Experiment 1:
BUILDING THE FOUNDATION
FOR THE CHEMISTRY LAB COURSE

Purpose: In preparation for the experiments to be performed this semester three aspects of the chemistry laboratory are examined; namely, preparation of graphs with the use of Excel 2010, safety in handling chemicals, and treatment of significant figures and units in the collection of data and in data analysis.

Introduction: Throughout the semester you will often be asked to analyze your data graphically. Instructions in this lab manual are written with the assumption that you have access to the Excel 2010 software. Graphing by hand is not acceptable.

As a student in the second semester of the General Chemistry Lab, you are expected to have already attained certain knowledge on the dangers we face in handling chemicals and what precautions to take. In previous course work, you have probably been provided information on safety precautions. In this exercise you will learn to search for this information yourself on the Internet.

You should have already learned how to use various chemistry laboratory apparatus (such as the graduated cylinder, buret and pipet) and to record measurements to the correct significant figures and with the proper units. You are also expected to remember how to handle significant figures and units during mathematical operations. In this exercise you will go through a brief tutorial and review some of the rules in handling significant figures and units.

Procedure

Part I: Graphing with Excel 2010

Work individually. If there are not enough laptops for every student in the class and you must wait your turn, start reading and working on Part III while you are waiting.

Write down the last four digits of your CCBC ID number ___ ___ ___ ___. If you don't have your CCBC ID number with you, get it from your instructor's class roster. Let the letter A represent this 4-digit number. If your ID ends in 0000 then use the number 9999 for A instead. You will use these answers for your B-values (for the x-axis) in the graphing exercise. If you do not have your calculator with you, ask your instructor to help you check one out. YOU MUST HAVE YOUR OWN NON-PROGRAMMABLE SCIENTIFIC CALCULATOR BY THE NEXT LAB PERIOD.

<table>
<thead>
<tr>
<th>B-Value (for x-axis in 4 sig.fig.)</th>
<th>C-Value (for y-axis)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A / (81.11 x 12.12)</td>
<td></td>
</tr>
<tr>
<td>A / 835.1</td>
<td></td>
</tr>
<tr>
<td>A x 1.234 x 10^-3</td>
<td></td>
</tr>
<tr>
<td>A x (88.88 / 66,666)</td>
<td></td>
</tr>
<tr>
<td>A / ((40.123 + 22.22) x 10.11)</td>
<td></td>
</tr>
</tbody>
</table>

Copy these B-values onto p. 23.
Follow the instructions below and plot the five data points above using Excel 2010. This graph must be properly labeled, include a trendline, and have the trendline equation displayed on the graph along with the $R^2$ value. (Refer to Appendix 1 for the meaning of the $R^2$ value.)

**Preparation of the Graph Using Excel 2010**

*The objective is to familiarize you with the use of Excel. The instructions below utilize Excel 2010, which is the version used on most CCBC college computers. There will be times this semester when you have to complete a graph in the lab. You are urged to learn to use Excel 2010 and not rely on a partner.*

Even if you have used Excel before, please follow the directions below carefully. The requirements for the graph may be different from what you were expected to do for math or other science courses. One of the focuses is on working with data that have exponentials. Another focus is to go beyond the default scale settings and learn to adjust the minimum and maximum for the scales so that data points are not bunched up together. In adjusting for the full use of the graph, the scale may be expanded, allowing you to read off the graph with better precision. For example Fig. 1.1B is preferred (with expanded x-scale) over Fig. 1.1A.

1. Label your columns: In Cell A1, type “B-Value” and B1, type “C-Value.”
   *(B-values go on the x-axis and C-values go on the y-axis.)*
2. Enter in Column A, starting in Cell A2, your B values and enter in Column B, the corresponding C values. Note that 1.43x10^{-4} is to be entered as 1.43e-4 or 1.43E-4.
3. After all the data have been entered, highlight both columns, beginning with Row 2, down to the last row that contains an entry.
4. Click on the **Insert** tab, on **Scatter**, and then on **Scatter with only Markers**.

![Figure 1.2](image-url)
5. The Legend on the right side of the graph (see Figure 1.3) is unnecessary whenever there is only one series (as is the case here). Remove the Legend by clicking on it and pressing Delete on the keyboard. The Legend unnecessarily takes up space, thus limiting the size of the graph.

6. You will be printing the data in the spreadsheet and the graph on the same page. To fit them both on the same page, place your cursor anywhere on the spreadsheet (not on the graph) and click on Page Layout, Orientation and select Landscape. The dotted lines that appear indicate the size of the page you will be printing. Click on the frame of the graph and then resize the graph so that it is as large as possible without letting it spill beyond the dotted lines. Allow a margin of one row at the bottom and one column on the side.

7. Add the line of best fit by clicking Layout, Trendline, and selecting More Trendline Options at the very bottom. The Format Trendline window will then appear.

10. Double check to see that the Linear option has been selected, then place a check mark at Display Equation on chart, and at Display R-squared value on chart, and then click on Close.

11. If necessary, move the equation to a position where it can be read easily. This is done by clicking on the equation once and then dragging it to the desired position (such as the top of the graph, next to the title).

**IMPORTANT NOTE ON THE TRENDLINE EQUATION:** The default notation for the trendline equation is in decimal form and if a number is very small, it will be truncated and appear as 0.000. For example in the graph shown, obviously the y-intercept is not zero, and yet the trendline equation is shown as $y = 7E-05x - 0.000$. This problem can be avoided by having the numbers in the trendline equation expressed in scientific notation. This is described on the following page.
Place your cursor on the trendline equation on the graph and right-click. In the pop-up menu, click on **Format Trendline Label**. In the pop up window select **Number** on the left column and under **Number Category**, select **Scientific**, and then **Close**. The trendline equation now appears as

\[ y = 6.77 \times 10^{-5}x - 5.49 \times 10^{-4} \]

showing the slope to be 6.77 \times 10^{-5} and the y-intercept to be −5.49 \times 10^{-4}.

12. Enter the title for the graph by checking to see that you are still in **Chart Tools, Layout**, then select **Chart Title, Above Chart**. Type in the title: *C*-values versus *B*-values. When you press **ENTER**, your title will appear on the graph.

13. To label each axis, click on **Axis Titles**, then select **Primary Horizontal Axis Title**, and **Title Below Axis**. Type in a title for the x-axis: *B*-value. Press **ENTER**.

14. Click on **Axis Titles**, and then select **Primary Vertical Axis Title**, and **Rotated Title**. Type in the title for the y-axis: *C*-Value Press **ENTER**.

As you have probably noticed, the data points are bunched up in a small area of the graph (See Fig. 1.3). We will now adjust the minimum and maximum for the x- and y-scales to make use of the full graph.

15. Click on **Axes**, select **Primary Horizontal Axis** and then on **More Primary Horizontal Axis Options**. This is where you will adjust for the x-scale. Select **Fixed** to allow you to change the default settings. Remember the minimum must be smaller than your smallest *B*-value, and the maximum must be larger than your largest *B*-value. Select **Fixed** to allow you to change the default settings. For example, if your lowest *B*-value is 9.972, and the maximum, is 15.6, try setting the minimum= 9 and maximum = 16. You must choose settings that fit your data. Adjust the Major Unit (1.0?) and Minor Unit (0.1?) as needed to give more tick marks.

When you are finished, click on **Close**.

16. Click on **Axes**, select **Primary Vertical Axis** and then on **More Primary Vertical Axis Options**. Remember to select **Fixed** to change the default settings. Enter your **Minimum, Maximum, Major unit, Minor unit**. When you are finished, click on **Close**.

Next, you are going to add gridlines to make it easier to read values off the graph. You do not want so many gridlines that they merge together, nor do you want so few gridlines that you cannot read across the graph to get the coordinates of a point. The instructions below are just suggestions. Further adjustments may be necessary for your particular graph in the choice of Major unit, Minor unit and whether you need Major Gridlines or Minor Gridlines.

17. Click on **Gridlines**, select **Primary Horizontal Gridlines** and **Minor Gridlines**.

18. Click on **Gridlines**, select **Primary Vertical Gridlines** and **Minor Gridlines**.

19. In the area **above the graph** (such as in Cell D1), enter your course number, course section, semester, year, experiment #, experiment title, and name of student who is preparing the graph. For example:

*Chem 124 - Sec CM2 - Fall 2009 – Expt #1 Building the Foundation – Jane Smith*
EXPERIMENT 1: BUILDING THE FOUNDATION

(It is important to include your name so that somebody else does not pick up your printout from the printer in the room.) Drag and/or resize the graph if necessary in order to make space for the above information.

20. Highlight the entire page. Click on **Page Layout** tab, **Print Area**, and select **Set Print Area**.

21. Go over the **CHECK LIST** shown below before printing your graph.

22. Click on **File**, select **Print**, and click on **Print Preview** to double check that everything fits on the page, then click on **Print**. Your printout should include the data and the graph on the same page.

23. You may email the file to yourself if you wish, or save it on your own flash drive.

![Figure 1.4: Example of Graph and Data Fitted on One Page](image_url)

Go over this **CHECK LIST** before printing your graph:

1. Printout must have graph embedded inside the spreadsheet, as shown in Figure 1.4 above. Top of page must show Course #, Sec #, Experiment #, brief title of experiment, and your name.

2. Graph must have proper title.

3. Each axis must be properly labeled, and include units.

4. Graph must include trendline and $R^2$ value if appropriate

5. If only one series, get rid of Legend.

6. Scale of each axis is such that data points are not bunched together.

7. Scale of each axis is such that they are easily read.

8. Are gridlines necessary? Do not use so many gridlines that they merge together. Do not use so few gridlines that you cannot read off the graph precisely.
Part II: Safety Information from the MSDS forms

(Work individually & hand in before you leave the lab today.)

Each student should be familiar with the hazards for every chemical used. This information may be accessed from the Material Safety Data Sheets (MSDS) for each chemical. Any chemical sold is shipped with a MSDS form attached. In the lab you may not have access to them, but you can always find them on the vendor websites (such as fishersci.com or sigma.com).

Today you will look up several chemicals that will be used throughout the semester to familiarize yourself with the safety information found in the MSDS forms. If you do not know who sells the chemical, an excellent starting point is http://hazard.com (shown below). Click on the link for SIRI MSDS INDEX. The next screen will allow you to type in the chemical name to find the MSDS sheet.

Look up the MSDS forms for the following reagents that you will be using later this semester:
cyclohexane, sulfuric acid, and potassium thiocyanate

For each chemical, find the following information and record it into your lab notebook (or on a blank sheet of paper if you have not purchased your lab notebook yet). Do not copy verbatim, but give a summary for each item below:

1. Chemical formula
2. Emergency Overview, Safety issues, including any ratings if provided
3. Safety equipment required (gloves, hood, mask, etc.)
4. What to do if the chemical spills
5. What to do if you get the chemical on you
6. Anything else you find relevant to your safety

Keep in mind in the future where you can obtain this safety information for other chemicals you will be using.
Part III: Review of How to Handle Significant Figures and Units

Work individually. Turn in next week at beginning of prelab. This is worth ≈ 40% of the grade.

Significant figures are critical in the lab because they are what indicate how precise the measurements are. For example, if you were conducting a clinical trial for a new drug, you would need to calculate how different the results were in patients taking the drug. If you do not know how precise the data is (i.e., how many significant figures), then you will not know how reliable the results are. Below is a summary of the rules that are to be followed not only when recording the values but also when performing mathematical manipulations.

A. Recording Data to the Appropriate Number of Significant Figures: The best rule of thumb is that you record to one-tenth of the smallest division shown on the apparatus (one digit beyond what you can easily read). For example, the graduated cylinder shown in Figure 1.6A has nine lines between 30 mL and 40 mL, (divided into 10 divisions) so each division represents 1 mL. One-tenth of 1 mL is 0.1 mL. This means all readings on this graduated cylinder should be recorded to one decimal place. In the figure below, the correct reading would be 32.5 or 32.6 mL. There is always going to be uncertainty in the last digit.

In Figure 1.6B, the smallest division is 0.1 mL. One-tenth of 0.1 mL is 0.01 mL. All readings with this graduated cylinder should be recorded to two decimal places. The correct reading would be 8.47 mL or 8.48 mL. It is understood that there is always uncertainty in the last digit of any measurement.

Once you have recorded the data, you then follow a set of rules to ensure that you keep the same level of precision in your final answer as you had in your recorded data. The rules are there so that you do not end up with more precision than is allowed by the apparatus just by doing calculations.

All digits are significant except for two cases:
1) Leading zeroes (zeroes to the left of the first non-zero digit) are NOT significant because they merely hold the decimal place.
   0.007 has one significant figure
   0.00620014 has six significant figures
   12.1231 has six significant figures.
   1203.03 has six significant figures.
2) Tailing zeroes (zeroes on the end of a number) in a number WITHOUT a decimal point are ambiguous. They are assumed to be NOT significant. The ambiguity is removed by using scientific notation.

(Tailing zeroes in a number WITH a decimal point and zeroes between non-zero digits are significant.)

0.0073500 has five significant figures.
73500.00 has seven significant figures.
0.07305 has four significant figures.
7350. has four significant figures. The trailing zero is significant because of the decimal point.
73500 has ambiguity because it could have three, four or five significant figures. It is assumed to have only 3 significant figures. The trailing zeroes are assumed to be not significant.

If it were to have 5 sig. fig., it should be written as $7.3500 \times 10^4$.
If it were to have 4 sig. fig., it should be written as $7.350 \times 10^4$.
If it were to have 3 sig. fig., it should be written as $7.35 \times 10^4$.

B. Treatment of Significant Figures During Calculations: What happens to these significant figures during calculations? The reported answer should have the same precision as that of the least precise number. To do so, you must follow these rules:

**ADDITION & SUBTRACTION:** When adding and subtracting numbers, line up the decimal places and report the number with the same number of decimal places as that with the least decimal places.

<table>
<thead>
<tr>
<th>1123.123</th>
<th>(3 decimal places)</th>
<th>+ 0.002123</th>
<th>(6 decimal places)</th>
<th>= 1123.125123</th>
<th>(3 decimal places)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ans. 1123.125</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Ans. 3.0</td>
</tr>
</tbody>
</table>

If the numbers are in exponential form, they must first be adjusted to the same power before lining up the decimal place for addition or subtraction.

$2.431 \times 10^{12} + 0.001 \times 10^{13} = ?$

Incorrect to answer in 3 decimal places

Correct to answer in 2 decimal places

**MULTIPLICATION & DIVISION:** When multiplying or dividing, report your answer with the same number of significant figures as that with the smallest number of significant figures.
1123.123 x 0.0000123 x 1.1 = 0.01519585419
(7 sig. fig.) (3 sig. fig.) (2 sig. fig.)

Answer should have 2 sig. fig. = 0.015

C. **Rounding Off:** When an answer needs to be expressed with fewer significant figures, if the first digit to be dropped is $\geq 5$, round up. If it is $< 5$, merely drop the remaining digits. Technically, if it is exactly 5 then it depends on the number immediately to its left. Round up if the digit to its left is odd, and truncate if the digit to its left is even. However, in this course, we will just round up regardless of whether the following digit is even or odd.

The following numbers are each rounded to three significant figures.

<table>
<thead>
<tr>
<th>Original Number</th>
<th>Rounded Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.23124</td>
<td>1.23</td>
</tr>
<tr>
<td>0.013968</td>
<td>0.0140</td>
</tr>
<tr>
<td>1.675</td>
<td>1.68</td>
</tr>
<tr>
<td>0.0003245</td>
<td>0.000325</td>
</tr>
</tbody>
</table>

D. **Exact Numbers:** Counting and Definitions – When counting (not measuring) a number, the value that is obtained is considered to be *exact* and therefore has an infinite number of significant figures. For example, if there were 3 people in a room there is no uncertainty, thus there would be exactly 3.0000000... people in the room. Definitions are also an exact number. It is defined that there are 1000 milliliters in 1 liter, thus one can say there are 1000.0000000... mL in 1 liter. Constants like Avogadro’s number are not defined, but instead have been calculated and therefore they do have a correct level of significance that you should be aware of. Exact numbers do not affect the number of significant figures during calculations.

E. **Scientific Notation:** Often numbers are so large, or so small, that it becomes quite cumbersome to express the numbers without the use of scientific notation. For example the speed of light in a vacuum is nearly thirty million meters per second. This value expressed in conventional notation would be 300,000,000 m/s where one needs to write 8 zeroes and one wonders how many of those are significant. Better stated using scientific notation the number becomes $3.00 \times 10^8$ m/s to the precision of 3 significant figures or $2.9979 \times 10^8$ m/s to the precision of 5 significant figures.

*Scientific notation* is a method of expressing a value, such that the number has only one non-zero digit to the left of the decimal place, followed by the appropriate number of significant figures to the right of the decimal place and then multiplied by 10 raised to an exponent expressing the order of magnitude of the number. The number 3021.1 has too many digits to the left of the decimal point. In scientific notation it should be written as $3.0211 \times 10^3$.

The number $0.025 \times 10^5$ is not in scientific notation because the digit to the left of the decimal point is zero. It should be expressed as $2.5 \times 10^5$ instead.

*Please do not write 3.0211E03. The “E” notation is to be used only when within Excel graphs or certain online homework.*
F. **Calculation of Average:** When determining the average of several values, the average cannot end up with more precision than the values themselves. Thus, the average of 24.7 g and 24.8 g should not be recorded as 24.75 g but should be 24.8 g (rounded to one decimal place).

G. **Significant Figures Obtained from Graphs:** Values read off a graph or calculated from the trendline of the graph should *not be more precise* than the data used to create the graph. In addition, scales chosen for the graph should be such that it does *not yield answers that are less precise* than the data.

H. **Keeping Track of Units:** When recording measurements, **ALWAYS** include the units. For example if you are recording the reaction time as being 8, we would be wondering whether you mean 8 seconds, minutes or hours.

In showing your calculation setups, it is essential that you keep track of your units from beginning to end. One reason is it helps you catch careless algebraic mistakes. For example, if you were calculating the volume of a sample from its density and mass and set it up as shown below, you would see that the units do not work out properly: Volume cannot have a unit of l/mL. The unit tells you that your setup is upside down.

Incorrect: \[ \text{Volume} = \frac{1.09 \text{ g/mL}}{2.58 \text{ g}} = 4.22 \frac{1}{\text{mL}} \]

Correct: \[ \text{Volume} = \frac{2.58 \text{ g}}{1.09 \text{ g/mL}} = 2.37 \frac{\text{mL}}{\text{g}} = 2.37 \text{mL} \]

In recent publications, units in the denominator are expressed with exponents of -1, rather than with the use of a slash to avoid confusion. For example g/mol is written as g mol\(^{-1}\). The exponents should be treated as you would with the exponents of numbers. For example, (g/mL• mL) is confusing as written. It can be read as [(g/mL).mL] or [g/(mL.mL)]. To avoid such confusion, [(g/mL).mL], such as dividing density by the volume, is best written as (g mL\(^{-1}\) mL), which simplifies to (g):

\[ (\text{g mL}^{-1} \text{ mL}) = \text{g mL}^{-1} \text{ mL}^1 = \text{g mL}^{-1+1} = \text{g mL}^0 = \text{g} (1) = \text{g} \]

*Reminder: Anything to the power of zero equals one.* e.g. \(x^0 = 1\)

There is another important reason why keeping track of units at every step is important. If you were to calculate the pressure of a gas using the Ideal Gas Law, PV = nRT and you neglected to pay attention to units, you are likely to end up with the wrong answer:

What is the pressure in torrs of 0.200 mole of gas occupying 962 mL at 25.0°C?

Incorrect: \[ P = \frac{nRT}{V} = \frac{(0.200)(0.08206)(25.0)}{(962)} = 4.27 \times 10^4 \text{ torr} \]

Why is it incorrect? By including units you would have seen that the units do not cancel properly. T must be in units of K and V must be in L.

Correct: \[ P = \frac{nRT}{V} = \frac{(0.200 \text{ mol})(0.08206 \text{ atm.L/mol.K})(298 \text{ K})}{(0.962 \text{ L})} = 5.08 \text{ atm} \]

\[ P = 5.08 \text{ atm} \left( \frac{760 \text{ torr}}{1 \text{ atm}} \right) = 3.86 \times 10^3 \text{ torr} \]
Calculations & Results:  
Name: _____________________ 
CHEM 124 Sec: _________

Part I Information from the Excel Graph

Last four digits of your CCBC ID number ___ ___ ___ __.

<table>
<thead>
<tr>
<th>B-Value (x-axis in 4 sig.fig.)</th>
<th>C-Value (y-axis)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B = A / (81.11 x 12.12)</td>
<td>1.43 x 10^{-4}</td>
</tr>
<tr>
<td>B = A / 835.1</td>
<td>2.22 x 10^{-4}</td>
</tr>
<tr>
<td>B = A x 1.234 x 10^{-3}</td>
<td>2.77 x 10^{-4}</td>
</tr>
<tr>
<td>B = A x (88.88 / 66,666)</td>
<td>3.33 x 10^{-4}</td>
</tr>
<tr>
<td>B = A / (( 40.123 + 22.22) x 10.11)</td>
<td>5.19 x 10^{-4}</td>
</tr>
</tbody>
</table>

Using the graph, for C-value = 2.85 x 10^{-4}, what is the corresponding B-value?  
(Read it directly off the graph.) Review Sig.Fig. Rule III G in the previous discussion.

Ans. ________________________________

Trendline equation copied from the graph: ________________________________

Rewrite the equation in terms of B and C instead of x and y:

______________________________

Substitute C = 2.85x10^{-4} into the trendline equation and calculate B. Review Sig.Fig. Rule IIIB in the previous discussion

Show calculations below:  
Ans. ________________________________

Briefly explain, in full sentences, what the R^2 value of this graph tells you. Write legibly.
**Part III: Review of Significant Figures & Units**  
**Name:** _________________________

Determine the number of significant figures in each of the following quantities and convert them to scientific notation:

<table>
<thead>
<tr>
<th># sig.fig.</th>
<th>Scientific Notation</th>
<th># sig.fig.</th>
<th>Scientific Notation</th>
</tr>
</thead>
<tbody>
<tr>
<td>102.3</td>
<td></td>
<td>0.00123</td>
<td></td>
</tr>
<tr>
<td>123.00</td>
<td></td>
<td>123,000.</td>
<td></td>
</tr>
<tr>
<td>1.00230</td>
<td></td>
<td>0.0000123</td>
<td></td>
</tr>
</tbody>
</table>

Determine the number of significant figures in each of the following numbers and convert them to conventional notation (non-exponential, decimal form).

<table>
<thead>
<tr>
<th># sig.fig.</th>
<th>Conventional Notation</th>
<th># sig.fig.</th>
<th>Conventional Notation</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.56x10^-2</td>
<td></td>
<td>0.0229 x 10^3</td>
<td></td>
</tr>
<tr>
<td>1.200 x 10^5</td>
<td></td>
<td>1.000 x 10^-5</td>
<td></td>
</tr>
<tr>
<td>1.201 x 10^4</td>
<td></td>
<td>7.5 x 10^6</td>
<td></td>
</tr>
</tbody>
</table>

Perform each of the following indicated operations and report the answers to the proper number of significant figures and units. Use scientific notation only if appropriate.

1. \(12.34 \text{ g} \times 1.54 \text{ g/mL} = \) ____________
2. \(4.56 \text{ cm}^2 / 0.012326 \text{ cm} = \) ____________
3. \(1.74 \text{ mL} \times 0.0342 \text{ g/mL}^{-1} = \) ____________
4. \(0.00957 \text{ cm}^{-1} / 2.94645 \text{ cm}^{-3} = \) ____________
5. \(8.55 \text{ cm} + 0.154 \text{ m} = \) ____________
6. \(7.00199 \text{ g} - 9.567 \text{ mg} = \) ____________
7. \(6.75 \times 10^{-8} \text{ mol} + 5.44 \times 10^{-7} \text{ mol} = \) ____________

Find the average of 138 mL and 139 mL. Ans. ____________

*Remember the special rule about sig. fig. of averages.*

There are \(10^3\) millimoles in 1 mole. (1 mol = \(10^3\) mmol)

For a solution that is 0.528 M (0.528 moles/Liter), what is the concentration in units of millimoles/milliliter? Show your setup. Be very careful in including units in your setup.