**Academic Senate**
Committee on Academic Planning and Review

Annual Program Report

| | |
|---|---|
| College | College of Science |
| Department | Chemistry and Biochemistry |
| Programs | BS/BA Chemistry, BS/BA Biochemistry, and MS Chemistry |
| Reporting for the Academic Year | 2020-2021 |
| Last Five-Year Review | 2018-2019 |
| Next Five-Year Review | 2022-2023 |
| Department Chair | Patrick E. Fleming |
| Date Submitted | October 1, 2021 |

## II. Summary of 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

Our plan was to assess PLO 2, work effectively and safely in a laboratory environment to perform experimental procedures and operate modern chemical/biochemical instruments. However, the Covid-19 pandemic forced us out of the teaching laboratories, making assessment of this PLO impossible. As such, data were collected in Chem 332 (Organic Chemistry II) and Chem 352 (Physical Chemistry II) in order to assess student knowledge in various areas of chemistry or biochemistry.

### C. Summary of Assessment Process

See notes below.

## D. Summary of Assessment Results

CHEM 332-2 Assessment Spring 2021

The student learning outcomes (SLOs) for CHEM 331 and CHEM 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.

### Assessment Tool:

During the Spring semester 2021, SLOs 1, 2, 3, and 4 were assessed in CHEM 332-2. Due to COVID, the course was 100% on-line and so there was no opportunity to assess students on SLOs 5, 6, and 7 which require physical demonstration in a laboratory.

### Assessment Data:

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 four 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 | 1/4 | 3/4 | 4/8 | 50% |
| 2 | 34 | 1/4 | 4/4 | 5/8 | 62.5% |
| 3 | 50 | 4/4 | 3/4 | 7/8 | 87.5% |

| | | | | | |
|---|---|---|---|---|---|
| 4 | 14 | 1/4 | 2/4 | 3/8 | 37.5% |

### Assessment Analysis:

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. Most of the students were able to demonstrate knowledge of the reactivity of a functional group. 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.

It is not surprising that students did the best on questions in using the results of the spectroscopic methods to determine structure because the techniques learned to carry out SLO #3 are heavily emphasized and practiced in the laboratory portion of the course. We will look for more opportunities in the course to include a greater emphasis in the practice of writing and predicting reaction mechanisms (SLO #4).

## 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*

Students who successfully complete Chem 352 should 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.

| J | ν ($cm^{-1}$) |
|---|---|
| | 0.5718 |
| | 1.1436 |

| | |
|---|---|
| | 1.7154 |
| | 2.2871 |
| | 2.8588 |
| | 3.4305 |
| | 4.0022 |

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.

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 $\psi(x) = Ax\text{^}2(a - x)$.
   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.)

| $C_{2v}$ | E | $C_2$ | $\sigma_{xz}$ | $\sigma_{yz}$ | | |
|---|---|---|---|---|---|---|
| $A_1$ | 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 | $R_y$ |

4. Consider the molecule iodine trifluoride.

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 20 students who completed this course break down into subgroups by degree program as follows:

BS Chemistry: 6
BS Biochemistry: 13
Other: 1

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% | 13 (65%) | 1 (5%) | 7 (35%) | 8 (40%) | 20 (100%) |
| 75% | 20 (100%) | 3 (15%) | 13 (65%) | 16 (80%) | 20 (100%) |
| 50% | 20 (100%) | 10 (50%) | 15 (75%) | 17 (85%) | 20 (100%) |
| 25% | 20 (100%) | 18 (80%) | 18 (80%) | 20 (100%) | 20 (100%) |

### BS Chemistry (6 students)

| | Q1 | Q2 | Q3 | Q4 | Q5 |
|---|---|---|---|---|---|
| 100% | 5 (83%) | 0 (00.0%) | 0 (0.0%) | 1 (17%) | 6 (100%) |

| | | | | | |
|---|---|---|---|---|---|
| 75% | 6 (100%) | 1 (17%) | 3 (50%) | 6 (100%) | 6 (100%) |
| 50% | 6 (100%) | 4 (67%) | 5 (83%) | 6 (100%) | 6 (100%) |
| 25% | 6 (100%) | 5 (83%) | 5 (83%) | 6 (100%) | 6 (100%) |

### BS Biochemistry (13 students)

| | Q1 | Q2 | Q3 | Q4 | Q5 |
|---|---|---|---|---|---|
| 100% | 7 (54%) | 1 (7.7%) | 7 (54%) | 7 (54%) | 13 (100%) |
| 75% | 13 (100%) | 2 (15%) | 10 (77%) | 9 (69%) | 13 (100%) |
| 50% | 13 (100%) | 2 (15%) | 10 (77%) | 10 (77%) | 13 (100%) |
| 25% | 13 (100%) | 12 (92%) | 12 (92%) | 13 (100%) | 13 (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. This problem might also benefit from being separated to multiple parts which scaffold a final solution.

### E. Assessment Plans for Next Year

Or plan for next year is to assess PLO 3, use quantitative reasoning to analyze chemical problems and evaluate chemical data.

## MS Chemistry Program

### A. Program Learning Outcomes

Students graduating with a Master of Science in Chemistry will be able to:

1. demonstrate mastery of specialized knowledge in the chemical sciences beyond the undergraduate level
2. work effectively and safely in a laboratory environment using chemistry laboratory techniques and chemical/biochemical instrumentation.
3. use theoretical and experimental chemistry methods to test hypotheses or analyze and design solutions to problems
4. research, understand, organize, and critically assess information from the chemical literature
5. present complex chemical information via oral and written reports

## B. Program Learning Outcomes Assessed

We assessed the Written Communication ILO, which closely aligns with the written communication portion of PLO 5.

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.

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.

## C. Summary of Assessment Process

The faculty members supervising either CHEM 691 or CHEM 693 evaluated their students' paper or thesis with respect to the organization of scientific content, presentation of data, and analysis using appropriate literature references following the attached rubric.

## D. Summary of Assessment Results

During the 2020-2021 academic year, four students completed their capstone experience: two students through CHEM 691 and two students through CHEM 693. Using the rubric, the average of all of their scores was 30/32. All of the students met expectations (score of greater than 24/32) and three of them exceeded expectations (score of 27/32). The students who completed the thesis option did slightly better on average than the students who completed the non-thesis option, but no students were assessed as below expectations on any of the metrics.

| **Criteria** | **Average Score (out of 4)** |
|---|---|
| Statement of Purpose | 3.75 |
| Organization | 3.75 |
| Presentation of supporting ideas | 3.5 |
| Presentation of data | 4 |
| Interpretation of data | 3.75 |
| Explanation of methods | 3.5 |

| | |
|---|---|
| Language usage | 4 |
| Writing mechanics | 4 |

### Assessment Analysis:

The written communication ILO was assessed in Chemistry by using a rubric to assess the graduate students' written capstone project (University Thesis or Review Paper). All of the students met expectations with 75% exceeding expectations. The greatest difficulties were determined to be in the areas of "presentation of supporting ideas and appropriate use of literature references" and "explanation of methods and techniques". The highest scores were in "presentation of data", "language usage", and "writing mechanics". This is an indication that despite the challenges of often interacting remotely, individual faculty advisors worked very well with the graduate students in mentoring them on the completion of their capstone project.

## E. Assessment Plans for Next Year

We plan to assess PLO1, demonstrate mastery of specialized knowledge in the chemical sciences.