Institutional Effectiveness Report

Name of Program/Department:	**Chemistry**
Year:	**2019-2020**
Name of Preparer:	**Pete Peterson, Chemistry IE and Gen Ed Coordinator, and Department Chair**

Program Mission Statement

The mission of the chemistry department is to provide a dynamic and inquiry based curriculum in chemistry that provides knowledge and skills needed for students to be successful in their professional and life-long endeavors. Accordingly, the department offers introductory, foundation, and in-depth chemistry courses that satisfy requirements in liberal arts, pre-professional programs, the basic chemistry degree, and the American Chemical Society approved degree program. The department strongly encourages students to engage in undergraduate research, service, and networking within the scientific community.

Program Learning Outcomes (PLOs)

Senior chemistry majors at Francis Marion University will be characterized with the following qualities or attitudes:

Direct Assessments:

PLO #1 – Chemistry majors will demonstrate that they have the knowledge and skills needed that will allow them to communicate chemistry effectively in both oral and written form.

PLO #2 – Chemistry majors will demonstrate that they can apply critical thinking skills in chemistry.

PLO #3 – Chemistry majors will demonstrate an understanding of core concepts, methods and limits of scientific inquiry that will allow them to successfully solve integrated problems in chemistry.

PLO #4 – Chemistry majors will demonstrate that they can adequately apply their knowledge of chemistry.

PLO #5 – Chemistry majors will demonstrate that they can adequately use the scientific literature.

PLO #6 – Chemistry majors will demonstrate an understanding of safe laboratory skills and procedures for laboratory experiments that they perform.

PLO #7 – Chemistry majors will have accrued over the period of their undergraduate studies, an overall favorable view of the Department of Chemistry's quality of instruction, advising, and facilities.

Executive Summary of Report

Note: The Department of Chemistry conducts most of the IE assessment in our Spring Chemistry Capstone course after mid-term. But due to the stoppage of in-person classes at mid-term during the Spring 2020 semester because of the Covid-19 Pandemic, The Department of Chemistry was not able to fully evaluate all of its SLO's to the level established during the previous year's IE report (2018-2019). As a result, all SLO's and PLO's that we were able to assess are on a Pass/Fail (P/F) scale. All others will be labeled as NA (not assessed) for the 2019-2020 IE Cycle.

Presented in this report are the Chemistry Department's Mission, Program and Student Learning Outcomes, the assessment and results of each, and action items for the academic year 2019-2020. Achievement and attitudes of our senior chemistry majors on their chemistry concept knowledge and critical thinking skills, and on communication skills were assessed with (1) Capstone writing assignments, (2) a Department generated, In-House Chemistry Diagnostic Exam, (3) a written chemistry term paper, (4) and a chemical safety exam.

Six Students enrolled in the Chemistry 499 Senior Capstone course performed at a 100.00% pass level on a Pass/Fail basis on three Writing Assignments. A score of 60.0% or above is considered a passing score, and anything below 60.00% is considered a failing grade.

Students in the Chemistry 499 Senior Capstone Passed a Department generated, In-House Chemistry Diagnostic Exam at a 100.00% pass level (SLO # 2). A score of 60.0% or above is considered a passing score, and anything below 60.00% is considered a failing grade.

Students in Chemistry 499 Senior Capstone, on average, performed at the 100.0% level or above when demonstrating competency in presenting technical information through their written communication skills on a chemistry topic of their choosing that was approved by the chemistry faculty (SLO # 3). Our goal for SLO # 3 was 80.00%. Therefore, our target was achieved.

All students (100%) enrolled in Chemistry 201 demonstrated an adequate level of understanding of laboratory safety procedures at or above the 70% level (SLO # 5). Our goal for SLO # 5 was 70%. Therefore, our target was achieved.

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Student Learning Outcomes (SLOs)

SLO# 1.0: Students in the Chemistry Senior Capstone course, on average, will perform at or above the 80.00% level, on a Pass/Fail basis, on capstone writing assignments that assess their understanding of key chemical concepts.

SLO# 2.0: 80% of graduating Chemistry majors will Pass a Department generated, In-House Chemistry Diagnostic Exam that assess their understanding of integrated chemical concepts.

SLO #3.0: Students in the Chemistry Senior Capstone course, on average, will perform at or above the 80.00% level on a Pass/Fail basis on their ability to present technical information through written communication.

SLO #4.0: Students in the Chemistry Senior Capstone course, on average, will perform at or above the 80.00% level on their ability to present technical information through oral communication.

SLO #5.0: 100% of students enrolled in Chemistry 201 will demonstrate at an adequate level of 70.00% on their understanding of laboratory safety procedures as evidenced by a Passing grade.

SLO #6.0: 95% of chemistry majors will have accrued over the period of their undergraduate studies, an overall favorable view of the Department of Chemistry's quality of instruction, programs, and facilities.

SLO #7.0: 80% of students tested who are enrolled in General Chemistry 101 will demonstrate an adequate level or above in at least one of the Gen Ed STEM assessment goals.

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Assessment Methods

SLO# 1.0: Students in the Chemistry Senior Capstone course, on average, will perform at or above the 80.00% level, on a pass/fail basis, on capstone writing assignments that assess their understanding of key chemical concepts.

Assessment Method for SLO# 1.0: Three writing assignments (Appendix 1) were administered to eight students during the course of the senior Chem 499 Capstone course for the spring of 2019 semester. The assignments were graded on a pass/fail basis. A passing (P) grade was assigned if the student presented an adequate knowledge or above on the chemical concepts tested as determined by Capstone instructor Pete Peterson. Otherwise a grade of fail (F) was assign.

SLO# 2.0: 80% of graduating Chemistry students will, on average, perform at or above the 50th percentile on their understanding of integrated chemical concepts based on their performance on a Department generated, In-House Chemistry Diagnostic Exam that assess their understanding of integrated chemical concepts.

Assessment Method for SLO# 2.0: Six graduating chemistry senior chemistry majors were administered a Department generated, In-House Chemistry Diagnostic Exam that assess their understanding of integrated chemical concepts.

SLO #3.0: Students in the Chemistry Senior Capstone course, on average, will perform at or above the 80.00% Pass level on their ability to present technical information through written communication

Assessment Method for SLO# 3.0: To assess their written communications skills, six students enrolled in the Chemistry Senior Capstone course wrote a term paper near the end of the spring semester of 2020, based on a technical chemistry topic they select and then was faculty approved. Each paper was graded by Capstone instructor Pete Peterson using a standard, department generated grading rubric for scientific term papers.

SLO #4.0: Students in the Chemistry Senior Capstone course, on average, will perform at or above the 80.00% level on a Pass/Fail level.

Assessment Results

SLO# 1.0: Students in the Chemistry Senior Capstone course, on average, will perform at the 80% level, on a pass/fail basis or above, on capstone writing assignments that assess their understanding of key chemical concepts.

Assessment Results for SLO# 1.0: Students in 499 Chemistry Senior Capstone on average, performed at a 100% pass rate for the 2019-2020 academic year for SLO # 1. Therefore, this passing level for SLO # 1 did reach our target goal of 80.00%.

SLO# 2.0: 80% of graduating Chemistry students will, on average, perform at the 50th percentile or above when demonstrating their understanding of integrated chemical concepts based on their performance on a nationally standardize chemistry exam. The exam, which is the ACS (American Chemical Society) Diagnostic of Undergraduate Chemical Knowledge (DUCK) exam, consisted of several chemistry scenarios testing integrated chemical concepts, each of which was followed by several multiple choice questions based on it. There are a total of 60 questions in all.

Assessment Results for SLO# 2.0: Senior FMU chemistry majors scored an average at the 20.75 percentile with a range of 38.00-8.00 percentile for the 8 students taking the DUCK exam. Therefore, this 20.75 percentile of students scoring at or above the 50th percentile for SLO # 2.0 did not reach our target goal of 80.00%.

SLO #3.0: Students in the Chemistry Senior Capstone course, on average, will perform at the 80% level or above when demonstrating competency in presenting technical information through written communication in the form of a chemistry term paper.

Assessment Results for SLO# 3.0: 100% of the students in 499 Chemistry Senior Capstone, on average, performed at the Pass level on their chemistry term paper as graded by the Chemistry 499 Capstone instructor using a standard scientific term paper rubric (Appendix 3). Our target for SLO # 3 was 80.00%. Therefore, our target was achieved.

SLO #4.0: Students in the Chemistry Senior Capstone course, on average, will perform at the 80% level or above when demonstrating competency in presenting technical information through oral communication.

Assessment Results for SLO# 4.0: No SLO 4 Assessment is available for the 2010-2020 IE Cycle.

SLO #5.0: 100% of students enrolled in Chemistry 201 will demonstrate an adequate or above understanding of laboratory safety procedures at the Passing Level.

Assessment Results for SLO# 5.0: 100% of students enrolled in Chemistry 201 demonstrated an understanding of laboratory safety procedures at the Passing level on a comprehensive and cumulative lab safety exam that was produced and administered by the Chemistry Department. Respective lab instructors graded the lab safety exams.

Action Items

No action items are available at the present. The Department of Chemistry are in the process of evaluating the above results to establish new action steps to be launched during the Spring 2021 semester.

Appendix 1

Capstone Writing Assignment 1 **Due Date: By 5:00 pm on 28/Jan/20**

Name_____

Title: Production of Table Salt from the Reaction of Baking Soda with Hydrochloric Acid

Lab Setup:

A lab experiment was performed to produce table salt (sodium chloride, NaCl) by reacting a quantity of baking soda (sodium bicarbonate, $NaHCO_3$) with a stoichiometric amount of hydrochloric acid (HCl) according to the reaction:

$NaHCO_3$ (s) + HCl (aq) → NaCl (s) + CO_2 (g) + H_2O (l)

The experiment begins by weighing a clean, dry, empty test tube. The baking soda was then placed in the test tube and the mass of the tube plus the baking soda was determined. Stoichiometric amounts of hydrochloric acid was then slowly and carefully added to the tube, whereupon the reaction occurred to completion as described above, until all the baking soda reacts.

The resulting solution was then carefully heated to dryness, leaving behind only the table salt, a white solid. The test tube with the table salt product were allowed to cool to room temperature and then weighed again. The mass of the table salt produced was then determined by subtraction.

Circle the correct answer for the questions below and give a brief justification for your answer directly below it. Use additional sheets for the justification if needed.

1. If the baking soda was unknowingly added to a wet test tube and then weighed, the calculated mass of table salt at the end of the experiment in comparison to the mass calculated using the dry test tube would be

(a) too high (b) too low (c) the same (d) equal to the excess water

Justification:

2. The formula NaCl tells us that there is

(a) 1 gram of sodium per 1 gram of chlorine. (b) 1 atom of sodium per 1 atom of chlorine.

(c) 1 mole of sodium per 1 gram of chlorine. (d) 1 atom of sodium per 1 mol of chlorine.

Justification:

3. When the procedure is carried out correctly using stoichiometric amounts of baking soda and hydrochloric acid, the mass of table salt formed is less than the mass of the baking soda reacted. Why is this?

(a) The mass of sodium in the table salt is less than the mass of sodium in the baking soda.
(b) The mass of chlorine in the table salt is less than the mass of bicarbonate in the baking soda.
(c) The mass of bicarbonate in the baking soda is less than the mass of chlorine in the table salt.
(d) Much of the baking soda is lost due to splashing.

Justification:

4. After the conversion of baking soda to table salt is complete, and the tube and sodium chloride is weighed, a student then adds more hydrochloric acid to the table salt in the tube, again heated to dryness, and then weighs the tube and its contents a second time. The mass of the tube and its contents should be _____ .

(a) the same as its mass before adding more hydrochloric acid.
(b) more than its mass before adding more hydrochloric acid.
(c) less than its mass before adding more hydrochloric acid.
(d) the same as the mass of the hydrochloric acid added.

Justification:

5. A student wishes to prove that the conversion of baking soda to table salt is complete. Which of the following observations would most likely indicate that the conversion was completed?

(a) The solid remaining in the test tube was white.
(b) The solid remaining in the test tube gives a positive test for chloride ion.

(c) Addition of HCl to the solid remaining in the test tube yields no evolution of gas
(d) Litmus paper shows that the white solid is basic.

Justification:

6. Student A uses twice as much HCl in the procedure as student B. Which of the following statements is true?

(a) Both students will obtain the same amount of NaCl.
(b) Student A will obtain twice as much NaCl.
(c) Student A will obtain $NaCl_2$.
(d) Student A's reaction will not work, and the solid remaining in the test tube will be baking soda.

Justification:

Capstone Writing Assignment 2 Due Date: By 5:00 pm on 11/Feb/20

Name_____

For the compound with the molecular formula $C_5 H_{10} O$, determine the correct structure from its corresponding proton nmr spectrum, C-13 nmr spectrum, IR spectrum, and its mass spectrum, all of which are given below. Draw your structure using a molecular drawing software program such as ChemDraw or Accelrys Draw and attach it to this report. For each of the spectra, provide a reasonable explanation below on what specific piece of information it provided to allow you to ascertain the structure.

Correct structure of $C_5 H_{10} O$ (Draw by hand here):

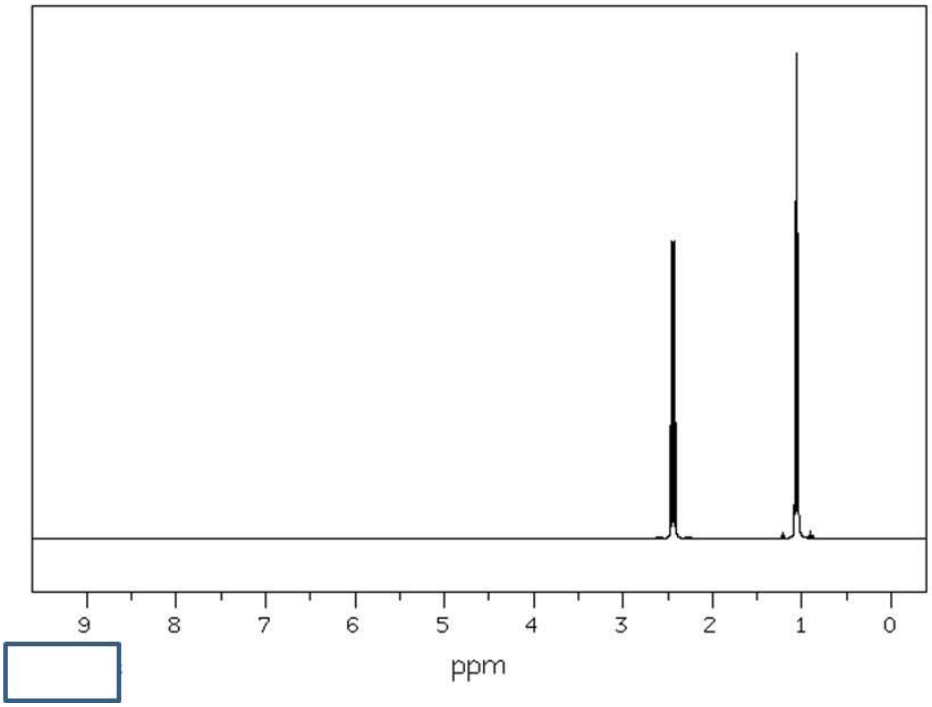
Proton NMR spectrum:

^{13}C NMR spectrum:

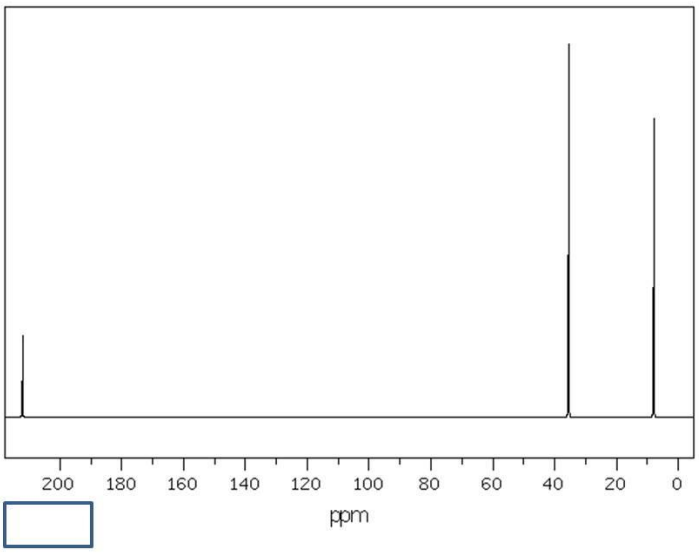
IR Spectrum:

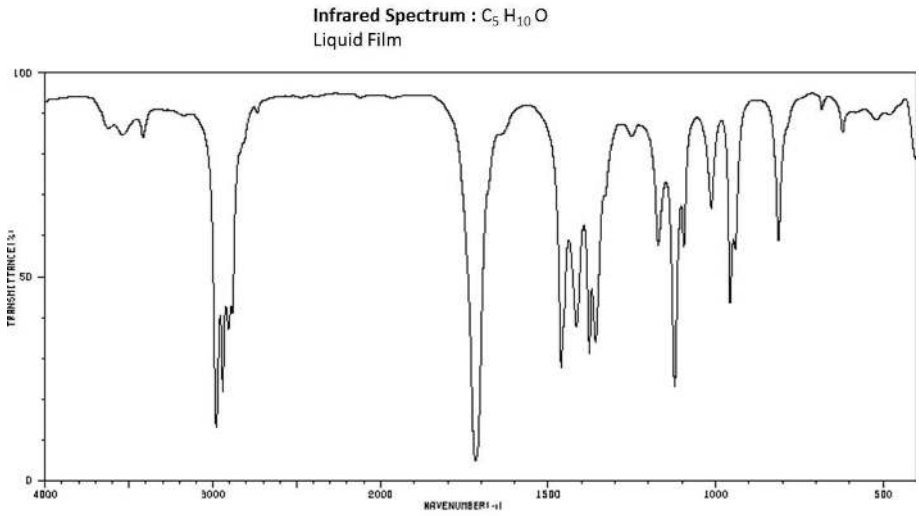
Mass Spectrum:

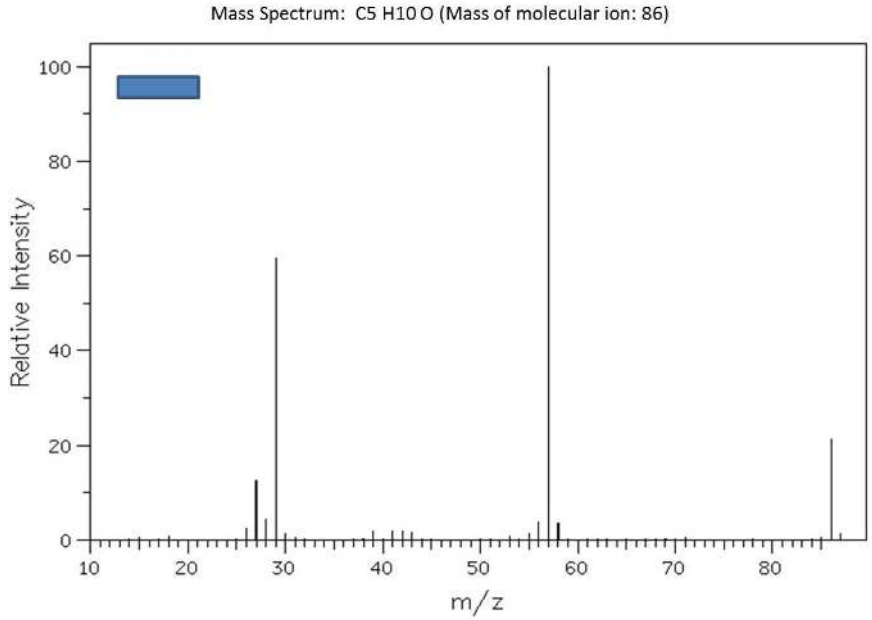
Proton NMR Spectrum: $C_5H_{10}O$
$CDCl_3$ Solvent 399.65 MHz



^{13}C NMR Spectrum: $C_5H_{10}O$
$CDCl_3$ Solvent 15.09 MHz







Capstone Writing Assignment 3 Due Date: By 5:00 pm on 2/Mar/20

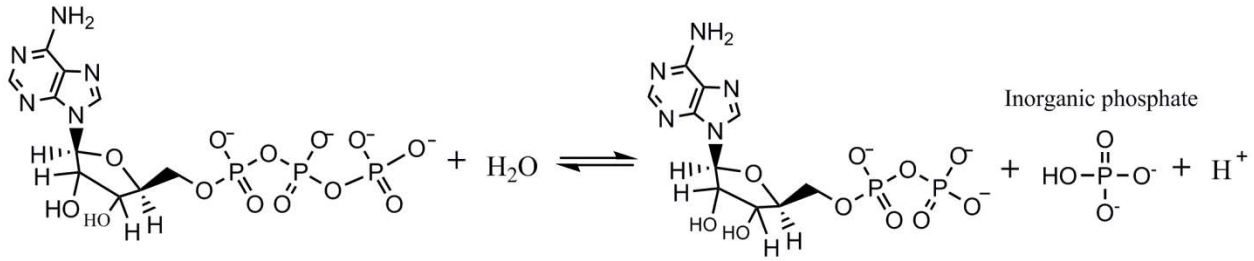
Name_____

The hydrolysis of adenosine triphosphate (ATP) to yield adenosine diphosphate (ADP) plus an inorganic phosphate (HPO_4^{2-} or p_i) is a crucial biochemical reaction:

, P_i

Adenosine triphosphate, ATP

Adenosine diphosphate, ADP



$$ATP^{4-} + H_2O \rightleftharpoons ADP^{3-} + HPO_4^{2-} + H^+ \qquad \Delta G^{o'} = -30.5\ kJ/mol$$

Write a short paper of about 250 words or less that discusses both the importance of this reaction and addresses the following topics:

(a) Describe the basic structural components of ATP, and tell why the reaction above is classified as a hydrolysis?

(b) The value of $\Delta G^{o'}$ is -30.5 kJ/mol. Determine and then justify whether or not the reaction is spontaneous under standard state conditions at 25°C.

(c) The standard enthalpy change (ΔH^o) for the ATP hydrolysis reaction above is -16.7 kJ/mol at 25°C. Determine the corresponding value for ΔS^o, and decide if this value makes sense based on the number of reactants and products species given in the ATP-to-ADP hydrolysis reaction above? Justify your response.

(d) ATP is a major energy transporter for many biochemical reactions in the cell to make nonspontaneous reactions spontaneous. Describe how ATP performs this task, and give a specific example of this.

(e) ADP must constantly be converted back to ADP to meet the steady energy requirements of cells. Give a very brief and general overview of where the energy comes from to convert ADP back to ATP?

Your paper will be graded on the degree to which it addresses the points above, on basic grammar and punctuation, and on its organization and structure. You are free to order the topics in any way to produce an effective, well written paper. You may also discuss additional topics for continuity and support.

Chemistry 499 Capstone Assessment Exam Spring 2020

Name _____

Instructions: All capstone students must take this exam for the assessment of our chemistry program. Your grade on this exam will not affect your grade in the course, but you must take it to receive that part of your course grade. This is a multiple choice exam (a,b, c, or d) consisting of 31 problems. You may use a calculator with no programmed information.

You must email to me your answers (a,b,c,or d) by 11:00am on Monday May 4th to be counted.

The periodic table and other information that you may want to use are given at the end of this exam. You should work this exam alone and use only the information given and no other outside information.

You must email to me by 11:00am on Monday May 4th your answers (a, b, c, or d) in the following format:

1.____ , 2.____, 3.____, 4.____, 5.____, 6.____, 7.____, 8.____, 9.____, 10.____

11.____ , 12.____, 13.____, 14.____, 15.____, 16.____, 17.____, 18.____, 19.____, 20.____

21.____ , 22.____, 23.____, 24.____, 25.____, 26.____, 27.____, 28.____, 29.____, 30.____

31. ____, 32.____, 33.____, 34.____, 35.____

I do not need to see any work; just your answers (a,b,c,or d).

If you still have other exams then this exam must not conflict with them, so it is strongly advised that you finish this exam over the weekend when there should not be any conflicts with your other classes.

1. 4.00 mol of Fe (s) and 6.00 mol of O_2(g) are brought together and a reaction occurs to produce Fe_2O_3 (s), with a yield of 1.90 mol of Fe_2O_3 (s) according to the reaction 4 Fe (s) + 3 O_2 (g) —> 2 Fe_2O_3 (s). Which statement is true about this reaction?
(a) Fe is the limiting reagent. (b) O_2 is the limiting reagent.
(c) The yield of Fe_2O_3(s) is less than 50.0%. (d) The equation is not balanced.
2. Calculate the concentration of OH^- in a solution that contains 2.6 x 10^{-11} M H_3O^+ at 25°C. Identify the solution as acidic, basic, or neutral.
(a) 2.6 × 10^{-11} M, basic
(b) 3.8 × 10^{-4} M, basic
(c)) 2.6 × 10^3 M, acidic
(d) 3.8 × 10^{-4} M, acidic
3. Place the compounds CH_4 ,H_2O, and CH_3Cl in order of **increasing** strength of intermolecular forces.
(a) H_2O < CH_3Cl < CH_4
(b) CH_4 < CH_3Cl < H_2O
(c) CH_3Cl < CH_4 < H_2O
(d) CH_4 < H_2O < CH_3Cl
4. Which of the following terms is INCORRECTLY defined?
(a) titration error: the difference between the end point and the equivalent point.
(b) equivalent point: volume of titrant added in excess of the end point to change a physical property of the analyte solution.
(c) blank titration: titration performed without analyte to calculate titration error.
(d) standardization: titration of a known amount of analyte to determine the concentration of the titrant.
5. A student must prepare 500.0 mL of solution containing 0.999 grams of solid copper(II) sulfate. Which of the following statements are FALSE regarding the proper procedure to prepare this solution?
I The 0.999 grams of solid copper(II) sulfate is dissolved in a 500.0-mL volumetric flask containing 500.0 mL of water.
II The 0.999 grams of solid copper(II) sulfate is dissolved in a 500.0-mL volumetric flask containing 400 mL of distilled water before dilution to 500.0-mL.

III The 0.999 grams of solid copper(II) sulfate is placed in an empty 500.0-mL volumetric flask, diluted to 500.0 mL and allowed to dissolve.

(a) I and III (b) II and III

(c) I and II (d) I, II, and III

6. An aromatic electrophilic substitution reaction to produce nitrobenzene ($C_6H_6NO_2$) may be accomplished by _____.

(a) the reaction of benzene (C_6H_6) with the nitronuim ion (NO_2^+).

(b) the reaction of hexane (C_6H_{14}) with nitric oxide (NO).

(c) the reaction of cyclohexane (C_6H_{12}) with nitric oxide (NO).

(d) the reaction of benzene (C_6H_6) with dinitrogen and dioxygen.

7. A solution proton NMR spectrum of ferrocene [$(C_5H_5)_2Fe(II)$] shows only one resonance. What does this suggest about the structure of ferrocene?

(a) All the H atoms in the molecule are in the same environment.

(b) All the H atoms are in the molecule are in different environments.

(c) The molecule is paramagnetic

(d) The molecule is diamagnetic.

8. Which of the following statements is true about paramagnetic substances?

(a) A paramagnetic substance is repelled by a magnetic field.

(b) The magnetic susceptibility measurement of a paramagnetic substance will give a negative reading.

(c) A paramagnetic substance has one or more unpaired electrons.

(d) A paramagnetic substance must be ionic.

9. Which of the following compounds is aromatic?

(a) benzene, C_6H_6 (b) cyclopentadiene, C_5H_6

(c) propane, C_3H_8 (d) cyclopropane, C_3H_6

10, Which statement is true about the conformations of ethane, C_2H_6?
(a) The staggered conformation of ethane is lowest in energy.
(b) The eclipsed conformation of ethane is lowest in energy.
(c) Any two H atoms on different C atoms in the staggered conformation have the closest distance apart compared to other conformations of ethane.
(d) All conformations of ethane have the same energy.
11. Which of the following processes will most likely lead to a decrease in entropy of the system?
(a) H_2 (g) + 1/2 O_2 (g) → H_2O (l)
(b) H_2O (s) → H_2O (g)
(c) H_2O (l) → H_2O (g)
(d) H_2O (s) → H_2O (l)
12. Which of the following substance is an ether?
(a) C_3H_6 (b) $CH_3CH_2OCH_2CH_3$
(c) CH_3CO_2H (d) $CH_3CH_2NH_2$
13. Which of the reactions may be classified as a hydrolysis reaction?
(a) $CH_3C(O)_2CH_3 + H_2O$ → $CH_3CO_2H + CH_3OH$
(b) $2H_2O$ → $2H_2 + O_2$
(c) $2H_2 + O_2$ → $2H_2O$
(d) H2 □ 2H
14. For the quantum mechanical particle in a one-dimensional box of length a, what would be the effect on its energy levels if the length of the box is increased?
(a) All the energy levels will be lowered in energy.
(b) Only the n=1 energy level will be lowered, while the other levels will remain the same.
(c) All the energy levels will be increased in energy.
(d) Only the n=1 energy level will be increased, while the other levels will remain the same.

15. What is the equilibrium constant expression for the reaction below?
$CaCO_3$ (s) ⇄ CaO (s) + CO_2 (g)
16. The reaction A + B —> C is first order in A and zero order in B. Which of the following statements is true?
(a) The reaction rate does not depend on the concentration of A.
(b) The reaction rate does not depend on the concentration of B.
(c) The reaction rate depends on the concentration of B only.
(d) The reaction rate depends on the product of the concentrations of A and B.
17. Which combination for the signs (positive or negative) of ΔH and ΔS will always lead to a spontaneous reaction?
(a) ΔH negative, and ΔS negative (b) ΔH positive, and ΔS positive
(C) ΔH negative, and ΔS positive (d) ΔH positive, and ΔS negative
18. Unlike to the ideal gas equation, the van der Waals equation for gases accounts for both the _____.
(a) bond energies and bond distances of the gas particles.
(b) rms speed and viscosity of the gas particles.
(c) enthalpy and entropy changes of the gas particles.
(d) molecular gas volume and attractive intermolecular forces of the gas particles.
19. Which spectrum depends on the existence on the vibrational motion of a molecule?
(a) infrared (b) UV-visible (c) NMR (d) X-ray photoelectron

20. In the Schrodinger equation with wave function Ψ, the square of the wave function Ψ_2 gives information about _____.

(a) the probability of finding a particle in a particular region in a quantum mechanical system.

(b) the mass of a quantum mechanical particle.

(c) the momentum of a quantum mechanical particle.

(d) the charge of a quantum mechanical particle.

21. Which of the following is characteristic of an S_N2 reaction?

(a) An S_N2 reaction occurs in multiple steps.

(b) An S_N2 reaction results in the inversion of stereochemistry.

(c) An S_N2 reaction is unimolecular.

(d) An S_N2 reaction does not involve a nucleophile.

22. Which statement is true for reactions A → B (solid line) and C → D (dashed line) as shown on the potential energy diagram provided?

(a) Reaction A→ B is endothermic, whereas reaction C → D is exothermic.

(b) Reactions A→ B and C → D are exothermic.

(c) The activation energy for A→ B is greater than the activation energy for C → D.

(d) The activation energy for A→ B is less than the activation energy for C → D.

23. The reaction A + B ---> D proceeds according to the following mechanism:

Step 1. A --> E (slow)

Step 2. E + B --> D (fast)

What is the rate law for the overall reaction?

(a) Rate = k[A] (b) Rate = k[E][B]

(c) Rate = k[A][B] (d) None of the above

24. The equilibrium between hemoglobin (Hb) and dioxygen is vital for human life : Hb *(aq)* + $4O_2$ *(g)* ⇋ $Hb(O_2)_4$ *(aq)*. What will be an effect on this equilibrium of an increase in the concentration of O_2 at a given temperature?
(a) The equilibrium will shift to the left to the reactant side.
(b) There will be no change in the concentrations of reactants and the product.
(c) More $Hb(O_2)_4$ *(aq)* will be produced.
(d) There will be an increase in the value of the equilibrium constant.
25. Which valence orbitals are typically being filled in the transition metals?
(a) s orbitals (b) p orbitals (c) d orbitals (d) f orbitals
26. Identify the element or ion with the atomic number 77.
(a) Au (b) Se (c) Au^{2+} (d) Ir^{2+}
27. The geometry or shape of PCl_5 may be described as _____.
(a) trigonal planar. (b) square planar.
(c) trigonal bipyramidal. (d) octahedral.
28. The H-N-H bond angles in NH_3 is _____.
(a) 109.5 ^{o}. (b) 180.0 ^{o}.
(c) less than 109.5 ^{o}. (d) the same as the H-N-H bond angle in NH_2-.
29. What information can X-ray crystallography provide for a given molecular crystal?
(a) the identity of the atoms. (b) bond distances
(c) bond angles (d) all of the above (a, b, and c)
30. The most significant intermolecular interaction that exists between water molecules is _____.
(a) ion-ion (b) ion-dipole (c) hydrogen bonding (d) dispersion forces
31. Ozone (O_3) is a bent molecule. Its point group is _____.
(a) C_{3v} (b) D_{3h} (c) C_{2v} (d) T_d
32. Which iron (II) complex ion is expected to be low spin? All complex ions are octahedral.
(a) $[Fe(CN)_6]^{4-}$ (b) $[Fe(H_2O)_6]^{2+}$ (c)) $[Fe(Cl)_6]^{4-}$ (d)) $[Fe(Br)_6]^{4-}$

33. Which term symbol represents the **highest** energy state for a given element?
(a) $_3P$ (b) $_3F$ (c) $_1P$ (d) $_1S$
34. Which of the following absorption of electromagnetic radiation requires the highest energy to achieve?
(a) H: n=1 → n=2 (b) H: n=1 → n=3
(c) Li^{2+}: n=1 → n=2 (d) Li^{2+}: n=1 → n=3
35. The effect of backbonding in metal carbonyl complexes is to _____.
(a) lower the CO infrared stretching frequency compared to free CO.
(b) increase the CO infrared stretching frequency compared to free CO.
(c) decrease the CO bond distance compared to free CO.
(d) increase the CO bond strength compared to free CO.

Useful Information R: 8.314 J / K.mol ; 1 atm = 101325 Pa = 1.01325 bar
0.08314 L. bar/mol . K ; 0.0821 L atm/mol K
= 83.145 cm^3 bar $mol^{-1}K^{-1}$;
K = ^oC + 273 Boltzman constant = 1.381 X 10^{-23} JK^{-1}
Avogadro's number : 6.022 X 10^{23}
c= speed of light in vacuum= 3.00 X 10^8 m/s 100 cm = 1 m 1 pm = 1 x 10-12 m
h= Planck's Constant = 6.626 X 10^{-34}J.s
Rydberg Constant (R_H) = 2.179 X 10^{-18}J or 1.097 X 10^7m^{-1}