II. Assessment

BS/BA Chemistry and Biochemistry Programs

A. Program Learning Outcomes

The Undergraduate Program Learning Outcomes (PLOs) are as follows:

Students graduating with a BS /BA degree in Chemistry or Biochemistry will be able to:

1. demonstrate knowledge in the various areas of chemistry, including inorganic chemistry, analytical chemistry, organic chemistry, physical chemistry, and biochemistry.
2. work effectively and safely in a laboratory environment to perform experimental procedures and operate modern chemical/biochemical instruments.
3. use quantitative reasoning to analyze chemical problems and evaluate chemical data.
4. write and speak clearly on chemical or biochemical issues.
5. work collaboratively in teams to solve chemical problems.

B. Program Learning Outcomes Assessed

We have gathered data to assess PLO 2, use quantitative reasoning to analyze and solve chemical problems and evaluate chemical data.

C. Summary of Assessment Process

Data were collected in Chem 332 (Organic Chemistry II) and Chem 352 (Physical Chemistry II), a standardized national exam in the case of Chem 332, and embedded questions in the final exam. As this is the first time (at least in some time) that Chem 352 data was collected, these data will provide a baseline for future assessments of the course.

D. Summary of Assessment Results

Chem 332 – Organic Chemistry II

Organic Chemistry II is a required course for all of our undergraduate degree programs. It is also an important service course in many life-science-related programs.

Student Learning Outcomes

The student learning outcomes (SLOs) for CHEM 331 and CHME 332 are that at the successful completion of the yearlong sequence of courses, students should be able to:

1. predict bonding, nomenclature, chemical properties and some physical properties of organic compounds if the molecular structure is known.
2. identify common organic functional groups and show a knowledge of the chemistry and reactivity of each functional group.
3. use the results of the common spectroscopic methods (NMR, IR, and mass spectroscopy) to determine the structures of simple organic compounds.

4. know and understand the common reaction mechanisms of organic reactions, and indicate the mechanism and type of intermediate involved in the reactions.
5. safely carry out standard laboratory techniques for the purification of organic compounds, including distillation, recrystallization, column chromatography, thin layer chromatography, and extraction.
6. measure the infrared spectrum of an unknown solid or liquid and be able to identify the functional groups present.
7. carry out standard functional group transformations of organic compounds, and isolate and characterize the resulting products.

Modifications to Assessment due to Covid-19

Due to COVID-19 and the University's conversion to on-line courses during the Spring semester, the capstone lab project was not able to be completed. This is where the laboratory portion of the course (SLOs 5, 6, and 7) is normally assessed. Therefore, for this year, only the lecture portion and SLOs 1, 2, 3, and 4 were assessed.

Course Assessment

The assessment was conducted by evaluating questions from the Final exam. Four questions from the exam which measured each of the SLOs (1-4) were selected. There were four Chemistry majors and seven Biochemistry majors in the class. The results for the Chemistry and Biochemistry majors are as follows:

SLO	Exam Question	Chemistry major correct answers	Biochemistry major correct answers	Total Chemistry and Biochemistry major correct answers	Percent Total correct answers
1	9	3/4	4/7	7/11	63.6 %
2	34	3/4	6/7	9/11	81.8 %
3	50	4/4	5/7	9/11	81.8%
4	14	3/4	2/7	5/11	45.5 %

Reflections

An overwhelming majority of the majors were able to answer a question using the results of the common spectroscopic methods to determine the structures of simple organic compounds and a question that required them to show knowledge of the reactivity of a functional group. Most of the students were able to predict chemical properties of an organic compound given the molecular structure. The SLO that gave the most difficulty, and in which less than half of the majors were able to answer correctly, dealt with indicating a reaction mechanism of a given organic reaction. We will use these results to inform our teaching for the upcoming year. More emphasis will be placed on practicing writing and predicting reaction mechanisms.

Chem 352 – Physical Chemistry II

Physical Chemistry II is a required course for BS Chemistry and BS Biochemistry students. It may also be taken as an elective bot BA and MS students. The course was assessed using embedded final exam questions. In this year, all of the final exam questions were used in this assessment report.

Student Learning Outcomes

A student who has completed this course, meeting all of the course objectives will be able to:

1. describe the failures of classical physics that led to the formation of a quantum theory
    - including how classical models and quantum models predict differences in physical behavior
2. utilize the tools of Group theory to classify the geometry of a molecule
    - including applications in spectroscopy and molecular orbital theory
3. describe the quantum theory both qualitatively and quantitatively in terms of its fundamental postulates
4. employ quantum theory to describe the motions and observable properties of an atom or molecule in terms of vibrations, rotations, and electronic motions, as appropriate
5. analyze the results of spectroscopic measurements that probe molecular behavior

Final Exam Questions

1. Consider the first seven lines in the microwave spectrum of MgO.

    a. Find the reduced mass (μ) of the molecule.
    b. Assign the spectrum (assign the lower J value to each transition) and fit the data to an appropriate functional form in order to determine values for B and D.
    c. Use your value of B and μ to find the value of r (the bond length) for the molecule.

J	ν (cm^{-1})
	0.5718
	1.1436
	1.7154
	2.2871
	2.8588
	3.4305
	4.0022

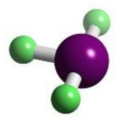
2. Consider a particle of mass *m* in a one-dimensional box of length *a* (defined between x = 0 and x = *a*), for which the wave function is given by $\psi(x) = Ax^\wedge 2(a - x)$.
    a. Make a graph of the wavefunction.
    b. Find the value of *A* that normalizes the wavefunction.
    c. Find the expectation vale <E> for the particle.
    d. Find the expectation value of <x> for the particle.

3. Consider a new element, Crazium, that is discovered to have two electrons in its highest-energy subshell. *l* for this subshell is 3/2. *s* for these electrons is the same as any other electron, 1/2.

    a. What are the possible values of m_s for this subshell?

b. Write an orbital diagram to predict the lowest-energy term symbol for the ground state of Crazium. (You do not have to write out all of the microstates. Just find the ground state using the method outlined in class.)

4. Consider the molecule iodine trifluoride.



C_{2v}	E	C_2	σ_{xz}	σ_{yz}		
A_1	1	1	1	1	z	
A_2	1	1	-1	-1		R_z
B_1	1	-1	1	-1	y	R_x
B_2	1	-1	-1	1	x	R_y

a. Using the character table below, find the number of vibrations of a_1, a_2, b_1, and b_2 symmetry.

5. Draw an energy level diagram for a four-level laser system (such as the Nd:YAG laser, and write a paragraph describing how the system achieves a population inversion.

Correlation of Exam Questions

Exam Question	Learning Outcome				
	1	2	3	4	5
Question 1				X	X
Question 2			X		
Question 3		X			
Question 4		X			
Question 5			X	X	X

Summary of Results

The 17 students in this course break down into subgroups by degree program as follows:

BA Chemistry: 1
BS Chemistry: 5
BS Biochemistry: 9
Other: 2

The tables below indicate the portion of students who score at least the indicated percentage on each question on the final exam. The weakest results are clearly on Question 2, indicating that this Learning Outcome requires more support in the course in future iterations.

All Students

	Q1	Q2	Q3	Q4	Q5
100%	15 (88.2%)	5 (29.4%)	11 (54.7%)	11 (54.7%)	17 (100%)
75%	15 (88.2%)	9 (52.9%)	15 (88.2%)	15 (88.2%)	17 (100%)
50%	17 (100%)	17 (100%)	16 (94.1%)	17 (100%)	17 (100%)
25%	17 (100%)	17 (100%)	16 (94.1%)	17 (100%)	17 (100%)

BA Chemistry (1 student)

	Q1	Q2	Q3	Q4	Q5
100%	1 (100%)	0 (0.0%)	0 (0.0%)	1 (100%)	1 (100%)
75%	1 (100%)	1 (100%)	1 (100%)	1 (100%)	1 (100%)
50%	1 (100%)	1 (100%)	1 (100%)	1 (100%)	1 (100%)
25%	1 (100%)	1 (100%)	1 (100%)	1 (100%)	1 (100%)

BS Chemistry (5 students)

	Q1	Q2	Q3	Q4	Q5
100%	4 (80.0%)	1 (20.0%)	2 (40.0%)	3 (60.0%)	5 (100%)
75%	4 (80.0%)	3 (60.0%)	4 (80.0%)	4 (80.0%)	5 (100%)
50%	5 (100%)	5 (100%)	5 (100%)	5 (100%)	5 (100%)
25%	5 (100%)	5 (100%)	5 (100%)	5 (100%)	5 (100%)

BS Biochemistry (9 students)

	Q1	Q2	Q3	Q4	Q5
100%	9 (100%)	2 (22.2%)	7 (77.8%)	6 (66.7%)	9 (100%)
75%	9 (100%)	5 (55.6%)	9 (100%)	8 (88.9%)	9 (100%)
50%	9 (100%)	9 (100%)	9 (100%)	9 (100%)	9 (100%)
25%	9 (100%)	9 (100%)	9 (100%)	9 (100%)	9 (100%)

Reflections

Overall, the students did well on this exam. On reflection, I think the last question should have been weighted about half (10 pts.), with the addition of a 10-point question that would have supported the first learning objective (as that was not assessed on this final exam, although it was on an earlier mid-term exam.)

Question 2, which really examined Learning Outcome 3 showed the poorest results. These topics will need more review and more supporting problems in homework to support student learning in future iterations of this course.

It is important to recognize that the structure of this course changed substantially due to the Covid-19 pandemic, which forced us to move to online instruction and examination in mid-March.

E. Assessment Plans for Next Year

For the coming year, we have planned to assess PLO3, *work effectively and safely in a laboratory environment to perform experimental procedures and operate modern chemical/biochemical instruments*. However, the Covid-19 pandemic makes this learning outcome difficult to assess. Pending approval to hold Chem 355 (Physical Chemistry Laboratory) and Chem 415 (Advanced Inorganic Lab), we will proceed with this PLO. In the event that the pandemic precludes the collection of meaningful data in these courses, we will again look at PLOs 1 and 2, *demonstrate knowledge in the various area of chemistry, including inorganic chemistry, analytical chemistry, organic chemistry, physical chemistry, and biochemistry*, and *use quantitative reasoning to analyze and solve chemical problems and evaluate chemical data*, based on data collected in appropriate online lecture courses.

MS Chemistry Program

Assessment for ILO: Quantitative Reasoning through CHEM 691 and CHEM 693 (AY 2019-2020)

All chemistry graduate students must complete either CHEM 691 (University Thesis) or CHEM 693 (Review Paper) as their capstone experience. For CHEM 691, students conduct original research in a chemistry department faculty members' lab, and write a University approved thesis on their results which includes a review of the current literature relevant to the topic. For CHEM 693, students select a topic in chemistry or biochemistry, search the literature, and write a review paper on the topic. They also have an individual chemistry department faculty mentor who works with them on the review paper.

Course Learning Outcomes

Students who successfully complete CHEM 691 should be able to:
1. organize and critically assess results from independently conducted research.
2. organize and critically assess related information from the chemical literature.
3. present research results via a formal written thesis following the University specified format.

Students who successfully complete CHEM 693 should be able to:
1. demonstrate understanding of information from the chemical literature.
2. organize and critically assess information from the chemical literature.
3. present complex chemical information via a formal written review paper and oral exam.

Assessment Tool

The faculty members supervising either CHEM 691 or CHEM 693 evaluated their students' paper or thesis with respect to problem formulation, representation, quantitative analysis, interpretation, implications, limitations, and overall communication of the data following the attached rubric.

Assessment Data

During the 2019-2020 academic year, five students completed their capstone experience: four students through CHEM 691 and one student through CHEM 693. Using the rubric, the average of all of their scores was 22.6/28. All of the students met expectations (score of greater than 17/28) and three of them exceeded expectations (score of 24/28). Although this was an unusually small graduating class, there was not a large disparity in scores between students who completed the thesis option vs the student who completed the non-thesis option.

Criteria	Average Score (out of 4)
Problem formulation	3.4
Representation/Visualization	3.4
Quantitative analysis	3.4
Interpretation	3.2
Implications	2.8
Limitations	3.0
Overall communication	3.6

Closing the Loop

The quantitative reasoning ILO was assessed in Chemistry by using a rubric to assess the graduate students' written capstone project (University Thesis or Review Paper). The students did best in formulating, representing, and analyzing problems, as well as in overall communication. The areas that need the most work were in the students' discussions of implications and limitations. These findings will be shared with the faculty to inform their approaches to teaching next year. Keeping in mind the results of the assessment, we will try to determine in what courses we can implement more quantitative reasoning practice, especially in the area of understanding and describing limitations from data.