

CHE 135. General Chemistry III Lab

Kahveci Group

Last generated: September 07, 2020



© 2020 Kahveci Group. All rights reserved. No part of this publication may be reproduced, distributed, or transmitted in any form or by any means, including photocopying, recording, or other electronic or mechanical methods, without the prior written permission of the publisher, except in the case of brief quotations embodied in critical reviews and certain other noncommercial uses permitted by copyright law.

Table of Contents

Course Details

Course Overview	2
-----------------------	---

Experiments

Experiment 1. Acids and Bases	3
Experiment 2. Buffer Solutions.....	9
Experiment 3. Amino Acid Titration.....	14
Experiment 4. Le Châtelier's Principle	17
Experiment 5. Spectrophotometric Analysis of Manganese in Steel	19
Experiment 6. Thermodynamics of a Cobalt Complex	24
Experiment 7. Electrochemistry	28
Experiment 8. Coordination Chemistry	31

General Chemistry III Lab

Note: CHEM 135 General Chemistry III Lab (undergraduate level) was taught by [Murat Kahveci](#) at [DePaul University](#) in Autumn 2020, Spring 2020, Autumn 2019, Autumn 2017, Summer 2017. [CHEM 135 Course URL](#)

CHE 135 is a co-requisite for CHE 134, General Chemistry III. Credit for CHE 122/132 and CHE 133 are prerequisites for this course. This course, in conjunction with CHE 134, can be used by non-science majors to fulfill a Scientific Inquiry-Lab (SI-Lab) learning domain requirement in the Liberal Studies Program. The laboratory experiments you will perform will reinforce material presented in lecture and allow you to explore lecture topics in more detail. Specific learning objectives for each experiment can be found in the laboratory manual on D2L. You will be assessed based on your level of preparedness, accuracy, laboratory technique, data analysis, and overall understanding of the experiments. Your results, analysis, and understanding will be presented in laboratory reports. The writing of laboratory reports will also offer you the opportunity to develop your scientific writing skills.

The laboratory is a critical component of your education as a scientist. Because of the importance of the laboratory, if you have two or more laboratory absences for invalid reasons, you will fail this course.

The scientific inquiry learning domain learning outcomes and writing expectations

The learning outcomes for the SI:Lab learning domain are listed below. They may also be found online on the Liberal Studies Program web site.

In the context of natural science content, and building on the understanding of the scientific worldview and the nature and process of science they have developed in the Science as a Way of Knowing (SWK) course:

Students will understand how science serves as a mechanism for inquiry into the natural world through hands-on, experience-based investigation.

1. Students will be able to pose meaningful scientific questions and generate testable scientific hypotheses.
2. Students will be able to plan, design and conduct scientific investigations in a collaborative environment using appropriate tools and techniques to gather relevant data in order to test and revise scientific hypotheses.
3. Students will be able to develop and use scientific models (conceptual, physical, and mathematical) to make predictions and develop explanations of natural phenomena.
4. Students will be able to address variability in the data and recognize and analyze alternative explanations and predictions.
5. Students will be able to communicate scientific procedures, results, and explanations and engage in arguments based on scientific evidence.

Formal writing is essential for communicating ideas and progress in science, mathematics, and computation to experts within the field and to the broader society. Courses within the Scientific Inquiry Domain should include both formal writing (for example lab reports, essays, and written responses to questions) and supplemental elements that are appropriate for the subject of the course such as mathematical equations, computer code, figures and graphs, lab notebooks, or field journals.

Acids and Bases

Summary: Goals, assignments, and Q&A highlights about the Acids and Bases Experiment.

Note: AQ20: Experiment 1

1 Goals

1.1 Examine the effect of dilution on the pH of strong and weak acids and bases

- Calculate, using $M_1V_1 = M_2V_2$, the concentration of HCl, NaOH, CH_3COOH , and NH_4OH for the 1:10 and 1:100 diluted solutions and the mixtures.
- Calculate $[\text{H}_3\text{O}^+]$ for each solution using the measured pH values and Equation 2.

$$\text{pH} = -\log[\text{H}_3\text{O}^+] \quad (1)$$

$$[\text{H}_3\text{O}^+] = 10^{-\text{pH}} \quad (2)$$

- Make a plot of pH vs. concentration for HCl and CH_3COOH , and another for NaOH and NH_4OH .
- The strong and weak species should show a different dependence of pH on concentration.

1.2 Calculating the values of K_a and K_b

$$K_a = \frac{[\text{A}^-][\text{H}_3\text{O}^+]}{[\text{HA}]} \quad (3)$$

where, $[\text{H}_2\text{O}]$ is omitted because it is pure liquid.

$$K_b = \frac{[\text{BH}^+][\text{OH}^-]}{[\text{B}]} \quad (4)$$

where, $[\text{H}_2\text{O}]$ is omitted because it is pure liquid.

$$\% \text{ ionization} = \frac{[\text{H}_3\text{O}^+]}{[\text{HA}]_0} \times 100\% = \frac{[\text{A}^-]}{[\text{HA}]_0} \times 100\% \quad (5)$$

$$\% \text{ ionization} = \frac{[\text{BH}^+]}{[\text{B}]_0} \times 100\% = \frac{[\text{OH}^-]}{[\text{B}]_0} \times 100\% \quad (6)$$

- Calculate K_a using Equation 3,
- Calculate K_b using Equation 4,
- Calculate the percent dissociation of the weak acid using Equation 5, and
- Calculate the percent dissociation of the weak base using Equation 6.

1.3 Examine the pH of mixtures of strong and weak acids and bases

- Examine the pH of mixtures of strong and weak acids and bases to see how the presence of a strong acid or base impacts the percent dissociation of the weak acid or base.
- Calculate the percent dissociation of the weak acid using Equation 5, and
- Calculate the percent dissociation of the weak base using Equation 6.

2 Assignment

- Watch pH meter calibration video
- Watch solution preparation and pH determination video
 - Only shown for HCl; same process used for other solutions
- Take the post-lab quiz with a 70% or higher
- Download the data set and do the data analysis
- You must upload a PDF file of **partial lab report**:
 - This is a deviation for the summer session only
 - Include the following sections: **Procedures**, **Results**, **pH Data Tables**, **pH vs. Concentration Plots**, and **Discussion** (not a full discussion section; just itemize and answer the questions.)
 - You don't need to include sample calculations in the partial report (it is in Excel only), don't need to write narrative explaining data tables and calculations.
- You must upload all calculations and data tables in an MS Excel file
- You should review the **Lab Report Guidelines**, **Sample General Chemistry Lab Report**, and **Appendix E** on D2L while writing to ensure that your drafts are correctly formatted.

3 Q&A Highlights

3.1 Calculating the concentration of 1:10 and 1:100 solutions

I think V_1 for stock solutions is 50 mL, but can't figure out what V_1 is for 1:10 (10 mL ?) and 1:100 dilutions. I want to confirm that M_1 is 1.0 M for all calculations and V_2 is 100 mL. I've looked at the lab procedure and lab video, but get confused about the process of dilutions regarding volumes of V_1 .

As an example, I will walk through the concentration calculations for the hydrochloric acid dilutions.

The concentration of the stock solution, (let's use 3 sig. figs.)

where 1 means initial state. Likewise, we would use 2 to indicate the final state.

3.2 10-fold or 1:10 dilution

Dilute the solution 10-fold by using a clean, primed, 10 mL volumetric pipette to add 10.00 mL of the stock acid solution to a 100 mL volumetric flask and filling it to the line with deionized water.

This means:

- $V_1 = 10.00$ mL, which is the amount taken from the stock solution.
- $V_2 = 100.00$ mL, final volume after the dilution.

Calculate the concentration of 10-fold dilution as follows.

$$M_1 V_1 = M_2 V_2$$

Isolate M_2 :

$$M_2 = \frac{(1.00 \text{ M})(10.00 \text{ mL})}{100.00 \text{ mL}} = 0.100 \text{ M HCl solution}$$

3.3 Second 10-fold or 1:100 dilution

Dilute this solution [i.e. 10-fold diluted solution] another 10-fold by using a 10 mL volumetric pipette to add 10 mL of the 1:10 acid solution to a 100 mL volumetric flask and filling it to the line with deionized water.

So, we are using the concentration of 10-fold dilution as the initial concentration for the second 10-fold dilution.

$$M_2 = \frac{(0.100 \text{ M})(10.00 \text{ mL})}{100.00 \text{ mL}} = 0.0100 \text{ M HCl solution}$$

3.4 Volumes in L or mL for dilution calculations

I noticed in your sample calculations for the 10 and 100 fold dilutions you used the volumes in mL where molarity is calculated using the units liters. I was wondering if we were to use the volumes in mL as you did in the sample calculations under the Q&A's or convert these to the units of liters.

The unit of analysis for volume could be mL or L in dilution calculations because the volume units cancel.

4 Assessment

4.1 Misconceptions

The ratio of the hydronium ion concentration that was calculated came out to be 0.645% for the weak

base and 0.912% for the weak acid. Based on the data gathered for the combination of a strong acid and weak acid, the percent dissociation of a weak acid affected the presence of a strong yield by caused the weak acid to dissociate. The calculated pK_a is less than the pK_b which would mean there was an error that occurred

Chemical species are not clearly defined. Arguments are not supported by the experimental findings.

When the strong acid and the weak acid are combined, the concentration of the hydroniumions increases for the weak acid. This increase of hydronium ions would increase the percent ionization for the weak acid. This is shown in the calculated percent ionization of the combined strong and weak acid.

...Therefore, the percent dissociation of the weak acid increases in the presence of a stronger acid because...

The percent dissociation of a weak acid in the presence of a strong acid causes the weak acid to dissociate more than usual.

What is the evidence for supporting these arguments? *Hint:* Perhaps pH is only affected by the strong acid.

Based on the data for CH_3COOH , as the concentrations of the weak acid decreases, the percent dissociation of the acid increases.[more explanation continues based on experimental values.]

Nice that you are using experimental values to justify your argument. However, it would be nicer to explain this phenomenon by considering the Le Châtelier's Principle. *Hint:* What happens to the equilibrium condition when you dilute the solution?

4.2 Formatting issues

$3.31 * 10^{-14}$

Should be reported as: 3.31×10^{-14}

2.82E-14

Should be reported as: 2.82×10^{-14}

NH4OH

Should be reported as: NH₄OH

Figures with missing legends.

All legends should be present when there are more than one data series.

Figures with gridlines.

All gridlines should be removed. Formatting requirement.

4.3 Feedback

- The PDF file you uploaded: annotations are highlighted with gray background and pink font.
- E-Rubric: D2L will show the rubric with scores and any feedback provided.

4.4 Grades

Table 1. Grade stats for this experiment.

Term Statistics ^a	Average	Stdev	Median	Maximum	Minimum
SSQ 2020	79.26%	14.96%	77.42%	95.83%	43.83%
^a All zero values are excluded.					

4.5 Team grading

Table 2. Task sharing for team grading based on the sections of the rubric.

Instructor	Teaching Assistant
Overall Clarity and Flow	Procedure
Results	Table Formatting
Proofreading and General Formatting	Figure Formatting
pH Data Tables	Prelab Quiz
pH vs. Concentration Plots	Postlab Quiz
Discussion Questions	Excel Calculations

Buffer Solutions

Summary: Goals, assignments, and Q&A highlights about the Buffer Solutions Experiment.

Note: AQ20: Experiment 2

1 Goals

1.1 Prepare the buffers A1-E1

- Calculate the concentration of each component present in buffers A1-E1 using the concentration of each stock solution, the volume of each solution delivered, and the total volume of buffer created.

Table 1. Preparing buffer solutions.

Solution	Volume (mL) of CH_3COOH or NH_4Cl	Volume (mL) of CH_3COONa or NH_3
A1	15.00	15.00
B1	20.00	10.00
C1	25.00	5.00
D1	5.00	25.00
E1	10.00	20.00

1.2 Generate the plot of pH vs. $\log([\text{base}]/[\text{acid}])$

- Fit the data to a line (i.e. trendline).
- Calculate the slope (3 sig. figs required) using `=SLOPE()` function in Excel.
- Calculate the intercept (3 sig. figs required) using `=INTERCEPT()` function in Excel.

1.3 Generate the plot pH vs. the logarithm of the dilution factor

- Generate a single scatter plot of pH vs. the logarithm of the dilution factor (1, 10, 100) for each buffer component using Excel.
- Both data sets should be presented on the same plot.
- Do not fit the data to a trendline.

2 Assignment

- Watch pH meter calibration video
- Watch the videos, pass the postlab quiz, and download your data set for Experiment 6
- Analyze the data in Excel
- Submit your partial lab report in a PDF file and all calculations in an Excel file.
- You should review the [Lab Report Guidelines](#), [Sample General Chemistry Lab Report](#), and [Appendix E](#) on D2L while writing to ensure that your drafts are correctly formatted.

3 Q&A Highlights

3.1 Total volumes of buffer solutions

I'm not confident which volumes I should use as my volume delivered and total volume. Should I add the volumes of NH_4Cl and NH_3 together as my volume delivered? In my Excel calculations, I then added 75mL from HCl for my total volume for A1, C1, and D1. The procedure mentions adding HCl to A1, C1, and D1, but I'm not sure what I need to incorporate into my total volume for B1 and E1 since the procedure doesn't say much else about them, or what to do with A2.

First of all, please try to make your questions more concise. It is a little hard to follow what is being asked here. Perhaps, sending your existing work might help clarify your confusion easier.

According to Table 2, solution A1 has the following total volume:

$$V_{tot,A1} = V_{\text{CH}_3\text{COOH or NH}_4\text{Cl}} + V_{\text{CH}_3\text{COONa or NH}_3}$$

$$V_{tot,A1} = (15.00 \text{ mL}) + (15.00 \text{ mL}) = 30.00 \text{ mL}$$

Likewise, sum the volume values of each species for B1, C1, D1, and E1 to calculate their respective V_{tot} values.

Next step is about addition of HCl solution. [Obtain 75 mL of 0.10 M hydrochloric acid and 75 mL of 0.10 M sodium hydroxide. Add 10 mL of hydrochloric acid to solutions A1, C1, D1, and Water 1.](#)

I will show the volume calculation for A1 only. 10.00 mL HCl solution is added to A1. Thus:

$$V_{tot,A1 \text{ with HCl}} = V_{tot,A1} + V_{HCl}$$

$$V_{tot,A1 \text{ with HCl}} = (30.00 \text{ mL}) + (10.00 \text{ mL}) = 40.00 \text{ mL}$$

4 Assessment

4.1 Misconceptions

4.1.1 Henderson-Hasselbalch plot

- The plot should have one data series
- Variables are confused:
 - x- axis should be $\log \frac{[base]}{[acid]}$.
 - One refers to this variable as **Henderson-Hasselbalch constant**.
 - How can a constant be a variable at the same time, plotted in the axis?
 - So, common sense can easily avoid some confusions¹ (page 13).
 - See the relevant instructions [above](#).

Log[base/acid]

It should be $\log \frac{[base]}{[acid]}$. Bracket represents molarity. Bracket of base/acid does not represent molarity.

4.1.2 Dilution plot

- Variables are confused:
 - x- axis should be $\log(\text{dilution factor})$.
 - See the relevant instructions [above](#).

4.3 Formatting Issues

NH3 and NH4

Should be written as: NH_3 and NH_4^+

4.3.1 Data table

- Sig. fig. errors. For example:

- Presented:
 - 0 mL
 - 5 mL
- Expected:
 - 0.00 mL
 - 5.00 mL
- Title is missing

4.4 Feedback

- The PDF file you uploaded: annotations are highlighted with gray background and pink font.
- E-Rubric: D2L will show the rubric with scores and any feedback provided.

4.5 Grades

Table 2. Grade stats for this experiment.

Term Statistics ^a	Average	Stdev	Median	Maximum	Minimum
SSQ 2020	88.55%	8.19%	91.80%	100.00%	73.00%
^a All zero values are excluded.					

4.6 Team grading

Table 3. Task sharing for team grading based on the sections of the rubric.

Instructor	Teaching Assistant
Overall Clarity and Flow	Procedure
Abstract	Table Formatting
Results	Figure Formatting
Proofreading and General Formatting	Prelab
Strong Acid-Strong Base Data Table	Postlab
Henderson-Hasselbalch Plot	Excel Calculations
Dilution Plot	

Instructor	Teaching Assistant
Discussion	

1. Being confused is good because it means you are learning. *Can you learn without thinking? Can you think without any confusion? Can you get confused without any desire to learn?...* → [\(page 11\)](#)

Amino Acid Titration

Summary: Goals, assignments, and Q&A highlights about the Amino Acid Titration Experiment.

Note: AQ20: Experiment 3

1 Goals

1.1 Identification of the unknown amino acid

- Plot a graph of pH vs. V(mL) of NaOH added.
- If a break (or breaks, in the case of polyprotic acids) is clearly visible, estimate the pKa (or multiple pKa values in the case of polyprotic acids).
- Use the example titration curve in the previous slide as a guidance:
 - The vertical dashed line shows equivalence point and corresponding NaOH volume.
 - The horizontal dashed line shows pH value, which is equal to pKa value. So, you determined the pKa value.
 - Repeat this process for each break if you have multiple breaks and determine all values.
- Estimate the molar mass of the acid.
- Use these data to find a match in Table 2, Table 3, or Table 4.

1.2 Calculate the molar mass of the acid

- At the equivalence point:

$$\text{mol } OH^- = \text{mol amino acid} \quad (1)$$

which means:

$$\text{volume of } OH^- \times \frac{\text{mol } OH^-}{L} \times \frac{1 \text{ mol amino acid}}{1 \text{ mol } OH^-} = \text{mol amino acid} \quad (2)$$

- Calculate molar mass using the moles of amino acid and the mass of sample.

$$\text{molar mass of amino acid} = \frac{\text{g amino acid}}{\text{mol amino acid}} \quad (3)$$

1.3 Determine the identity of amino acid

- Using the pKa and molar mass values determine the identity of amino acid.
- Find a match in Table 2, Table 3, or Table 4.

2 Assignment

- Watch the videos, pass the postlab quiz, and download your data set.
- Analyze the data in Excel
- Submit your partial lab report in PDF and all calculations in Excel file.
- You should review the [Lab Report Guidelines](#) , [Sample General Chemistry Lab Report](#) , and [Appendix E](#) on D2L while writing to ensure that your drafts are correctly formatted.

3 Q&A Highlights

3.1 The unknown amino acid I found doesn't match

The molar mass of the unknown amino acid I found doesn't match any of the options in Tables 2-4. My unknown number is XYZ [hidden for general post]. I'm unable to figure out which calculation I am not doing correctly and have attached my Excel file. Based on my graph, I think I have a monoprotic acid and that I did do the calculation correctly since the break is approximately XYZ [hidden for general post] and my calculated molar mass is XYZ [hidden for general post].

Reviewing your calculations in Excel reveals that you are pretty much okay with the methodology. I would double-check the values such as the mass of sample, etc. If they are okay, then you can leave this analysis as is. Hint: Your calculated molar mass is much smaller than its actual value. So, I would not rely on molar mass if everything is correct, and it stays as is. Finding the correct half-way(s) might be much more helpful.

With respect to finding the half-way points, I would make the plot much larger. Only then, you would see that there are more than one half-way points.

4 Assessment

4.1 Feedback

- The PDF file you uploaded: annotations are highlighted with gray background and pink font.
- E-Rubric: D2L will show the rubric with scores and any feedback provided.

4.2 Grades

Table 1. Grade stats for this experiment.

Term Statistics ^a	Average	Stdev	Median	Maximum	Minimum
SSQ 2020	89.47%	8.74%	92.00%	99.00%	72.50%
^a All zero values are excluded.					

4.3 Team grading

Table 2. Task sharing for team grading based on the sections of the rubric.

Instructor	Teaching Assistant
Overall Clarity and Flow	Procedure
Abstract	Table Formatting
Results	Prelab
Discussion	Postlab
Proofreading and General Formatting	Results Table
Equivalence Points	Titration Curve
Discussion Prompts	Excel Calculations

Le Châtelier's Principle

Summary: Goals, assignments, and Q&A highlights about the Le Châtelier's Principle Experiment.

Note: AQ20: Experiment 4

1 Goals

- Observe the effect of adding mixing various solutions or changing the temperature of a solution.
- Explain the observations using the relevant chemical reactions and Le Châtelier's principle.
- Be thorough!
 - Do not simply state "Sodium hydroxide was added and the reaction shifted left."
 - See the lecture notes posted for more elaborate examples.

2 Assignment

- Watch the videos, pass the postlab quiz, and download the Word document worksheet posted.
- Make careful observations.
- Type your responses on the Word document.
- Still photos are shown in addition to the video content to allow you to see the results more clearly.
 - For precipitates, describe the color, apparent consistency.
 - For translucent solutions, state the color and the depth of color (dark, light, etc.).
 - Note the formation of gas bubbles and any comments regarding temperature changes.
- Upload your final worksheet as a PDF document.
- You should review the [Lab Report Guidelines](#) , [Sample General Chemistry Lab Report](#) , and [Appendix E](#) on D2L while writing to ensure that your drafts are correctly formatted.

3 Q&A Highlights

No incoming questions for this experiment.

4 Assessment

4.1 Feedback

- The PDF file you uploaded: annotations are highlighted with gray background and pink font.
- E-Rubric: D2L will show the rubric with scores and any feedback provided.

4.2 Grades

Table 1. Grade stats for this experiment.

Term Statistics ^a	Average	Stdev	Median	Maximum	Minimum
SSQ 2020	82.72%	8.84%	83.00%	96.50%	70.00%
^a All zero values are excluded.					

4.3 Team grading

Table 2. Task sharing for team grading based on the sections of the rubric.

Instructor	Teaching Assistant
Proofreading and General Formatting	Prelab
Magnesium Chloride Solution	Postlab
Cobalt II Chloride Solution	Saturated Sodium Chloride Solution
Silver Ion Solution	Potassium Chromate Solution

Spectrophotometric Analysis of Manganese in Steel

Summary: Goals, assignments, and Q&A highlights about the Spectrophotometric Analysis of Manganese in Steel Experiment.

Note: AQ20: Experiment 5

1 Goals

1.1 Generate the standard curve

- Mass by difference calculate the mass of the known steel sample.
- The percent by mass of the known steel sample is known as 0.94% Mn.
 - Using the mass of the known steel sample and the weight to weight percent of Mn in this sample, calculate the mass and moles of Mn in the sample. Use Equation 1 and 2.

$$m_{Mn} \text{ (g)} = m_{\text{known sample}} \text{ (g)} \times \frac{0.94 \text{ g } Mn}{100 \text{ g steel sample}} \quad (1)$$

$$n_{Mn} \text{ (mol)} = m_{Mn} \text{ (g)} \times \frac{1 \text{ mol } Mn}{54.938049 \text{ g } Mn} \quad (2)$$

- Calculate the molarity of known steel sample solution using Equations 3 and 4.

$$n_{MnO_4^-} \text{ (mol)} = n_{Mn} \text{ (mol)} \quad (3)$$

$$[MnO_4^-] = \frac{n_{MnO_4^-} \text{ (mol)}}{0.25000 \text{ L solution}} \quad (4)$$

- Using Equation 5, calculate the concentrations of each diluted solutions of MnO_4^- . Remember that the dilutions were 3:1, 2:2, and 1:3 volume to volume ratio.

$$M_1 V_1 = M_2 V_2 \quad (5)$$

- Generate a standard curve (absorbance at 525 nm vs. concentration of MnO_4^- in M) for the solutions of known MnO_4^- concentration.
 - In doing so, add 0 absorbance, 0 molar values as well.
 - Thus, in total there are five data points in this plot.

1.2 Determine the molar absorptivity

- Apply trendline analysis over the standard curve.

- Following Beer's Law, Equation 6, the slope of the plot determines the molar absorptivity a of MnO_4^- .

$$A = abc \quad (6)$$

where the path length, $b = 1.00$ cm.

$$a = \frac{\text{slope}}{1 \text{ cm}} \quad (7)$$

1.3 Calculate the concentration of unknown steel solution

- Use Equation 6 to calculate the concentration, c of MnO_4^- .
- Probably your data has three trials of absorbance value.
- Repeat this calculation over all trials.
- Calculate the average concentration of MnO_4^- , and also report the standard deviation.

1.4 Calculate %Mn in the unknown steel sample

- This is a straightforward calculation as you will be plugging in the average concentration of MnO_4^- in Equation 8.

$$\text{percent Mn} = \frac{(V_{\text{MnO}_4^-})([\text{MnO}_4^-])}{m_{\text{sample}}} \left(\frac{1 \text{ mol Mn}}{1 \text{ mol MnO}_4^-} \times \frac{54.938049 \text{ mol Mn}}{1 \text{ mol Mn}} \right) \times 100 \quad (8)$$

where m_{sample} is the mass of unknown sample; $V_{\text{MnO}_4^-}$ is the total volume of unknown sample solution, which is 250.00 mL; $[\text{MnO}_4^-]$ is the average concentration of MnO_4^- in the unknown solution (calculated in subsection 1.3 (page 0)).

2 Assignment

- Compare the molar absorptivity from your plot to the literature value given in the lab instructions.
- Read the lab instructions carefully so you can explain why you do or do not have to worry about Cu^{2+} and Ni^{2+} ions interfering with your results.
- Think through how a molar absorptivity that is too low would affect your results. To answer this correctly, follow the computational steps to make sure you can clearly state if an a value that is too small will lead to a higher or lower percent Mn than the correct value.
- Incorporate the responses to the above prompts in your overall discussion. Be sure to discuss the quality of your fit, the spread in the absorbance readings for the unknown, etc. to ensure your discussion is complete.
- Watch the videos, pass the postlab quiz, and download your data set.
- Submit your **full lab report** in a PDF file and **calculations** in an Excel file.
- You should review the [Lab Report Guidelines](#), [Sample General Chemistry Lab Report](#), and [Appendix E](#) on D2L while writing to ensure that your drafts are correctly formatted.

3 Q&A Highlights

3.1 Taking the prelab quiz

Is there anyway you can give me an example of how to enter the answers for the calculations? I just can't seem to figure that out.

Please pay attention to the values of calculations. The values should be entered with correct significant figures and units. Units are case sensitive. Use the SI unit conventions.

For example:

- 1250 is not equal to 1250.
- L is not equal to l

3.2 Calculations

I would like to attend your office hours at 4pm tomorrow to ask a couple questions about the calculations for Experiment 10.

After this meeting, the Goals section was revised. Although the lecture notes were elaborate enough, now this page has more details with relevant formulae, for those of whom are confused ¹ (page 23).

3.3 The unit of absorbance

I was wondering if there are units that are necessary for the absorbance values on the figure needed for this lab.

Absorbance does not have a unit. The absorbance, A , is defined by the incident intensity, I_0 , and transmitted intensity, I .

$$A = \log_{10} \left(\frac{I_0}{I} \right) \quad (9)$$

Overall, the equation shows no unit.

3.4 The concentration of undiluted solution

I am confused on where the fifth point on the standard curve graph comes from. I know that there is supposed to be a point where it is at the origin so I added that in the curve but since the volume of the diluted water is 0 isn't the concentration of MnO_4^- also 0? If it is then it is way off the trend line and I don't know what I did wrong. Please let me know if you can help me figure out what I did wrong that made the point for 1.610 absorbance have 0 concentration.

I suspect a **potential misunderstanding** here. When there is an aqueous solution, it is mostly water. Water is the **solvent**, so by definition solvent is in abundance. When the solution is diluted, more water added. This is an important point to understand about aqueous solutions.

Undiluted solution has the highest concentration. Follow Equations 1, 2, 3, and 4 to calculate the molarity of permanganate. This value is the undiluted concentration, in which the highest absorbance (A) value is observed.

3.5 Dilution formula

I just wanted to follow up on my last email. I read the questions page and I am still confused on how the concentration is less than the concentration multiplied by three. Because of the dilution formula where $M_2 = M_1 V_1 / V_2$ wouldn't the one with the highest volume standard with the lowest volume DI water had the highest value. I am sorry if I am getting confused on something simple here.

You are applying the dilution formula incorrectly. You should follow the following steps to find and plug in the correct V values. I am using the second row of your data table.

- $V_1 = 30.00$ mL of the stock MnO_4^- solution.
- Add 10.00 mL of DI water.
- Final volume becomes $V_2 = 40.00$ mL of diluted MnO_4^- solution.
- In sum, you should plug in the following values:
 - $V_1 = 30.00$ mL
 - $V_2 = 40.00$ mL
 - $M_1 = 0.0005126$ M based on your first row. (Please check this calculation, the concentration value looks too low.)

4 Assessment

4.1 Feedback

- The PDF file you uploaded: annotations are highlighted with gray background and pink font.
- E-Rubric: D2L will show the rubric with scores and any feedback provided.

4.2 Grades

Table 1. Grade stats for this experiment.

Term Statistics ^a	Average	Stdev	Median	Maximum	Minimum
SSQ 2020	84.06%	10.24%	86.67%	95.83%	57.33%
^a All zero values are excluded.					

4.3 Team grading

Table 2. Task sharing for team grading based on the sections of the rubric.

Instructor	Teaching Assistant
Overall Clarity and Flow	Procedure
Abstract	Table Formatting
Proofreading and General Formatting	Figure Formatting
Results	Prelab
Discussion	Postlab
Mass Percent of Mn in Unknown Sample	Results Table
Discussion Prompts	Calibration Curve
	Excel Calculations

1. Being confused is good because it means you are learning. *Can you learn without thinking? Can you think without any confusion? Can you get confused without any desire to learn?...* → [\(page 21\)](#)

Thermodynamics of a Cobalt Complex

Summary: Goals, assignments, and Q&A highlights about the Thermodynamics of a Cobalt Complex Experiment.

Note: AQ20: Experiment 6

1 Goals

1.1 Calculate the equilibrium concentration

- Calculate the equilibrium concentration of tetrachlorocobaltate(II) in solution at each temperature using Beer's law with the measured absorbance value at the temperature of interest.

$$A = abc \quad (1)$$

- Assume that the molar absorptivity, b , of CoCl_2^{2+} in water at 690 nm is constant ($6.00 \times 10^2 \text{ M}^{-1} \cdot \text{cm}^{-1}$) for all 4 temperature values.
- The path length, a , is equal to 1.00 cm.
- The equilibrium concentration of uncomplexed cobalt(II), Co^{2+} , ions in solution at any given temperature is found using conservation of mass, the initial concentration of cobalt(II) ions in the stock solution, and the equilibrium concentration of tetrachlorocobaltate(II) at that temperature.

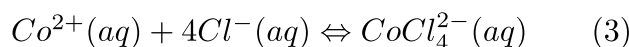
1.2 Calculate the equilibrium constant

- Calculate the equilibrium constant for the reaction of interest at each temperature using Equation 2.

$$K = \frac{[\text{CoCl}_4^{2-}]}{[\text{Co}^{2+}][\text{Cl}^-]^4} \quad (2)$$

In doing this calculation, assume that the $[\text{Cl}^-]$ is constant due to the presence of strong 6.00 M HCl acid. For the sake of significant figures in this calculation, assume the concentration of HCl is exactly 6.00 M.

1.3 Calculate the equilibrium concentration of uncomplexed cobalt(II)



The equilibrium concentration of uncomplexed cobalt(II), Co^{2+} , ions in solution at any given temperature is found using conservation of mass (i.e. the stoichiometric calculation based on Equation 3), the initial concentration of cobalt(II) ions in the stock solution, and the equilibrium concentration of tetrachlorocobaltate(II) at that temperature.

1.4 Calculate ΔG° using K

- Calculate ΔG° at each temperature studied for each trial using Equation 4.

$$\Delta G^\circ = -RT \ln K \quad (4)$$

where $R = 8.3145 \text{ J/mol}\cdot\text{K}$ (use all figures to ensure proper significant figures), and all temperature values are in Kelvin.

1.5 Make $\ln K$ vs. $1/T$ plots

- Make $\ln K$ vs. $1/T$ plots for each trial separately.
- Temperature values are in Kelvin.
- Using the Excel formulas, calculate slope, `=SLOPE()`, and intercept `=INTERCEPT()` for the line of best fit.
- Calculate ΔH° and ΔS° for each trial using Equation 5.

$$\ln K = -\left(\frac{\Delta H^\circ}{R}\right)\left(\frac{1}{T}\right) + \left(\frac{\Delta S^\circ}{R}\right) \quad (5)$$

where slope = $-(\Delta H^\circ / R)$, y- intercept = $(\Delta S^\circ / R)$, R is in energy unit like in Equation 4, and temperature is in Kelvin.

1.6 Calculate ΔG° using ΔH° and ΔS°

- Calculate ΔG° at each temperature studied for each trial using Equation 6.

$$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ \quad (6)$$

where T is in Kelvin.

- Assume that ΔH° and ΔS° are constant with temperature.

1.7 Generate a combined plot of $\ln K$ vs. $1/T$

- Generate a combined plot of $\ln K$ vs. $1/T$. In this plot, you should include the results from all trials.

2 Assignment

- Watch the videos, pass the postlab quiz, and download your data set
- Analyze the data in Excel
- Submit your **full lab report** in a PDF file and **calculations** in an Excel file.
 - Be sure to fully discuss your results.
 - Compare the values from the two trials and discuss how similar or different they are, as well as potential reasons for differences observed.

- Discuss the values of ΔG° : are the values obtained similar for each type of calculation? Why might they be different?
- There are two discussion prompts that should be incorporated into your overall discussion
 - One relates to the signs of ΔG° and ΔH° , and why the signs you obtained do or do not follow your expectations.
 - The other relates to the conditions for spontaneity. Remember that ΔG° and ΔH° relate to standard state conditions when you calculate the temperature range over which the reaction will occur spontaneously.
- You should review the [Lab Report Guidelines](#), [Sample General Chemistry Lab Report](#), and [Appendix E](#) on D2L while writing to ensure that your drafts are correctly formatted.

3 Q&A Highlights

3.1 Calculating the equilibrium concentration of Co^{2+}

I had a question on how to calculate the equilibrium concentration of Co^{2+} . In the lab, it gives a brief description but no equation.

To answer this question, a new subsection was added to this document. Please [see](#) : Calculate the equilibrium concentration of uncomplexed cobalt(II)

4 Assessment

4.1 Feedback

- The PDF file you uploaded: annotations are highlighted with gray background and pink font.
- E-Rubric: D2L will show the rubric with scores and any feedback provided.

4.2 Grades

Table 1. Grade stats for this experiment.

Term Statistics ^a	Average	Stdev	Median	Maximum	Minimum
SSQ 2020	79.30%	13.65%	76.17%	97.00%	52.83%
^a All zero values are excluded.					

4.3 Team grading

Table 2. Task sharing for team grading based on the sections of the rubric.

Instructor	Teaching Assistant
Overall Clarity and Flow	Procedure
Abstract	Table Formatting
Proofreading and General Formatting	Figure Formatting
Results	Prelab
Discussion	Postlab
ln K vs. 1/T Figures	Temperature Study Table
Discussion Prompts	Free Energy Comparison Table
	Excel Calculations

Electrochemistry

Summary: Goals, assignments, and Q&A highlights about the Electrochemistry Experiment.

Note: AQ20: Experiment 7

1 Goals

- It is important that you identify the cathode and anode half-reactions for each galvanic cell before beginning the following calculations.

1.1 Experimental E for Cu

- From the standard reduction potential, E° , of the copper half-reaction of 0.340 V and the concentration of Cu^{2+} , calculate the actual value of E for the experimental copper half-reaction using the Nernst equation (Equation 1).

$$E_{\text{red}} = E_{\text{red}}^\circ - \left(\frac{RT}{nF} \right) \ln \left(\frac{1}{[M^{n+}]} \right) \quad (1)$$

1.2 Experimental E for Al

From the actual value of E for the experimental copper half-reaction and the measured value of E_{cell} for the copper-aluminum cell, determine the value of E for the experimental half-reaction for aluminum (Equation 2).

$$E_{\text{cell}} = E_{\text{cathode}} - E_{\text{anode}} \quad (2)$$

1.3 Experimental E° for Al

From the calculated value of E for the experimental aluminum half-reaction and the actual concentration of Al^{3+} , calculate E° for the aluminum half-reaction using the Nernst equation (Equation 1).

1.4 Experimental E for Zn

From the actual value of E for the experimental copper half-reaction and the measured value of E_{cell} for the copper-zinc cell, determine the value of E for the experimental half-reaction for zinc (Equation 2).

1.5 Experimental E° for Zn

From the calculated value of E for the experimental zinc half-reaction and the actual concentration of Zn^{2+} , calculate E° for the zinc half-reaction using the Nernst equation (Equation 1).

1.6 Experimental E for Pb

From the actual value of E for the experimental copper half-reaction and the measured value of E_{cell} for the copper-lead cell, determine the value of E for the experimental half-reaction for lead (Equation 2).

1.7 Experimental E° for Pb

From the calculated value of E for the experimental lead half-reaction and the actual concentration of , calculate E° for the lead half-reaction using the Nernst equation (Equation 1).

1.8 Internal Consistency Check

Using the experimental E values for zinc and lead calculated above, calculate . Compare this result to the value you measured.

2 Assignment

- Watch the videos, pass the postlab quiz, and download your data set.
- Analyze the data in Excel.
- Submit your worksheet in a PDF file.
- You should review the [Lab Report Guidelines](#) , [Sample General Chemistry Lab Report](#) , and [Appendix E](#) on D2L while writing to ensure that your drafts are correctly formatted.

3 Q&A Highlights

3.1 Printing off the worksheets

I was wondering if I may print off the worksheets for Experiments 11 and 12, hand write them and then upload them as a pdf file as I did for a previous experiment. In the lab guide, it says you may either write or type your responses, but other places it says that they must be typed. Thank you for the clarification!

Yes, you may print and fill out them. However, if any part of the worksheet requires you to copy and paste a graph, you should print and attach the graphs physically. One drawback for this approach is that you may not have enough space to attach a graph. In that case, you could add your graph as a separate page and make sure that you refer to the page in the given space, where you are expected to provide the graph.

4 Assessment

4.1 Feedback

- The PDF file you uploaded: annotations are highlighted with gray background and pink font.
- E-Rubric: D2L will show the rubric with scores and any feedback provided.

4.2 Grades

Table 1. Grade stats for this experiment.

Term Statistics ^a	Average	Stdev	Median	Maximum	Minimum
SSQ 2020	82.71%	9.01%	85.40%	96.08%	62.07%
^a All zero values are excluded.					

4.3 Team grading

Table 2. Task sharing for team grading based on the sections of the rubric.

Instructor	Teaching Assistant
Proofreading and General Formatting	Prelab
Questions 6-9	Postlab
Questions 10-11	Table 1
Questions 12-13	Question 2
	Question 3-5

Coordination Chemistry

Summary: Goals, assignments, and Q&A highlights about the Coordination Chemistry Experiment.

Note: AQ20: Experiment 8

1 Goals

1.1 Mass of Copper(II) Sulfate Pentahydrate

Calculate the mass of copper(II) sulfate pentahydrate used in the reaction from the initial and final mass of the reagent vial.

1.2 Moles of Copper(II) Sulfate Pentahydrate

Calculate the moles of copper(II) sulfate pentahydrate used in the reaction using the mass and the molar mass of the compound.

1.3 Moles of Ammonia Added

Calculate the moles of ammonia added using the volume added and the molarity of the solution.

1.4 Theoretical Yield of Tetraamminecopper(II) Sulfate Monohydrate

Calculate the theoretical yield (in moles) of tetraamminecopper(II) sulfate monohydrate produced from the limiting reagent and the relevant balanced chemical equation.

1.5 Mass of Product Collected

Calculate the mass of the collected product from the initial and final mass of the beaker.

1.6 Actual Yield of Tetraamminecopper(II) Sulfate Monohydrate

Assuming that all of the collected solid was the product of interest, calculate the actual yield (in moles) of the reaction from the mass of the product and the molar mass of tetraamminecopper(II) sulfate monohydrate.

1.7 Percent Yield

Calculate the percent yield of the reaction using the theoretical and actual yields.

2 Assignment

- Watch the videos, pass the postlab quiz, and download your data set.
- Analyze the data in Excel.
- Submit your worksheet in a PDF file.
- You should review the [Lab Report Guidelines](#) , [Sample General Chemistry Lab Report](#) , and [Appendix E](#) on D2L while writing to ensure that your drafts are correctly formatted.

3 Q&A Highlights

3.1 Printing off the worksheets

I was wondering if I may print off the worksheets for Experiments 11 and 12, hand write them and then upload them as a pdf file as I did for a previous experiment. In the lab guide, it says you may either write or type your responses, but other places it says that they must be typed. Thank you for the clarification!

My response is posted [here](#) .

4 Assessment

4.1 Feedback

- The PDF file you uploaded: annotations are highlighted with gray background and pink font.
- E-Rubric: D2L will show the rubric with scores and any feedback provided.

4.2 Grades

Table 1. Grade stats for this experiment.

Term Statistics ^a	Average	Stdev	Median	Maximum	Minimum
SSQ 2020	88.03%	3.11%	87.50%	93.00%	83.00%
^a All zero values are excluded.					

4.3 Team grading

Table 2. Task sharing for team grading based on the sections of the rubric.

Instructor	Teaching Assistant
Proofreading and General Formatting	Prelab
Mass and Moles of the Species	Postlab
Theoretical Yield	Chemical Equation
Mass of Product, Actual Yield, Percent Yield	Data and Results Table