UNIVERSITY OF SAN FRANCISCO | College of Arts and Sciences

Chemistry Majors and Minors Aggregate Report

Academic Year 2022-2023
Assessment Report (regular template)

I. Logistics

1. **Please indicate the name and email of the program contact person to whom feedback should be sent (usually Chair, Program Director, or Faculty Assessment Coordinator).**

   Michael Stevenson (mstevenson3@usfca.edu)

2. **Please indicate if you are submitting report for (a) a Major, (b) a Minor, (c) an aggregate report for a Major & Minor (in which case, each should be explained in a separate paragraph as in this template), (d) a Graduate or (e) a Certificate Program.**

   This is an aggregate report for Major and Minor.

3. **Please note that a Curricular Map should accompany every assessment report. Has there been any revisions to the Curricular Map since October 2022?**

   This is the first year of our 3-year assessment. The 3-year assessment plan is a repeat of the previous 3-year assessment plan (AY 19-20 to AY 21-22). No changes were made to the assessment plan.

II. Mission Statement & Program Learning Outcomes

1. **Were any changes made to the program mission statement since the last assessment cycle in December 2022? Kindly state "Yes" or "No." Please provide the current mission statement below. If you are submitting an aggregate report, please provide the current mission statements of both the major and the minor program.**

   No

   Mission Statement (Major/Graduate/Certificate):
   To deliver a broad-based and challenging chemistry experience that will train students for graduate school in science or as professionals in a variety of health, government or private industry positions. The program will foster a culture that values our students, faculty and staff; strives to help students become self-learners; creates opportunities for students to discover the excitement and creativity of research, and promotes an understanding that social consciousness and ethical behavior are essential features of a principled chemistry community.

   Mission Statement (Minor):
   To deliver a broad-based and challenging chemistry experience that will train students for graduate school in science or as professionals in a variety of health, government or private industry positions. The program will foster a culture that values our students, faculty and staff; strives to help students become self-learners; creates opportunities for students to discover the excitement and creativity of research, and promotes an understanding that social consciousness and ethical behavior are essential features of a principled chemistry community.

2. **Were any changes made to the program learning outcomes (PLOs) since the last assessment cycle in December 2022? Kindly state "Yes" or "No." Please provide the current PLOs below. If you are submitting an aggregate report, please provide the current PLOs for both the major and the minor programs.**

   Yes. The Department revisited the PLOs and discussed whether they should be identical for the major and minor programs. We voted that the PLOs for the minor program should demonstrate intermediate levels of mastery. Revisions are below.

   PLOs (Major/Graduate/Certificate):
   LO #1: Students will demonstrate their mastery of the four (or five for BS biochemistry emphasis) principal disciplines: analytical, organic, physical, (biochemistry) and inorganic chemistry.
   LO#2: Students will recognize and understand the concepts and skills learned in prerequisite courses at or before the start of the new course or laboratory.
   LO#3: Students or student teams will demonstrate mastery in problem solving by performing a broad variety of analytical, computational and synthetic procedures using proper safety protocols, and will critically evaluate the results.

LO#4: Students will demonstrate effective scientific communications skills in both written and oral form. Students will be able to write reports and present results while following professional policies regarding intellectual property, plagiarism, and group work.

PLOs (Minor):
LO #1: Students will demonstrate intermediate level of mastery of the four (or five for BS biochemistry emphasis) principal disciplines: analytical, organic, physical, (biochemistry) and inorganic chemistry.
LO#2: Students will recognize and understand the concepts and skills learned in prerequisite courses at or before the start of the new course or laboratory.
LO#3: Students or student teams will demonstrate intermediate levels of mastery in problem solving by performing a broad variety of analytical, computational and synthetic procedures using proper safety protocols, and will critically evaluate the results.
LO#4: Students will demonstrate scientific communications skills in both written and oral form. Students will be able to write reports and present results while following professional policies regarding intellectual property, plagiarism, and group work.

3. State the particular Program Learning Outcome(s) you assessed for the academic year 2022-2023.

PLO(s) being assessed (Major/Graduate/Certificate):
LO#2: Students will recognize and understand the concepts and skills learned in prerequisite courses at or before the start of the new course or laboratory.

PLO(s) being assessed (Minor):
LO#2: Students will recognize and understand the concepts and skills learned in prerequisite courses at or before the start of the new course or laboratory.

III. Methodology

Methodology used (Major/Graduate/Certificate):
LO#2 was assessed in General Chemistry II (CHEM 113), Organic Chemistry I (CHEM 230), Inorganic Chemistry (CHEM 320), Biochemistry I (CHEM 350), and Biochemistry II (CHEM 351). Due to faculty on leave, we are unable to provide assessment for Physical Chemistry I (CHEM 340). Additionally, we were unable to provide assessment for Organic Chemistry Lab II (CHEM 234). The methodologies used in each course assessment are listed below:

CHEM 113: During the first week of class, students were assigned an online, extra credit, prerequisite quiz through Canvas. The quiz consisted of twelve multiple choice questions on topics from the previous, General Chemistry I (CHEM 111) class. The quiz was based on the following topics: Atoms, molecules, and the mole; Chemical compounds; Redox reactions; Stoichiometry; pH and molar concentration; Enthalpy changes; Periodic trends; Formal charges and resonance; Electronegativity and bond polarity; Valence bond theory. Students were informed about the topics that will be on the quiz and were allowed to use their notes/textbooks and other resources. The quiz remained open for a week, but once started students had 20 min to complete the quiz.

CHEM 230: The instructors in each of the four sections of Organic Chemistry I (CHEM 230) gave a Lewis Structures quiz on the Friday of the first week of class. The ability to draw accurate chemical structures with proper formal charges and nonbonding electrons on specific atoms presumably correlates with success in organic chemistry. Students are taught how to draw Lewis structures in General Chemistry, and a few weeks before the semester started students were emailed a list of topics—including Lewis structures—that they should review to prepare themselves for success in Organic Chemistry I. They were also told via email and Canvas announcements that there would be a quiz during the first week of class that is primarily focused on Lewis structures. Each instructor also reviewed this skill in the context of organic chemistry on the first day of class. In addition to providing an assessment of Chemistry Program Learning Outcome #2—"Students will recognize and understand the concepts and skills learned in prerequisite courses at or before the new course or laboratory"—the quiz also encouraged Organic Chemistry I students to start the semester strong by studying Lewis structures and a few other topics prior to the first day of class. We assessed students' abilities to: (1) generate structures from molecular formulas and condensed molecular formulas, (2) properly employ single and multiple covalent bonds and ionic bonds, (3) apply the octet rule, and (4) assign formal charges to atoms within the structures.

CHEM 320: To assess the PLO of prerequisite knowledge, a quiz was given on the first day of class. Students (n=16) learned the concepts assessed in the prerequisite course of Organic Chemistry and included formal charges, polar bonds, isomerism, chirality, and redox. See the quiz in the appendix. Responses were graded with a total of 10 points available.

CHEM 350: During the first week of class, students were assigned an online, extra credit, prerequisite quiz through Canvas. The quiz consisted of eight multiple format questions based on the topics from the previous General Chemistry and Organic Chemistry courses. The topics included: basic concepts of thermodynamics, oxidation-reduction reactions, pH, titration curves and buffers, functional groups and reaction mechanisms. Students were not informed about the specific topics that will be on the quiz, but were allowed to use their notes/textbooks and other resources. The quiz remained open for a week, but once started students had 20 min to complete the quiz.

CHEM 351: During the first week of class, students were assigned an online, extra credit, prerequisite quiz through Canvas. The quiz consisted of eleven multiple format questions on topics from the previous, Biochemistry I (CHEM 350) class. The quiz focused on topics that were previously identified as most challenging for students in CHEM 350 and are essential for understanding of CHEM 351. The topics included: basic concepts of thermodynamics, titration curves and buffers, osmosis and osmotic pressure, hydrogen bonding, levels of protein structure, forces stabilizing protein structure, enzyme-catalyzed reactions and enzyme mechanisms, structure and nomenclature of carbohydrates and lipids. Students were not informed about the specific topics that will be on the quiz but were allowed to use their notes/textbooks and other resources. Once started students had 15 min to complete the quiz.

Methodology used (Minor):
LO#2 is the same for the major and the minor. Since assessment happens at the course level, the data presented for each course is reflective of all students in our majors and minors. To minimize the unnecessary redundancy that would arise from copying and pasting the same information for the minor in this document, we have decided to leave those sections blank from this point on. The data presented under the “major” section should be treated as an aggregate of both the major and minor.

IV. Results & Major Findings

Results (Major/Graduate/Certificate and Minor):
The results and major findings for each course are listed below.

CHEM 113: Total of 34/36 students completed the quiz with 77.9% average score. Results (outlined in the table below) show that students struggled most with questions about redox reactions, stoichiometry and enthalpy changes. Students were also struggling with questions regarding formal charge and resonance and valence bond theory.

Topic		Percentage of students who correctly answered the question
Atoms, molecules, and the mole	Isotopes	91%
	Periodic table: Groups vs. periods	68%
	Periodic table: Transition metals	97%
	Gram to mole conversion	88%
Chemical compounds		97%
Redox reactions	Recognizing oxidation/reduction	47%
	Recognizing oxidizing/reducing agent	71%
Stoichiometry		53%
pH		79%
Molar concentration		88%
Enthalpy changes		53%
Periodic trends		76%
Formal charge and resonance		62%
Electronegativity and bond polarity		82%
Valence bond theory		62%

Comparison of prerequisite quiz scores and the final grades showed that strong correlation exists between prerequisite knowledge and success in CHEM 113. All students who got the final grade of C or lower also scored below average on the prerequisite quiz. However, the quiz cannot serve as a predictor of how well students will perform in class. There were students who scored below average on the quiz but achieved above average final grades.

CHEM 230: We used the overall scores on the Lewis Structures quiz to assess the learning outcome in Organic Chemistry I. The benchmarks used were: Good (>80%), Adequate (70-80%), and Poor (<70%). We averaged the percentage of students who achieved each of these benchmarks over the four sections, which allowed for the variability in the difficulty of the quiz from section to section. The table below summarizes the results.

Mastery	***Percentage of Students***
Good (> 80%)	*87.8%*

Adequate (70-80%)	*5.2%*
Poor (< 70%)	*7.0%*

The data indicates that over 90% of the students in the first week of Organic Chemistry I have an adequate to good ability to draw Lewis structures with formal charges. With this assessment we are assuming that skill of drawing such structures indicates a potential for success in Organic Chemistry, and indeed this data accords with our experience teaching this class. There is a small but significant proportion of students who are unprepared at the beginning of the course. Since the attrition rate (students who either drop or earn below a C grade) in Organic Chemistry I is significantly higher than 10% (usually around 20-25% based on the number of students who begin the course), there are clearly other factors (beyond ability to draw Lewis structures) important to success in the course.

CHEM 320: The level of mastery is shown in the table below. Scores at or above 60% demonstrated some to complete mastery of the material while scores below 60% did not show any mastery of the material. This prerequisite quiz was given on the first day of class with no advanced warning for time to study. Surprisingly, only half of the students demonstrated some form of mastery of the material while the other half did not. This may be a result of no study time or that seven of the 16 students took Organic Chemistry over one year before (these students were fourth-year students and took Organic Chemistry as a second-year).

Level	***Score***	***Percentage of Students***
Complete Mastery of the outcome	*90 – 100%*	*12.5%*
Mastered the outcome in most parts	*80 – 90%*	*18.75%*
Mastered some parts of the outcome	*60 – 80%*	*18.75%*
Did not master the outcome at the level intended	*< 60%*	*50%*

CHEM 350: Total of 31/32 students (across 2 sections) completed the quiz with 69.4% average score. Majority of students did well on questions regarding oxidation-reduction reactions, pH and titration curves. Students struggled most with questions about thermodynamics and buffers. Students were also struggling with questions that contained multiple correct answers (functional groups and reaction mechanisms) as outlined in the table below:

Topic	**Percentage of students who correctly answered the question**
Oxidation-reduction reactions	84%
Functional groups	55%[*]
pH	90%
Titration curves 1	94%
Titration curves 2	94%
Buffers	52%

Thermodynamics	52%
Reaction mechanisms	61%*

* Questions containing multiple correct answers

Comparison of prerequisite quiz scores and the final grades showed that strong correlation exists between prerequisite knowledge and success in CHEM 350. All students who got the final grade of C or lower also scored below average on the prerequisite quiz. However, the quiz cannot serve as a predictor of how well students will perform in class. There were students who scored below average on the quiz but achieved above average final grades. This indicates that the prerequisite quiz is a useful tool to help students identify and focus their attention to the prerequisite concepts that are needed for success in CHEM 350.

CHEM 351: Total of 17/17 students completed the quiz with 81.3% average score. Results (outlined in the table below) show that students after taking CHEM 350 still struggle with questions about thermodynamics and structure and nomenclature of carbohydrates and lipids. Questions containing multiple correct answers (carbohydrates) remain the most challenging question format.

Topic	**Percentage of students who correctly answered the question**
Thermodynamics	53%
Peptide titration curve	71%
Buffers	100%
Osmosis and osmotic pressure	94%
Hydrogen bonding	76%
Levels of protein structure	100%
Forces stabilizing protein structure	94%
Classification of enzyme catalyzed reactions	100%
Enzyme mechanisms	88%
Carbohydrates	18%*
Lipids	53%

* Questions containing multiple correct answers

Comparison of prerequisite quiz scores and the final grades showed that strong correlation exists between prerequisite knowledge and success in CHEM 351. Majority of students who got below the average final grade also scored below average on the prerequisite quiz.

V. Closing the Loop

Closing the Loop (Major/Graduate/Certificate and Minor):
The action plan based on the assessment result for each course is listed below.

CHEM 113: The topics that were identified as most difficult for the students on the prerequisite quiz, especially redox reactions, stoichiometry and enthalpy changes were briefly reviewed at the beginning of each class that required prior knowledge of these concepts. While this was helpful for the students, in the future, I plan to include additional resources (videos and reading materials) and practice tests (low-stakes or extra credit) through the semester that focus on CHEM 111 materials. This can help students not only better understand CHEM 113 concepts but also prepare for the ACS test that is based on both CHEM 111 and CHEM 113 materials.

CHEM 230: As mentioned above, it is clear that the attrition rate in CHEM 230 is higher than would be predicted by the Lewis Structure Quiz alone. Nevertheless, the quiz provides some helpful data on student preparedness. We still need to determine whether there is a correlation between Quiz 1 performance and final student outcomes in the course (drop rate or final course grade). We also need to determine if there is a correlation between student grades in General Chemistry II (CHEM 113), their Quiz 1 scores, and their achievement in Organic Chemistry I. Such a correlation may guide advising, i.e. possibly encouraging some students to take Fundamentals of Organic Chemistry (CHEM 236) rather than Organic Chemistry I.

In the short term, we will continue to refine and provide review materials to students before the start of the semester, covering Lewis structures and other key aspects of General Chemistry to better prepare students for Organic Chemistry I.

CHEM 320: This prerequisite quiz showed that most students were not prepared for Inorganic Chemistry. A potential way to address this lack of preparedness would be to provide non-assessed study guides and/or worksheets that cover Organic Chemistry material for students to complete either over the summer or during the first week of the semester. It is worth noting that half of the students took Organic Chemistry remotely during the pandemic, which may affect their learning and retention of these concepts. Before implementing any wide reaching steps, we will assess prerequisite knowledge again with a cohort of the students who took Organic Chemistry in person.

CHEM 350: The prerequisite quiz was given online, and students were allowed to use their notes and/or other resources. Having an online quiz is less stressful and offers flexibility to students, especially those who joined the class later. However, conducting an in-person instead of an online quiz could more accurately assess the prerequisite knowledge. Another approach is to tell students what specific topics to focus on, so they can come to quiz prepared. While this may not give as accurate assessment of the prerequisite knowledge, it can motivate students to review the most important prerequisite concepts needed in CHEM 350, and improve their performance in class. Additionally, the quiz can include more topics and more in-depth questions. This will help further identify the most challenging concepts for our students, so that the instruction can be tailored, and additional materials and resources provided.

CHEM 351: One of the most challenging topics identified in both CHEM 350 and CHEM 351 is thermodynamics. Since knowledge of thermodynamics is essential for proper understanding of many biochemical processes, more questions on thermodynamics should be included on the prerequisite quiz. This can help more specifically identify difficult thermodynamics concepts, so that additional practice and more resources can be provided for the students. Students also struggled with structures and nomenclature of carbohydrates and lipids. This might be due to the limited number of lectures that focus on these topics in CHEM 350. In CHEM 351 this issue can be addressed by including additional practice problems/assignments that will help students review the structures and nomenclature of carbohydrates and lipids, before discussing their metabolism in class.

VI. Suggestions from AY 2021-2022 Feedback

Suggestions (Major/Graduate/Certificate and Minor):

In last year's assessment, the department was asked if the mission statements and PLOs for the major and minor are in fact identical because in most cases the minor is less emphatic. The Department revisited the PLOs for the minor and voted to reduce the emphasis in expectation for PLOs.

Additional Materials

BS CHEM Curriculum Map: 3-Year Assessment Plan (2022-2025)

Chemistry Program Learning Outcomes A=Assessed	**113**	**114L**	**230**	**232L**	**231**	**234L**	**260**	**320**	**332**	**333**	**334**	**340/341**	**350/351**	**352**	**397**	**410**
Year 1: AY 22-23 **Year 2: AY 23-24** **Year 3: AY 24-25**	**General II**	**General Lab II**	**Organic I**	**Organic Lab I**	**Organic II**	**Organic Lab II**	**Analytical + Lab**	**Inorganic**	**Medicinal**	**Advanced Organic Lab**	**Advanced Synth**	**Physical I/II**	**Biochemistry I/II**	**Biochemistry Lab**	**Research**	**Integrated Lab**
LO #1: Students will demonstrate his/her mastery of the five principle disciplines: analytical, organic, physical, inorganic, and biochemistry	A				A		A	A				A				
year of assessment (1-3 means you may be collecting data every year anyway….ACS exam or common final exam question).	1-3				1-3?		1-3	1-3				1-3				
LO#2: Students will recognize and understand the concepts and skills learned in prerequisite courses at or before the start of the new course or laboratory	A		A			A		A				A	A			
year of assessment	1		1					1				1	1			
LO#3: Students or student teams will demonstrate excellent problem-solving skills in performing a broad variety of analytical, computational and synthetic procedures using proper safety protocols, and will critically evaluate the results (i.e. Lab Practical)		A				A	A	A		A				A		A
year of assessment		3				3	3	3		3				3		3
LO#4: Students will demonstrate effective scientific communications skills in both written and oral form. Students will be able to write reports and present results while following professional policies regarding intellectual property, plagiarism, and group work								A	A	A			A	A	A	A
year of assessment (written or oral)								2	2	2			2	2	2	2

1. Which statement describes the composition of an isotope of iron, ^{58}Fe?
(*Multiple choice; worth 1 extra credit point*)

A. 26 neutrons, 32 protons, and 26 electrons
B. 26 neutrons, 26 protons, and 32 electrons
C. 32 neutrons, 26 protons, and 26 electrons
D. 26 neutrons, 26 protons, and 26 electrons

2. Which list of elements includes those in the same periodic group?
(*Multiple choice; worth 0.5 extra credit points*)

A. Mg, Fe, Al
B. B, Al, Tl
C. Ti, B, Ge
D. Cl, Si, Sn
E. Fe, Co, Ni

3. Which element is a transition metal?
(*Multiple choice; worth 0.5 extra credit points*)

A. hydrogen
B. iron
C. lithium
D. calcium
E. radon

4. The formula of barium molybdate is $BaMoO_4$. What is the formula of sodium molybdate?
(*Multiple choice; worth 1 extra credit point*)

A. Na_4MoO
B. Na_2MoO_4
C. Na_4MoO_4
D. $NaMoO$
E. Na_2MoO_3

5. Given 23 grams of NaOH, how many moles is this?
(*Numerical answer; worth 1 extra credit point*)

0.58 moles

6. Ammonia is prepared by the reaction:
(*Multiple choice; worth 0.5 extra credit points*)

$$N_2(g) + 3\ H_2(g) \rightarrow 2\ NH_3(g)$$

If you mix 10.0 mol of H_2 with excess N_2, the stoichiometric factor used to calculate the amount (moles) of NH_3 produced is:

A. 1 mol H_2/2 mol NH_3

B. 2 mol NH_3/3 mol H_2
C. 3 mol H_2/1 mol NH_3
D. 3 mol H_2/2 mol NH_3
E. 3 mol H_2/1 mol N_2

7. In the following redox reaction:
(*Multiple dropdowns; worth 1 extra credit point*)

$$3\,Ni^{2+}(aq) + 2\,Cr(s) \longrightarrow 2\,Cr^{3+}(aq) + 3\,Ni(s)$$

A. Which substance gets reduced?

Ni^{2+}
Cr
Cr^{3+}
Ni

B. Which substance is the reducing agent?

Ni^{2+}
Cr
Cr^{3+}
Ni

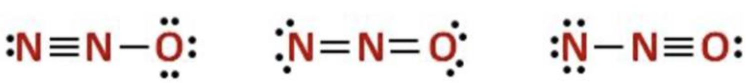
8. What is the pH of 1×10^{-3} M HCl(aq)?
(*Numerical answer; worth 1 extra credit point*)

3.00

9. What mass of Na_2CO_3 is present in 0.700 L of a 0.396 M Na_2CO_3 solution?
(*Multiple choice; worth 1 extra credit point*)

A. 74.2 g
B. 29.4 g
C. 42.0 g
D. 187 g
E. 60.0 g

10. Possible resonance structures of N_2O are given below:
(*Multiple dropdowns; worth 1 extra credit point*)



A B C

A. Which structure contributes the most to the overall structure of N_2O?
Hint: Remember to assign the formal charges to each atom. The formula for calculating the formal charge is given for reference.

$$FC = NVE - [LPE + \tfrac{1}{2}(BE)]$$

# of valence electrons

# of lone pair electrons

# of bonding electrons

B. What is the hybridization of the central nitrogen atom in N_2O?

sp^3
sp^2
sp
none

11. The thermochemical equation for the combustion of butane is given below.

$C_4H_{10}(g) + 13/2\ O_2(g) \rightarrow 4\ CO_2(g) + 5\ H_2O(l)$ $\Delta_r H° = -2877$ kJ/mol-rxn

(*Multiple choice; worth 0.5 extra credit points*)

What is the enthalpy change for the reaction below?
$8\ CO_2(g) + 10\ H_2O(l) \rightarrow 2\ C_4H_{10}(g) + 13\ O_2(g)$

A. +1439 kJ/mol-rxn
B. +2877 kJ/mol-rxn
C. –5754 kJ/mol-rxn
D. –2877 kJ/mol-rxn
E. +5754 kJ/mol-rxn

12. Based on the general trends in electronegativity, decide which bond, in the following bond pair, is less polar and indicate the negative and positive poles.
(*Multiple dropdowns; worth 1 extra credit point*)

H-F and H-I

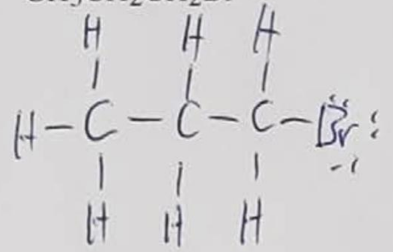
__H-I____ bond is less polar. In this bond, ___I_______ atom is the negative pole.

Chem 230–Karney
8/26/2022
Quiz 1 (20 points)

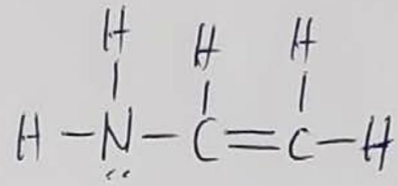
Name (print) KEY

1. (12) Draw the full Lewis structure (including all non-bonding electron pairs) for the following condensed formulas.

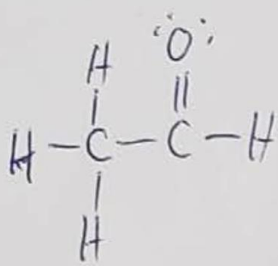
A. $CH_3CH_2CH_2Br$



B. NH_2CHCH_2

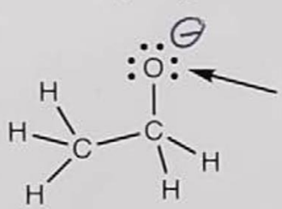


C. CH_3CHO

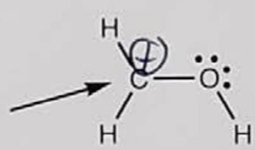


2. (6) For each species below, show the formal charge on the indicated atom. All nonbonding electrons are shown. If you predict a formal charge of zero, write "0".

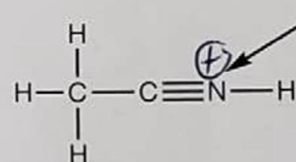
A.



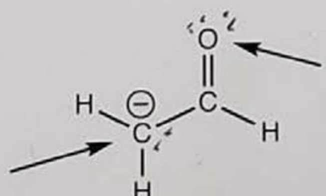
B.



C.



3. (2) For the species below, draw all missing nonbonding electrons on the indicated atoms. All formal charges are shown.

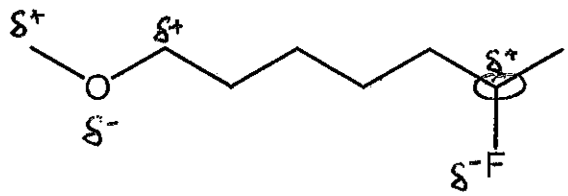


Name: Key

Review, CHEM 320, F22

1. Consider the molecule below.

   a. Show all polar bonds by assigning partial charges to all atoms that need them.



   b. Circle the atom(s) with the largest positive charge.

2. Consider the the pair of compounds below, one is chiral and the other is achiral.

$ClCH_2CHCH_2OH$ with OH on the central carbon $HOCH_2CHCH_2OH$ with Cl on the central carbon

   a. Circle the compound that is chiral.

   b. What type of isomerism is reflected in this pair of compounds?

   constitutional isomers

3. In the reaction below, what are the atom(s) that are oxidized and reduced?

$$2\ CH_3CH_2O\overset{+1}{H} + 2\ \overset{0}{Na} \rightarrow 2\ CH_3CH_2O\overset{+1}{Na} + \overset{0}{H_2}$$

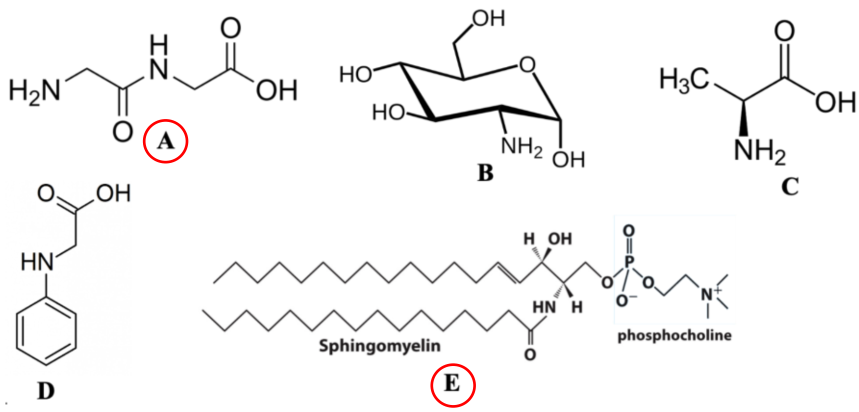
oxidized

reduced

1. Which of the following changes represents oxidation?
(*Multiple choice; worth 1 extra credit point*)

A. CH_3CHO to CH_3CH_2OH
B. Ketone to alcohol
C. Fe^{3+} to Fe^{2+}
D. CH_3OH to CH_4
E. Aldehyde to carboxylic acid

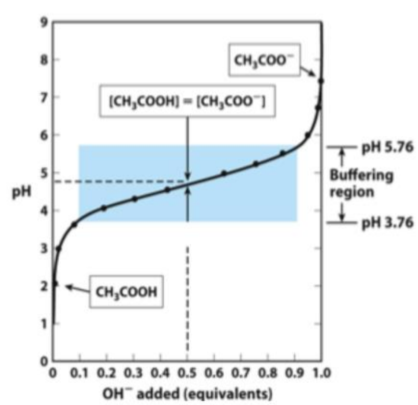
2. Which of the following molecules contains an amide bond? *Select all that apply.*
(*Multiple answer; worth 2 extra credit points*)



3. What is the pH of 1mM solution of HCl?
(*Multiple choice; worth 1 extra credit point*)

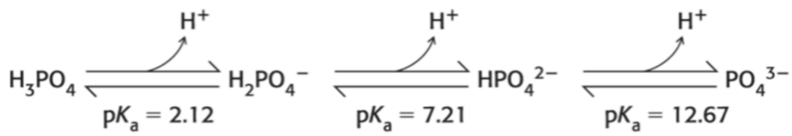
A. 0
B. 3
C. 6
D. 7
E. Cannot be calculated.

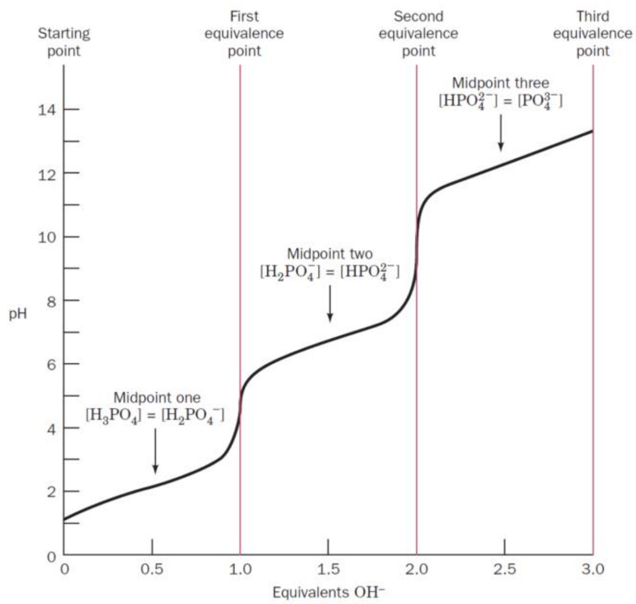
4. Given the following titration curve, what is the pKa of acetic acid?
(*Multiple choice; worth 1 extra credit point*)



A. 2
B. 4.76
C. 7.5
D. 3.76
E. Cannot be determined.

5. Phosphoric acid is triprotic (titration curve shown below).
(*Multiple choice; worth 1 extra credit point*)





The ionic form that predominates at pH 9.0 is:

A. H_3PO_4
B. $H_2PO_4^-$
C. HPO_4^{2-}
D. PO_4^{3-}
E. $[H_2PO_4^-]=[HPO_4^{2-}]$

6. Which of the following statements about buffers is true?
(*Multiple choice; worth 1 extra credit point*)

A. At pH values lower than the pKa, the salt concentration is higher than that of the acid.
B. When pH = pKa, the weak acid and salt concentrations in a buffer are equal.
C. The strongest buffers are those composed of strong acids and strong bases.
D. The pH of a buffered solution remains constant no matter how much acid or base is added to the solution.
E. The combination of CH_3CO_2H and CH_3COO^- (pKa = 4.76) would be best to buffer an aqueous solution at a pH of 9.0.

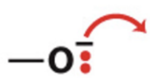
7. Which of the following statements is true?
(*Multiple choice; worth 1 extra credit point*)

A. A spontaneous process always happens very quickly.

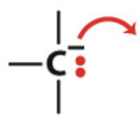
B. A reaction is said to be spontaneous when it can proceed in either the forward or reverse direction.
C. A reaction will always be spontaneous if $\Delta H < 0$ and $\Delta S > 0$.
D. A reaction will always be spontaneous if the standard free energy change, ΔG^0 is < 0.
E. A reaction will always be spontaneous if $\Delta G = 0$.

8. Chemical reaction mechanisms, which trace the formation and breakage of covalent bonds, are communicated with dots and curved arrows, a convention known informally as "electron pushing." A covalent bond consists of a shared pair of electrons. Nonbonded electrons important to the reaction mechanism are designated by dots (:). Curved red arrows represent the movement of electron pairs. Which of the following can serve as nucleophiles in biochemical reactions? *Select all that applies.* (*Multiple answer; worth 2 extra credit point*)

A. Negatively charged oxygen (*example:* an unprotonated hydroxyl group)



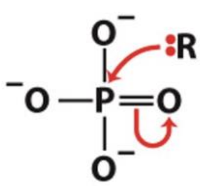
B. Carbanion



C. Carbon atom of a carbonyl group

D. Proton

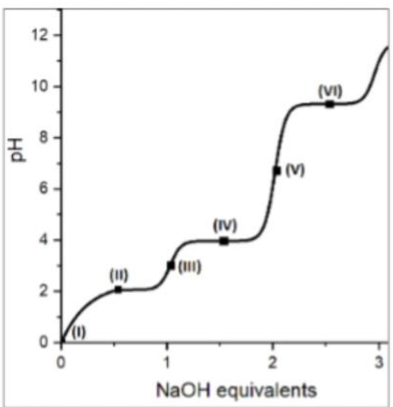
E. Phosphorous of a phosphate group



1. The reaction A -> B has an equilibrium constant, K_{eq}, of 3 x 10^2 at 25°C. In the cell, the [A] is 5 mM, and the [B] is 0.1 M. Select the TRUE statement regarding this reaction.
(*Multiple choice; worth 1 extra credit point*)

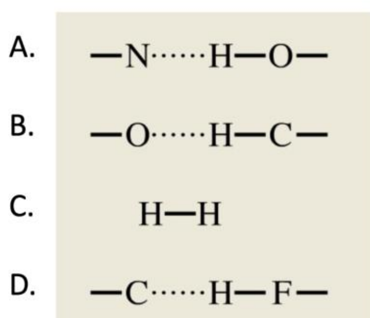
A. Q = Keq, and the reaction is at equilibrium.
B. Q > Keq, there are more products than expected at equilibrium; reaction tends to go to the left.
C. Q < Keq, there are more reactants than expected at equilibrium; reaction tends to go to the right.
D. Q > Keq, there are more products than expected at equilibrium; reaction tends to go to the right.

2. The titration curve of the peptide Ala-Glu-Ser is given below. The key points in the titration are designated I-VI. At what point is the pH equal to the pKa of the carboxyl (C-terminal) group?
(*Multiple choice; worth 0.5 extra credit points*)



A. Point I
B. Point II
C. Point III
D. Point VI
E. Point V
F. Point VI

3. Which of the following represents hydrogen bond?
(*Multiple choice; worth 0.5 extra credit points*)



A. A
B. B
C. C
D. D
E. Both A and B

4. Which statement about buffers is false?
(*Multiple choice; worth 1 extra credit point*)

A. $[A^-]$=[HA] when pH=pKa
B. They have maximum buffering capacity at pH=7
C. They are weak acids and basis
D. They can sometimes be biological macromolecules

5. Which of the following bonds/interactions is not disrupted during protein denaturation?
(*Multiple choice; worth 1 extra credit point*)

A. hydrogen bonds
B. peptide bonds
C. salt bridges
D. hydrophobic interactions
E. Van der Waals interactions

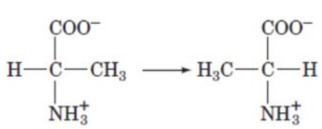
6. The term "quaternary" with respect to protein structure means
(*Multiple choice; worth 1 extra credit point*)

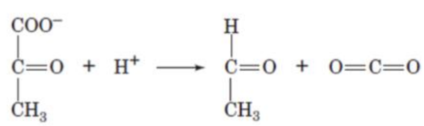
A. a repeating structure stabilized by intrachain hydrogen bonds.
B. the ability to form all four kinds of noncovalent bonds.
C. a multisubunit structure.
D. a linear sequence of four amino acids.
E. None of the answers is correct.

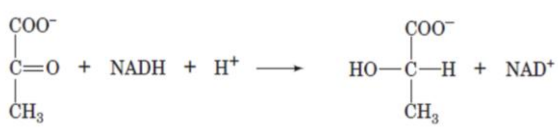
7. In a hypotonic solution:
(*Multiple choice; worth 1 extra credit point*)

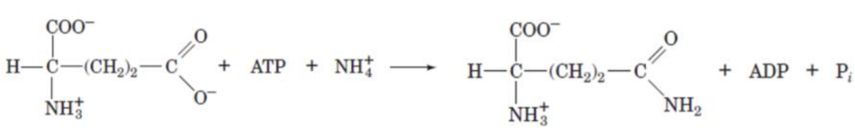
A. Water moves out and cell shrinks
B. There is no water movement
C. Water moves in, cell swell and may eventually burst
D. Water moves in and cell shrinks
E. Water moves out, cell swell and may eventually burst

8. Which of the following reactions is catalyzed by an oxidoreductase?
(*Multiple choice; worth 1 extra credit point*)

A.


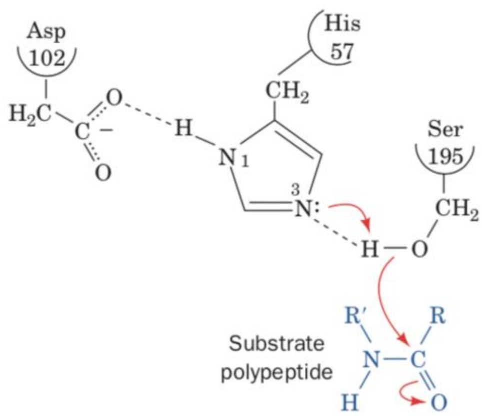
B.


C.


D.


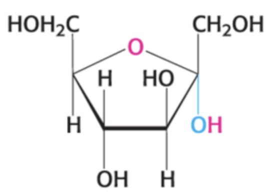
9. The image bellow represents a catalytic triad of a serine protease with a substrate polypeptide highlighted in blue.
(*Multiple choice; worth 1 extra credit point*)

Which of the following amino acid residues serves as a nucleophile?



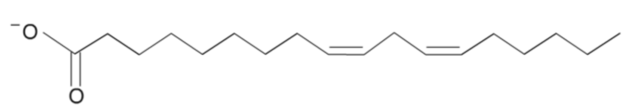
A. Asp102
B. His57
C. Ser195

10. The monosaccharide shown below is:
Select all that apply.
(*Multiple answer; worth 1 extra credit point*)



A. aldose
B. ketose
C. pentose
D. hexose
E. furanose
F. pyranose
G. reducing sugar
H. nonreducing sugar

11. Which of the following designations are accurate for the fatty acid shown?
(*Multiple choice; worth 1 extra credit point*)



A. 8,11-octadecadienoic acid
B. 17:2($\Delta^{8,11}$)
C. ω-6 fatty acid
D. 18:2($\Delta^{6,9}$)