2012-2013 Annual Program Assessment Report

Please submit report to your department chair or program coordinator, the Associate Dean of your College and the assessment office by Monday, September 30, 2013. You may submit a separate report for each program which conducted assessment activities.

College: **Science and Mathematics**

Department: **Chemistry and Biochemistry**

Program: **Chem BA, BS; Biochem BS, MS**

Assessment liaison: **Thomas Minehan**

1. **Overview of Annual Assessment Project(s).** Provide a brief overview of this year's assessment plan and process.

The following assessment activities were planned for this year:

a. **Assess basic knowledge in general, organic, inorganic, analytical and biochemistry (SLO1) using standardized exam questions in course finals.**
b. **Review evidence pertaining to the effectiveness of a curricular change to improve student learning: implementation of mandatory discussion sessions for Chemistry 333 (Organic Chemistry 1).**
c. **Review evidence pertaining to SLO2m: Organize and communicate scientific information clearly and concisely, both verbally and in writing.**
d. **Develop a signature assignment for longitudinal assessment to be given students in Chem 102 (gateway course) and Chem 495 (capstone course)**

2. **Assessment Buy-In.** Describe how your chair and faculty were involved in assessment related activities. Did department meetings include discussion of student learning assessment in a manner that included the department faculty as a whole?

Assessment activities and plans for assessment were discussed at departmental meetings on a regular basis, with the majority of faculty receptive to active participation in gathering and analyzing assessment data related to our program learning

outcomes. In addition, many of our department faculty also contributed to the development of a signature assignment for longitudinal assessment of student learning.

3. **Student Learning Outcome Assessment Project.** Answer items a-f for each SLO assessed this year. If you assessed an additional SLO, copy and paste items a-f below, BEFORE you answer them here, to provide additional reporting space.

3a. Which Student Learning Outcome was measured this year? SLO 1: Assess basic knowledge in the following areas of chemistry: general chemistry, organic chemistry, biochemistry, analytical chemistry, inorganic chemistry, and physical chemistry

3b. Does this learning outcome align with one or more of the university's Big 5 Competencies? (Delete any which do not apply)

- **Critical Thinking**
- **Quantitative Literacy**

3c. Does this learning outcome align with University's commitment to supporting diversity through the cultivation and exchange of a wide variety of ideas and points of view? In what ways did the assessed SLO incorporate diverse perspectives related to race, ethnic/cultural identity/cultural orientations, religion, sexual orientation, gender/gender identity, disability, socio-economic status, veteran status, national origin, age, language, and employment rank? N/A

3d. What direct and/or indirect instrument(s) were used to measure this SLO? Multiple choice questions taken from standardized American Chemical Society exams in general, organic, inorganic, and biochemistry embedded in course final exams were the instruments used to measure this SLO. In Chem 102 (61 students) and Chem 333 (55 students), the entire ACS exam in General or Organic Chemistry was administered on the last day of class. In another section of Chem 333 (36 students), 5 questions from the ACS exam in Organic Chemistry were embedded in the course final exam. In Chem 334 (109 students), 10 questions from the ACS exam in Organic Chemistry were embedded in the course final exam. One-half (25 questions dealing with topics emphasized in the course) of the ACS Analytical Chemistry exam was given in CHEM 321 (47 students) as an in-class graded review exercise for the final exam in this course. In Chem 401 (41 students), 11 questions from the ACS exam in Inorganic Chemistry were embedded in the course final exam. In Chem 461 (35 students) Chem 462 (27 students) and Chem 464 (43 students), 6 questions from the ACS exam in Biochemistry were embedded in the course final exam.

3e. Describe the assessment design methodology: For example, was this SLO assessed longitudinally (same students at different points) or was a cross-sectional comparison used (Comparing freshmen with seniors)? If so, describe the assessment points used.

A cross-sectional design methodology, in which freshman (Chem 102) are compared with sophomores/juniors (Chem 333, 334) and seniors (Chem 401, 461, 462, 464), was used:
General Chemistry: Chem 101 and Chem 102 are our gateway courses taken by both majors and non-majors, and are typically populated by students in the first year of required chemistry courses for their major. The foundational concepts introduced in these courses are crucial for student success in all subsequent courses in the major. Thus, assessment at this introductory stage will allow us to establish a baseline level of student performance useful for comparison with assessments done in later courses in our undergraduate program.
Organic Chemistry and Analytical Chemistry: the majority of our majors take Chem 321, Chem 333 and Chem 334 after completion of Chem 102. Assessment in these courses may provide information on how well our students retain fundamental concepts and apply foundational principles as they progress through the program.
Inorganic Chemistry (Chem 401) and Biochemistry (Chem 461, 462/L and Chem 464): for the chemistry and biochemistry seniors who typically make up a significant portion of the students in Chem 401, Chem 461, Chem 462 or Chem 464. These classes tend to be one of the last courses taken by our majors, and thus assessment in these classes may provide information on how our students have been able to both understand and apply the fundamental chemical concepts they have learned throughout the program.

3f. Assessment Results & Analysis of this SLO: Provide a summary of how the results were analyzed and highlight findings from the collected evidence.

General Chemistry: 11 out of 61 students achieved a score of 50th percentile (41/70) or higher, which represents 18% of the class. The class average was 33/70, which is 25th percentile. From this particular assessment it appears that most of our students are performing below the national average. Further data from the administration of the entire ACS general chemistry exam need to be collected, but these preliminary results suggest our students need more help in achieving the benchmark level of proficiency in general chemistry.

Analytical Chemistry: In CHEM 321, the class average on the 25 ACS exam questions was 51.0% compared to the national average of 52.6% on these same questions. This suggests that CHEM 321 students are performing at a level comparable to that of students in analytical chemistry courses across the nation.

Organic Chemistry: In Chem 333, 8 out of 66 students achieved a score of 50th percentile (41/70) or higher, which represents 12% of the class. The class average was 29/70, which is 18th percentile. These results suggest our students are performing well below the national average and need more help in achieving the benchmark level of proficiency in organic chemistry. Although the majority of students in Chem 333 are not Chem/Biochem majors, these results still suggest our students are having difficulty extrapolating concepts they learn in the course to questions they haven't specifically studied for, which represents a weakness in critical thinking ability.

Another Chem 333 instructor (in Spring 2013) used 5 ACS Organic Chemistry exam questions on the course final. With a benchmark of 2.5/5 or more correct, only 39% of students in a class of 36 achieved the benchmark level of performance.

In one section of Chem 334, 23 out of 59 students achieved the benchmark level of performance (7/10) or higher, which represents 39% of the class. In a separate section of Chem 334, 25 out of 50 students (50%) achieved a benchmark of 5/10 or more correct. All of these data consistently and strongly point to a need to help students in organic chemistry with critical thinking skills.

Inorganic chemistry: 15 out of 41 students (37%) achieved the benchmark level of performance (7/10 or more correct) for the assessment. As with the above results for Chem 334, these data involve a small subset of ACS exam questions and may point to the necessity of administering a larger subset of the ACS exam or the entire ACS exam.

Biochemistry: In Fall 2012 Chem 461, 12 out of 35 students (34%) achieved the benchmark level of performance (3/6 or more correct) for the assessment. For Spring 2013 Chem 462, 8 out of 27 students (27%) achieved the benchmark. For Spring 2013 Chem 464, 11 out of 43 students (26%) achieved the benchmark, which was a slight improvement over the performance for Spring 2012, in which 10 out of 43 students (23%) achieved the benchmark for the set of 6 assessment questions.

In Spring 2013 Chem 462L, 4 out of 15 students (27%) achieved the benchmark level of performance (45/50) on an assessment laboratory report question. Compared to Spring 2011 Chem 462L, where 6 out of 8 students (75%) achieved the benchmark level of success on the same laboratory report question, fewer laboratory students are currently achieving the expected standard in biochemistry. Although further data need to be collected, these data may suggest a benefit of having smaller class sizes for Chem 462L.

3g. Use of Assessment Results of this SLO: Describe how assessment results were used to improve student learning. Were assessment results from previous years or from this year used to make program changes in this reporting year? (Possible changes include: changes to course content/topics covered, changes to course sequence, additions/deletions of courses in program, changes in pedagogy, changes to student advisement, changes to student support services, revisions to program SLOs, new or revised assessment instruments, other academic programmatic changes, and changes to the assessment plan.)

The problem of student performance in organic chemistry has been highlighted in previous assessments and has prompted the departmental assessment and curriculum committees to propose the creation of a mandatory problem-solving session Chem 333D to accompany the Chem 333 lecture course. This course was implemented for the first time in Spring 2013 (vide infra). One suggestion to even further improve student performance in organic chemistry is to incorporate an online lecture component, so that more class time may be spent in problem solving activities, which are crucial for the development of critical thinking skills important for student performance both on course exams and standardized ACS exams. Such a strategy may also be implemented in general chemistry.

A detailed analysis of the analytical chemistry results indicates that CHEM 321 students performed significantly worse than the national average on two questions dealing with basic stoichiometric calculations. This may be the result of many students taking CHEM 321 after a break of several semesters since having had general chemistry where this skill was developed. This has prompted a more thorough review and emphasis of this topic in CHEM 321.

For inorganic chemistry, what is very concerning about the results is that the percentage of students achieving the benchmark level of performance is much lower than it was in the spring semester of 2011, when 25 out 46 students (54 %) gave 7 or more correct answers to the same set of questions. Considering that the same material was covered and the same pedagogy used in Chem 401 during the spring 2011 and spring 2013 semesters, this could reflect a shift in the quality of the students and/or their preparation in lower division courses. We will need to continue to assess student basic knowledge in inorganic chemistry to determine whether or not this may be the beginning of a trend. Altogether, this underlines the importance of continuous assessment of our curriculum.

For biochemistry, the results of assessment in Chem 462L seem to suggest that there may be some pedagogical benefit in having smaller class sizes. Further collection of assessment data in this and other biochemistry lab courses over multiple semesters will be needed in order to confirm that this is indeed the case. If so, the department may consider enrollment limits in these courses to facilitate student learning.

3. Student Learning Outcome Assessment Project. Answer items a-f for each SLO assessed this year. If you assessed an additional SLO, copy and paste items a-f below, BEFORE you answer them here, to provide additional reporting space.

3a. Which Student Learning Outcome was measured this year? SLO 2m: Organize and communicate scientific information clearly and concisely, both verbally and in writing

3b. Does this learning outcome align with one or more of the university's Big 5 Competencies? (Delete any which do not apply)

- **Oral Communication**

3c. Does this learning outcome align with University's commitment to supporting diversity through the cultivation and exchange of a wide variety of ideas and points of view? In what ways did the assessed SLO incorporate diverse perspectives related to race, ethnic/cultural identity/cultural orientations, religion, sexual orientation, gender/gender identity, disability, socio-economic status, veteran status, national origin, age, language, and employment rank? N/A

3d. What direct and/or indirect instrument(s) were used to measure this SLO? The department has an established oral presentation rubric for evaluating final oral presentations in upper division courses, as well as formal graduate student thesis and literature presentations. Categories in this rubric include organization, understanding of scientific content, style/delivery, use of visual aids, and ability to answer questions.

3e. Describe the assessment design methodology: For example, was this SLO assessed longitudinally (same students at different points) or was a cross-sectional comparison used (Comparing freshmen with seniors)?

SLO2m was implemented to assess oral and written communication abilities of students in our MS program.
Environmental Chemistry (Chem 541) is a 3-unit, graduate-level course typically populated by MS students and advanced undergraduate students. For graduate students, this course is typically taken before the graduate literature presentation and well before the oral thesis defense. As such, it serves as an early check of students' scientific communication skills in the MS program.

(For undergraduate students, this course serves as an upper division elective course for Chemistry and Biochemistry majors. Undergraduates taking this course should thus be performing at the mastery level with respect to our BA/BS SLO2. For Spring 2013, 19 students were enrolled in Chem 541, of which 16 were graduate students and 3 were undergraduate.

Graduate students giving literature seminars (Chem 691) are at (approximately) the half-way mark in their progress towards the master's degree; they have taken several upper division courses, some or most of which require in-class oral presentations. Graduate students giving their thesis seminar (Chem 692) have completed all required graduate coursework as well as experimental work. Thus, it is hoped that the sequential evaluations of literature and thesis seminars for individual students will allow an evaluation of the growth of a student's oral communication abilities. A total of twenty-five students presented seminars (14 literature and 11 thesis presentations) for the 2012-2013 academic year.

3f. Assessment Results & Analysis of this SLO: Provide a summary of how the results were analyzed and highlight findings from the collected evidence.

For Chem 541, students were required to give a 10-minute oral presentation about a topic relevant to the course based on the scientific literature. The department-wide rubric for student presentations was used to evaluate student presentations, and the scores obtained contributed to the students' overall course grade; a total of 10 points was assigned to each rubric category, so overall the presentations were worth a total of 50 points. The average score for the class was 46.9/50 (93.8%), and the breakdown of scores by rubric category is informative: organization, average score=7.0/10; understanding of scientific content, average score=8.6/10; style/delivery, average score=8.1/10; use of visual aids, average score=8.2/10; and ability to answer questions, average score=8.3/10. From these data it appears that our students overall are doing quite well relative to department standards, where the benchmark level of performance for all categories is 75%. It was found that students were performing below the benchmark in one category, organization, which is related to the time they took to deliver their presentation (many students exceeded the allotted time). Organizational skills may be improved for students by emphasizing practicing their talk in front of classmates/colleagues before giving the formal presentation. However, relative to the results for a similar oral presentation required in Chem 522 (Advanced Analytical Chemistry) from Spring 2012, the students in Spring 2013 have improved significantly in the category of understanding of scientific content.

For the literature and thesis seminars, the same scoring rubrics were used with the same five categories: organization, understanding of scientific content, style/delivery, use of visual aids, and ability of answer questions, and performance in each category could be rated with a score of 0-20 points. The rubric provided descriptions for excellent (16-20 points), good (11-15 points), marginal (6-10 points), and inadequate (0-5 points) performance. Faculty attending the seminars filled out the rubrics and forwarded them to the seminar coordinator. The seminar coordinator tabulated the results for each category and an average

score for literature seminars and thesis seminars was obtained. Since the 2011-2012 academic year was characterized by a very low number of seminar presentations (3 total), the current results are being compared to the 2010-2011 academic year, in which 15 seminars were presented (7 literature and 8 thesis). Results (average scores provided): 2010 - 2011 (including summer 2011, 15 seminars total): organization, 18.2 (literature seminars) and 18.0 (thesis seminars); understanding of scientific content, 17.8 (literature seminars) and 17.0 (thesis seminars); style and delivery, 17.6 (literature seminars) and 17.5 (thesis seminars); use of visual aids, 17.3 (literature seminars) and 17.4 (thesis seminars); ability to answer questions, 16.6 (literature seminars) and 16.4 (thesis seminars). 2012 - 2013 (including summer 2013, 25 seminars total): organization, 17.8 (literature seminars) and 18.5 (thesis seminars); understanding of scientific content, 17.4 (literature seminars) and 17.6 (thesis seminars); style and delivery, 16.5 (literature seminars) and 17.8 (thesis seminars); use of visual aids, 16.9 (literature seminars) and 17.9 (thesis seminars); ability to answer questions, 16.9 (literature seminars) and 17.1 (thesis seminars)

As can be seen, the overall scores for literature seminars decreased during 2012-2013 compared to 2010-2011, but the thesis seminar scores increased across the board. The results indicate that, on the whole, the graduate students are doing well in their oral seminars, since the average scores in most categories are in the 17-18 range. The weakest category in general is the ability to answer questions, with average scores ranging from 16.4-17.1. In the past this has been attributed to a lack of depth of scientific understanding on the part of the student; however, average scores on the understanding of scientific content category (17.8-18.2) do not necessarily corroborate this idea.

Another, perhaps more helpful, way to assess student performance is to determine whether the quality and content of the students' seminars improve between their literature seminar presentation and their thesis seminar. Survey of results from students who defended their theses in 2012-2013: organization, 17.9 (literature seminars) and 18.5 (thesis seminars); understanding of scientific content, 17.3 (literature seminars) and 17.6 (thesis seminars); style and delivery, 16.7 (literature seminars) and 17.8 (thesis seminars); use of visual aids, 17.1 (literature seminars) and 17.9 (thesis seminars); ability to answer questions, 16.8 (literature seminars) and 17.1 (thesis seminars).

These data show that the graduate students who presented their thesis seminars over the past year showed definite improvement in the quality of their presentation compared to their literature seminars (which were presented at least one semester prior to their thesis seminar) in all evaluation categories. In particular, the average score for style and delivery increased by 1.1 points, which is a very large margin. This suggests that the feedback given to the students after their literature seminars is helping the students focus in on some of their weaknesses and make efforts to improve them for their thesis seminars. Several students in particular showed significant overall improvement: in some cases they scored 10-14% higher overall on their thesis

seminar compared to their literature seminar.

3g. Use of Assessment Results of this SLO: Describe how assessment results were used to improve student learning. Were assessment results from previous years or from this year used to make program changes in this reporting year? (Possible changes include: changes to course content/topics covered, changes to course sequence, additions/deletions of courses in program, changes in pedagogy, changes to student advisement, changes to student support services, revisions to program SLOs, new or revised assessment instruments, other academic programmatic changes, and changes to the assessment plan.)

Based on the results from the 2010-2011 academic year, we have:
1.) Advised that students practice their literature and thesis seminars before one or two faculty members who can provide questions and feedback prior to their actual presentation may also improve their ability to answer questions.
2.) Advised that students meet with their faculty advisor(s) immediately after their literature seminar for helpful hints on how to improve their oral presentation skills for the thesis seminar. As described above in section 3f, these suggestions seem to be helping students in terms of improving their preparation for thesis seminar. These practices will be continued and emphasized by both the seminar coordinator and supervising faculty.

4. Assessment of Previous Changes: Present documentation that demonstrates how the previous changes in the program resulted in improved student learning. **We have implemented mandatory discussion (recitation) sessions for Chemistry 333 (Organic Chemistry 1) in the Spring of 2013, responding to previous assessment data suggesting that students attending problem solving sessions in addition to lecture performed better in the course than students who did not attend such sessions. With only two semesters of data so far, the results are encouraging: For one of our instructors, in Fall 2012 Chem 333 with optional Chem 333R, the class D/F percentage was 31%, while for Summer 2013 Chem 333 with mandatory Chem 333D, the class D/F percentage was only 9%! For another instructor, in Spring 2012 Chem 333 with optional Chem 333R, the class D/F percentage was 60%, while for Spring 2013 Chem 333 with mandatory Chem 333D, the D/F percentage was 42%. These preliminary results are quite positive and encourage the department faculty to find ways to implement mandatory discussion sessions for other courses such and Chem 334, Organic Chemistry II.**

5. Changes to SLOs? Please attach an updated course alignment matrix if any changes were made. (Refer to the Curriculum Alignment Matrix Template, http://www.csun.edu/assessment/forms_guides.html.) N/A

6. Assessment Plan: Evaluate the effectiveness of your 5 year assessment plan. How well did it inform and guide your assessment work this academic year? What process is used to develop/update the 5 year assessment plan? Please attach an updated 5 year assessment plan for 2013-2018. (Refer to Five Year Planning Template, plan B or C, http://www.csun.edu/assessment/forms_guides.html.)

We are currently on schedule with our five-year plan, starting the third year of the five-year cycle. This year we were to assess SLO1, and thus assessment data from as many courses in our program as possible were obtained. We have been assessing SLO1 on a yearly basis, since volumes of assessment data are generated each semester from the use of ACS exam questions. Revisions to the 5-year plan will be discussed at future departmental meetings, and the suggested plan for 2013-2018 is attached.

7. Has someone in your program completed, submitted or published a manuscript which uses or describes assessment activities in your program? Please provide citation or discuss. N/A

8. **Other information, assessment or reflective activities or processes not captured above.**

We are in the process of developing a signature assignment for longitudinal assessment of student learning. We are collecting appropriate questions from each subdivision of chemistry (physical, organic, analytical, inorganic and biochemistry) to include in an assignment that will be administered to students via Moodle at the end of general chemistry (Chem 102, one of our gateway courses) and then again in Chem 495/499 (our capstone courses). We are also adapting our established written assignment rubric for the evaluation of our signature assignment. See attached the questions obtained so far in general, organic, physical, inorganic, and biochemistry for the signature assignment.

Program Assessment Plan, 2013-2018

Department/Program: ____Chemistry and Biochemistry_______________________

Option: ___BS Chemistry, BS Biochemistry, BA Chemistry____________________

Assessment Activity Outcomes to be assessed, data analysis, assessment plan review	**Time Period**	**Direct Measures** Describe student work to be used to provide evidence for outcome	**Indirect Measures** Describe instrument: survey, interview	**Where will evidence be gathered?** Course name, internship, etc	**What results would indicate success?** What is the target?	**Status**
SLO 1: Demonstrate basic knowledge in the following areas of chemistry: analytical, biochemistry, inorganic, organic, physical.	2017-2018	Final exam M/C questions from ACS standardized exams in organic, inorganic, physical, analytical, and biochemistry		Chem 333/4 Chem 401, Chem 321, Chem 461/2, Chem 351/2	Performance at or above national average for the standardized exam questions	In progress
SLO 2: Organize and communicate scientific information clearly and concisely, both verbally and in writing.	2016-2017	Independent project/classroom oral presentation and written report; evaluated with an appropriate rubric		Chem 422L, Chem 411, Chem 433, Chem 495, Chem 499	Performance at the “good” or “excellent” levels for all rubric evaluation categories (≥60/100)	In progress
SLO 3: Effectively utilize the scientific literature, including the use of modern electronic search and retrieval methods, to research a chemistry topic or to conduct chemical research.	2016-2017	Final research report/literature review; evaluated with a written report rubric		Chem 495, Chem 499	Performance at the “good” or “excellent” levels for all rubric evaluation categories (≥60/100)	In progress
SLO 4: Work effectively and safely in a laboratory environment, including the ability to follow experimental chemical procedures and maintain a proper lab notebook.	2013-2014	Lab notebook reviews in Chem 101/2L, Chem 321L, Chem 333/4L, Chem 422L, Chem 411, Chem 401L; performance on lab safety quiz; evaluation with a lab notebook rubric; annual monitoring of Department accident reports		Chem 321L, Chem 422L, Chem 411; Chem 101L, Chem 333/4L, Chem 422L, CHem 401L	Performance at the “good” or “excellent” levels for all rubric evaluation categories (≥15/20); Scores of ≥4/5 on lab safety quiz	In progress
SLO 5: Effectively utilize modern chemical instrumentation to obtain data and perform research.	2014-2015	Experimental results in Chem 411, Chem 433, Chem 495		Chem 411, Chem 433, Chem 495	≥4/5 unknowns correctly identified in Chem 433 and Chem 411; quality of spectra obtained in Chem 495 (assessed in written report rubric)	Future assessment
SLO 6: Perform qualitative and quantitative chemical analysis.	2013-2014	Experimental results in Chem 321L, Chem 422L		Chem 321L, Chem 422L	average of 80% score on quantitative unknowns in Chem 321L	Future assessment
SLO 7: Describe the impact of chemistry on our world, including the environment, the economy, and medicine.	2015-2016	A writing assignment on the chemical implications or on how chemistry is impacting a field. Evaluated with an appropriate assignment rubric		Chem 101/2, Chem 333/4; Chem 401; Chem 499	Performance at the “good” or “excellent” levels for all rubric evaluation categories (≥60/100)	Future assessment
SLO 8: Demonstrate an ability to determine the scientific validity of a claim that pertains to consumer products, the environment or the life sciences.	2015-2016	Set of appropriate multiple-choice questions.		Chem 101L, Chem 495, 499	≥75% of multiple choice questions answered correctly	Future assessment

Curriculum Alignment: Resources for Assessment

In which courses or activities is relevant information covered?

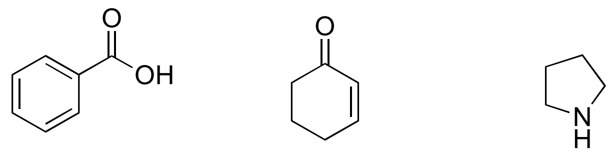
Which courses or activities provide student learning opportunities for the program learning outcome?

Specify whether the material is (I) introduced, (D) developed or (M) mastered.

Department/Program Courses	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8
Chem 101/D/L	I			I			I	I
Chem 102/D/L	I			I			I	
Chem 321/L	I			D	I	I		
Chem 422/L	D	D	D	D	D	D		
Chem 333/D/L	I			D			D	
Chem 334/L	D			D			D	
Chem 351/L	D		D	D				
Chem 352/L	D		D	D				
Chem 401/L	D	D		D			M	D
Chem 411	M	D	D	M	M	M		
Chem 433	M	M	M	M	M	M		
Chem 461	D	D	D					
Chem 462	M	M	M					
Chem 464	D	M	M					
Chem 465	M	M	M					
Chem 495	M	M	M	M				
Chem 499	M	M	M				M	M

Signature Assignment

1. You are given a separatory funnel, diethyl ether, 1M HCl solution, 1M NaOH solution, a saturated aqueous NaHCO3 solution, and a diethyl ether solution containing the following three compounds. Using the technique of extraction, describe how you would accomplish separation of each component of the mixture into a separate flask as a solution in diethyl ether.



A B C

2. The major component of corals is calcium carbonate ($CaCO_3$). Calcium carbonate (limestone) is very insoluble in pure water but will readily dissolve in acid according to the reaction:

$$2HCl\,(aq) + CaCO_3(s) \rightarrow Ca^{2+}\,(aq) + CO_2(g) + H_2O + 2Cl^-\,(aq)$$

In an experiment, 0.500 g of coral is completely dissolved in 10.00 mL of 1.00 M HCl. With access to a solution of 0.100 M NaOH and the indicator phenolphthalein, describe how you would use the technique of titration to find the weight percent of $CaCO_3$ in the coral. Assume that $CaCO_3(s)$ is the only component of the coral that reacts with aqueous HCl.

3. Explain the following observation: Most enzymes are globular water-soluble proteins, yet most enzyme-catalyzed reactions by those enzymes occur in non-aqueous environment.

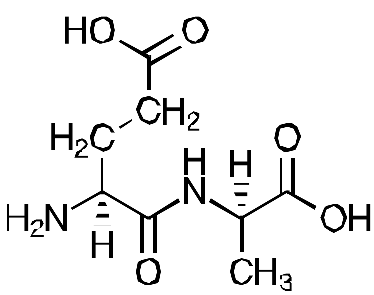
4. What experimental criteria can be used to determine allosteric regulation? What is the reason that oxygen uptake and delivery by hemoglobin are allosterically regulated and how is it that carbon monoxide wipes out the activity of hemoglobin in a single step. Why is it that hemoglobin can handle carbon dioxide so much better than carbon monoxide?

Useful Information

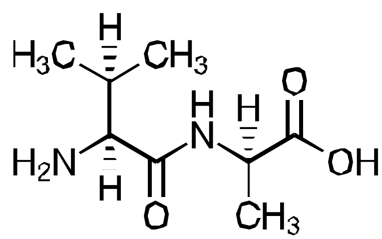
Group	pKa
Arg Sidechain	12.5
Asp Sidechain	3.7
Glu Sidechain	4.3
Lys Sidechain	10.5
His Sidechain	6.0
Peptide Amine Group	8.0
Peptide Carboxylate Group	3.4

a. In the two dipeptide structures shown below, circle the groups that would be ionized at physiological pH (pH=7.4).

b. In the structures below, mark the charge that would exist on each ionized group at pH = 7.4.



(1) Glu-Ala



(2) Val-Ala

c. What is the overall charge on peptide #1 at pH = 7.4? ____________________

d. What is the overall charge on peptide #2 at pH = 7.4? ____________________

e. You are given a solution that contains a mixture of the two dipeptides (1) Glu-Ala and (2) Val-Ala. In addition, you have access to an anion exchange chromatography column, a cation exchange chromatography column, a pH=7.4 buffer, a pH=4 buffer, a pH=9 buffer, and a chromatography system with fraction collector. Describe how you would separate the two dipeptides into separate flasks using chromatography.

5. An emission line in the Lyman (ultraviolet) series of the hydrogen atom spectrum has a wavelength of 9.50×10^{-8} m. It results from an electronic transition in which an electron originates in an excited (higher) energy level, gives up a photon during the transition, and ends up in the ground state (n = 1). What is the value of n associated with the excited level?

Use the Rydberg constant, $R=1.097 \times 10^{7}$ m^{-1}

6. Consider the following molecule: H_2.

a) Describe the H-H bond using Lewis theory. Include a drawing of the Lewis structure of H_2.
b) Describe the H-H bond using valence bond theory. Include a drawing of the valence bond picture of H_2.
c) Describe the H-H bond using molecular orbital (MO) theory. Draw a MO energy diagram including all appropriate labels and information. Sketch of the shape of molecular orbitals.
d) Using your response in 4c), explain how a transition metal can be used to activate H_2 (discuss two different modes of activation).
e) Give the definition of a catalyst.
f) Give two examples of homogeneous catalysts and processes that involve H_2 activation.
g) Give two examples of heterogeneous catalysts and processes that involve H_2 activation.