bonds; comparison of calculated energies with experimental values obtained from atomic and molecular spectroscopy; and the use of statistical mechanics to calculate thermodynamic variables and equilibrium constants. *Bieler, Lewis.*

**350** **Advanced Organic Chemistry** **(1/2)** **Fall: Learning Objective : 3 and 4**Prerequisites: Chemistry 211, 212.
Reinforces and extends the concepts introduced in Chemistry 211, 212 and introduces new concepts, reactions and molecular theories. Taught with one of two emphases: (1) the *synthetic* course extends understanding of organic reactions, introduces the most current synthetic organic methods and asks students to use their knowledge to propose syntheses of complex molecules; (2) the *physical/mechanistic* course includes topics such as aromaticity and models used to explain thermal and photochemical concerted reactions such as frontier orbital theory, Huckel-Mobius transition state theory and the conservation of orbital symmetry. Students in both courses are taught to read and understand the chemical literature, then write about and orally present the novel chemistry they have learned. *French, Harris, McCaffrey.*

**351** **Biophysical Chemistry** **(1/2)** **Spring: Learning Objective : 4**
Prerequisites: Chemistry 301, 337.
Examination of the physical chemistry of macromolecules in living systems. A study of thermodynamics, kinetics, ligand binding and spectroscopy related to the understanding of macromolecular structure and function. *Rohlman.*

**353** **Spectroscopy** **(1/2)** **Fall: Learning Objective :  4**Prerequisite: Chemistry 340.
General principles and theories of light absorption and emission at the molecular level, including the application of symmetry and group theory. Detailed applications to IR, Raman, microwave, UV-visible and radiofrequency spectroscopy (NMR, EPR). Additional topics chosen from X-ray crystallography, mass spectroscopy, photochemistry and Mossbauer spectroscopy. *Bieler, Lewis.*

**356** **Advanced Inorganic Chemistry** **(1/2)** **Spring: Learning Objective : 4**
Prerequisite: Permission of instructor. Normally a student is expected to have completed Chemistry 340. An advanced-level discussion of periodic properties, chemical bonding, and acidbase concepts with an emphasis upon the bonding and properties of transition metal complexes. *Bethune.*

**391, 392** **Internship** **(1/2, 1)** **Fall, Spring : Learning Objective : 4**
Offered on a credit/no credit basis. *Staff.*

**401** **Seminar** **(1/2)** **Fall, Spring** ***: Learning Objective : 4*** *Staff.*

**411, 412** **Directed Study** **(1/2, 1)** **Fall, Spring** **: Learning Objective : 3 and 4**

(Program components here)

**Step 4: Select methods/data sources and instruments (Due May 15, 2009)**

*...that you will use to gather information about whether expected outcomes and learning objective are being achieved. NOTE: You do not need to collect data from the same sources every year. Rather, some kind of assessment rotation will be sufficient (e.g., Years1 & 3, collect data from graduating seniors, Years 2 & 4 collect data from employers and alumni, etc.).*

**Learning Goal 1 – Content Knowledge: Key Concepts of Chemistry 121.**

*The student will have mastered key concepts of Stoichiometry, Equilibrium, Atomic and Molecular Structure and Acid – Base chemistry prior their entry into Chemistry 211.*

*In response to previous assessment, of 121 content, a computer-modeling component was added to to the121L in response to deficiencies found.*

In the past, to assess that the students are being prepared for entry into Chemistry 211, we identified questions on our Chemistry 121 final examinations which test material that will be used in the organic course (Chem. 211). The chosen questions covered the above areas and represented more than 50% of the exam. Performance on these questions relating to these key concepts, across the entire class, were tabulated every year. Mastery of this material was assumed by a score of 85% on these identified questions. Three years ago we changed textbooks from an in-house published book to a commercial textbook. This next year we plan to test our 121 students with a external standardized exam (Am. Chem. Soc. Gen. Chem. Exam) to assess their understanding of the key concepts of chemistry 121. We plan to do this both semesters in the coming year and every other year after that. This will allow us to see how our students compare to other students who take this exam.**We would like to see 50% of the Chemistry 121 students attain the 85% score indicating mastery of these concepts.**

Extensive data on enrollment patterns in chemistry in our department indicated that approximately 60% of students who take Chemistry 121 go on to take Chemistry 211. Student performance in 121 is a positive predictor of success in 211/212.

**Learning Goal 2 – Content Knowledge: Key Concepts of Chemistry 211/212.**

*The student will have mastered the key concepts of Chemical Bonding, organic nomenclature, stereochemistry, structure determination using NMR and IR Spectroscopy, specific organic chemical reactions, and reaction mechanisms upon completion of chemistry 211 and 212.*

Chemistry 211 and 212 are courses that are taken by both chemistry major and the numerous students seeking a pre-professional course of study (Medicine, dentistry, Vet-med). The numbers in chemistry 211 have grown every year for the past decade, so much so that in 2004 we added a tenure-track line to the Chemistry Department to allow us to offer three sections of 40 students in 211. Our assessment plan for 212 has been to periodically (Every year to every other year) administer the American Chemical Society Standardized Organic Exam; an exam given to graduates seeking a graduate work in organic chemistry. **We will continue this practice and seek for 50% of our students to receive a 50% on this exam. This represents the national mean for this exam.**

Presentation of course material will be adjusted to meet deficiencies in areas identified by these exams. The courses' content are limited by the presence of external examinations (GRE and MCAT) that our students take after completing organic chemistry. The expectations of these exams are high, so our expectations of our students must be equally high.

Additionally, in the fall of 2008, tablet PCs were introduced into one section of Chemistry 211 and 212. A formal assessment plan of this technology with respect to the learning goals as well as students’ attitudes about learning and the use of technology is ongoing. Faculty and staff from the Education Department (Kyle Shanton, Guy Cox) are performing these assessment rubrics in the absence of the instructor. Student responses will then be correlated to their academic performances on quizzes and tests. Interviews, both as a class and individually are being conducted by Shanton and Cox at intervals throughout the year, and in the event of course withdrawal. The results of this first year program have been diseminated at regional and national meetings. The use of tablets in beign expanded into one section of general chemistry and possibly into a second organci chemistry section.

**Learning Goal 3 –Research, Critical Thinking and Communication Skills**

*Our graduates will demonstrate a basic understanding of how to do research; to use the chemical literature, to identify a problem, design and carry out experiments, to analyze results and present research results. Students will demonstrate an ability to keep a professional laboratory notebook and write professional reports.*

Two courses specifically address the research goals: Chemistry 206 (Analytical Chemistry), and Chemistry 212 (Organic Chemistry II). In these classes, self-designed research projects are proposed, implemented, and the results presented at an end-of-semester poster session. Faculty evaluate the research proposals for originality and success potential, in addition to standard writing skills and content issues. Copies of proposals that prove to be successful will be kept. The research process itself is also critiqued by faculty, along with the final poster presentation. At this dissemination, students and departmental staff are asked to evaluate each others’ posters, along with all science faculty and staff. A standard assessment tool is used by all evaluators, which contains a place to identify the evaluator as student, faculty or staff. These are then used to assist the faculty in assigning a grade, in addition to assessing successful reaching of this learning goal. An example of the assessment device is attached.

Students are asked to do a number of different writing assignments such as lab reports, research proposals, critiques of literature papers, etc. In Chemistry 206, students are required to write lab reports at the same level of depth and breadth as found at a national lab (Argonne). In Chemistry 212 students are requires to submit a research proposal in a format similar to that of an external granting agency. Students learn through experience, what is necessary for success at these tasks. Rubrics will be used to appraise specific aspects of these various writing assignments such as using chemistry drawing software, spreadsheets, etc. Success can be measured in part by a passing grade on the research project assignment. In addition, oral presentations such as oral reports and poster presentations are an integral part of our curriculum. Peer and self assessment modalities will be used, in addition to traditional assessment methods to gauge successful demonstration of this goal.

All senior majors also take a capstone laboratory course, either Chemistry 323 (Advanced Lab: Biochemistry) or Chemistry 321 (Advanced Lab: Projects), or they do specific research with a faculty member which they write up as a Honors Thesis. We require that each major write up one project in either journal article, or thesis form. We expect that 90% of our majors will produce a paper or thesis of high quality (a grade of 3.0 or better). We also evaluate their laboratory notebooks. **Since we emphasize notebook keeping in all our introductory labs, we expect 90% of our students to meet equally high standards of notebook keeping. The papers, theses, and notebooks will be kept on file as a record.**

**Learning Goal 4 – Content Knowledge: Core Chemistry**

*Our graduates will have obtained knowledge of the basic core of chemistry and the professional skill set needed to be successful in postgraduate chemical endeavors. This would include graduate school in chemistry, professional employment as chemists, medical school, or other graduate programs with significant chemistry content.*

We survey our Alumni at graduation, at two years and five years after their graduation from Albion. We question them about their success in graduate school, professional schools, or on the job as professional chemists or scientists. We ask them if they think they have gained the necessary knowledge and preparation from their Chemistry major at Albion College for their post graduate courses or jobs. If they have been doing research, we ask them if they learned to write acceptable reports, keep adequate laboratory notebooks, and to present their research results.

**Step 5: Analyze and interpret the data (Due October 1, 2009 with preliminary data; due November 2, 2009 with final data for this assessment cycle)**

The data we have collected using previous rubrics, and our actions in regard to them is outlined below.

**Learning Goal 1 – Content Knowledge:  Key Concepts of Chemistry 121.**

*The student will understand key concepts of Reaction Stoichiometry, Equilibrium, Atomic and Molecular Structure and Acid – Base chemistry.*

Prior to 2006 the Chemistry Department was using an in-house published textbook for Chemistry 121. While this book was designed specifically for our 121 course, it was written in the 1980's and lacked color images and support materials (Web, CD, etc.).Given the plethora of new content available (web, CT, etc.) the department decided to make a change in textbooks, which it carried out in 2006. The Department took a 1-day retreat to Lansing during Spring Break and evaluated 20 or so Chemistry textbook and resource packages.  We adopted one textbook in 2006, piloted it for two years then tried a second in 2008.  We are completing the second year of this book and are continuing to collect data with regard to student learning.

In anticipation of the aforementioned change, the Department identified common questions that appeared on every final exam (since Spring 2003) and tested student competency in the key areas identified in our learning goals. During the past 7 years we have collected and analyzed the data each semester as a function of average score on each question. If we are able to achieve our learning goal (50% of all students passing these questions at 85% or higher) we should have a minimum average score of 42.5% on each of these questions. Under this criterion, we have achieved our learning goal in all content areas since Fall 2006, when we adopted a new textbook.

As a department, however, we have recently decided that this approach does not provide us with specific enough information (e.g., the actual number of students achieving the desired threshold) to direct pedagogical decision-making and strategic planning for Chemistry 121. Since it is based on the law of averages, we cannot determine if we have actually achieved 50% of all students attaining 85% or higher from 100% of students attaining 42% or higher.Therefore, we are currently in the process of collecting the raw data from recent years so that a more complete statistical analysis can be completed. At this time we are anticipating that at least 50% of our 121 students to score competency on the key concepts listed above.

We are also planning on having our students take a standardized General Chemistry final exam so that we 1) can have a more complete quantitative assessment of our student competency, and 2) can compare ourselves to students outside of Albion.  Our learning goal will NOT change based on the collected results. If any deficiencies in student learning are discovered, such that we do not achieve our learning goals, we hope to try new approaches to teaching these core areas that will increase our students learning of them.

**Learning Goal 2 – Content Knowledge: Key Concepts of Chemistry 211/212.**

*The student will have mastered the key concepts of Chemical Bonding, organic nomenclature, stereochemistry, structure determination using NMR and IR Spectroscopy, specific organic chemical reactions and mechanisms, upon completion of chemistry 211 and 212.*

We have periodically given the ACS Organic Chemistry final as described above.  Typically this happens every other year. In the past three years we have given it every Spring. Our student performance on this exam has improved over the past decade. We are at or above the national average of this exam. We are very happy with where we are at with respect to Organic chemistry content understanding. In the coming year we will continue to give the ACS-organic exam on a yearly basis.  Providing the data to support the statement about students at or above the national average is necessary.

**Learning Goal 3 – Research, Critical Thinking and Communication Skills**

*Our graduates will demonstrate a basic understanding of how to do research; to use the chemical literature, to identify a problem, design and carry out experiments, to analyze results and present research results. The student will demonstrate an ability to communicate in the language of chemistry; to keep a professional laboratory notebook and write professional reports.*

We have collected and analyzed our data with regard to this learning goal.  In Chemistry 206 100% of students in the past year completed this goal successfully.  95% of our students were successful in completing their research project.  I'm not sure to which set of students this applies.  If 100% of 206 students can do this, which ones can't? We did find a few shortcomings in our students in the second year (Organic) of chemistry (212).  We find that roughly 50% of our students fail to keep a complete research notebook and to write acceptably after the first semester of organic chemistry.  This number decreases significantly in the second semester. We also see a significant lack of understanding on how to use column chromatography as a way to purify compounds, a fundamental aspect of organic research.  In an effort to place less responsibility on the analytical class for good report writing and notebook keeping, the faculty in organic will be making adjustments this coming year to increase the number of laboratory reports and will spend a full laboratory period on column chromatography.  Great!!!

**Learning Goal 4 – Content Knowledge: Core Chemistry**

*Our graduates will have obtained knowledge of the basic core of chemistry and the professional skill set needed to be successful in postgraduate chemical endeavors.  This would include graduate school in chemistry, professional employment as chemists, medical school, or other graduate programs with a significant chemistry content.*

Our graduates are well-satisfied, according to their self assessment at zero, two, and five years post graduation. Data?  They continue to place into outstanding graduate and professional positions. Data? We are planning on using an external assessment device to better evaluate our students core knowledge of chemistry; The ACS's **DUCK08** – The 2008 Diagnostic of Undergraduate Chemistry Knowledge. Designed for use at the end of an undergraduate chemistry major, this exam will be given at the end of the spring semester to all seniors and will provide much needed quantitative data in assessing Learning goals 1, 2 and 4. Excellent idea!

**Step 6: How will the data collected be used for decision-making, strategic planning, etc. (Due October 1, 2009 with preliminary data; due November 2, 2009 with final data for this assessment cycle)**

The Chemistry department has continued to use its assessment results to evaluate and make changes to its pedagogy with respect to our learning goals.  With the implementation of American Chemical Society Standardized rubrics -what are these?  the standardized tests? - in place, the department will use them to critically evaluate what and how we bring the curriculum to our students.

Chemistry 121 is a unique course in the Chemistry department. Recognized as the entryway to all higher level chemistry courses in our department, *all* members of the chemistry faculty have equal rights with respect to input on the structure, content and direction of the course. Additionally, *all* faculty members have taken active teaching roles in the lecture and laboratory sections of this course. As a result of this shared departmental ownership, any desired change to the course, lecture or lab, is proposed to all faculty members in the Chemistry department, discussed and decided on collectively.

As discussed in Step 5, our current assessment data is insufficient to currently base any critical decision. We are working on reanalyzing raw data from recent years in hopes of obtaining a more quantitative description of our student learning. Additionally, we are planning on changing the way we perform assessment to achieve more quantitative results in the future. We are planning on having our students take a standardized General Chemistry final exam so that we might have data regarding both our students learning and how they compare to students outside of Albion, and anticipate our students to be within one standard deviation of the national norm.

In the event that any deficiencies are identified in student learning, we will meet as a department to discuss the data and to propose courses of action, which could range from changing the course curriculum, the curriculum order, or the pedagogical approaches to teaching. Once a suitable course of action is collectively decided, it will be implemented the following semester.

Additionally, with regard to Learning goals 2 - 4, and as described in Section 5, we will give the American Chemical Society's DUCK08 Exam to all graduating seniors.  This assessment will give us quantitative measures of every Chemistry major that graduates from Albion College.  Once data is collected over a period of a couple of years, we will have a good picture of what our students come away with, with respect to chemistry knowledge and skills.