Quantitative Reasoning Sample Prompts

Click here for the Quantitative Reasoning rubric

Quantitative Reasoning Dimensions:

<table>
<thead>
<tr>
<th>Communication and/or Representation of Quantitative Information</th>
<th>Analysis of Quantitative Arguments</th>
<th>Application of Quantitative Models</th>
</tr>
</thead>
</table>

General observations about Quantitative Reasoning dimensions:

**Example 1:** All the student artifacts that correspond to this assignment prompt were rated “proficient” for both selected dimensions. Raters said the “selected dimensions fit the assignment very well” and that this was a “fantastic question to evaluate both dimensions.”

<table>
<thead>
<tr>
<th>Gen Ed Area of Study</th>
<th>Course Name</th>
<th>Dimensions Selected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mathematics and Statistics</td>
<td>Intro to Statistics</td>
<td>Communication and/or Representation of Quantitative Information</td>
</tr>
</tbody>
</table>

**Assignment Description and Rubric:** This is a BIG project that gives you an opportunity to show what you've learned from the first six weeks of this course. The project is worth 100 points. It is due MARCH 13.

You will explore a research question that generates a list of at least 30 pieces of quantitative data. With that data, you will create graphs, find the measures of center and measures of variation, and analyze your results. (Be sure to have your research question approved by Cheryl before you begin.)

Attached here is the rubric which explains the five categories that you are expected to complete. They are shown in rows on the rubric: Research Question, Data Collection, Statistical Graphs, Summary Statistics, and Analysis of Data. You should aim to earn a "4" in each category

In past years, students have created posters to show their knowledge. But in this virtual world, you have many options. You could write a report of your findings, you could make a virtual poster or a Power Point or a video ... whatever way you would like to "show what you know" is fine, as long as you fulfill all the requirements of the rubric (below).
### Example 2

All the student artifacts that correspond to this assignment prompt were rated “proficient” for both selected dimensions.

<table>
<thead>
<tr>
<th>Gen Ed Area of Study</th>
<th>Course Name</th>
<th>Dimensions Selected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical and Natural Sciences</td>
<td>General Chemistry II Lab for</td>
<td>Communication and/or Representation of Quantitative Information</td>
</tr>
</tbody>
</table>
Assignment Description:

General Chemistry II (Laboratory)

Spring 2022

Lab Assignment 2: Rates of chemical reactions - The Iodine Clock Reaction

(Due on Monday, February 14, 2022)

Objectives
By completing the lab assignment 2, you will be able to

- Examine the effect of concentration of a reactant on the rate of the reaction
- Determine the order of the reaction with respect to a reactant

Introduction

Chemical kinetics is the study of how fast chemical reactions take place. The rate of a chemical reaction depends on various factors: nature of the reactant, concentration of reactants, temperature, and the presence of a catalyst.

The rate of a chemical reaction generally increases as the concentration of reactant increases.

Consider the generic equation given below:

\[ a \text{ A} + b \text{ B} \rightarrow \text{products} \]

The relationship between the rate of a reaction and the concentration of the reactants is given by the rate law.

\[ \text{Rate} = k [A]^m[B]^n \]

\([A]\) and \([B]\) are the concentrations of the two reactants A and B, respectively

\(k\) is the rate constant

\(m\) and \(n\) are known as the orders of the reaction with respective to the concentrations of A and B respectively

The sum of the individual orders of the reaction is known as the overall order.

The orders and the rate constant are generally determined experimentally.
In this experiment, you will study a reaction known as the “iodine clock” reaction. This reaction occurs between potassium iodate (KIO$_3$) and sodium bisulfite (NaHSO$_3$) and produces elemental iodine (I$_2$).

The balanced chemical equation is

$$5\text{HSO}_3^- + 2\text{IO}_3^- \rightarrow \text{I}_2 + 5\text{SO}_4^{2-} + 3\text{H}_2\text{O} + 3\text{H}^+$$

This reaction is an oxidation-reduction reaction. Here, iodine(V) is reduced to iodine (0) whereas sulfur (IV) is oxidized to sulfur(VI). Since the elemental iodine (I$_2$) has a color, the time required for the appearance of the color of I$_2$ can be used as an indication of the rate of the reaction. However, the light orange-brown color of I$_2$ in water makes it difficult to identify the appearance of the color. The presence of I$_2$ in the medium can be identified by adding a small quantity of starch into the medium as I$_2$ forms a dark blue-black color complex with starch. If starch is present in the medium, the first few molecules of I$_2$ react with starch producing the blue-black color complex. Thus, the solution turns into dark blue-black color.

The rate law written for the reaction

$$5\text{HSO}_3^- + 2\text{IO}_3^- \rightarrow \text{I}_2 + 5\text{SO}_4^{2-} + 3\text{H}_2\text{O} + 3\text{H}^+$$

takes the general form as shown below:

$$Rate = k [\text{HSO}_3^-]^m[\text{IO}_3^-]^n$$

$m$ is the order of the reaction with respect to the bisulfate ion (HSO$_3^-$)

$n$ is the order of the reaction with respect to the iodate ion (IO$_3^-$)

In this experiment, you will determine the order of the reaction with respect to the concentration of potassium iodate. You will perform several trials of the experiment by varying the concentration of potassium iodate systematically but keeping the concentrations of the other species constant. You will measure the time required for the reaction to occur (to appear the dark blue-black color). Finally, you can determine the order of the reaction with respect to potassium iodate (or iodate ion) using a graphical method.

If the plot of $[\text{IO}_3^-]$ vs time is linear, the order is 0. If the plot of $ln[\text{IO}_3^-]$ vs time is linear, the order is 1. A linear plot of $1/[\text{IO}_3^-]$ vs time suggests that the order is 2.

**Report your observations as a lab report and upload to UNM LEARN. Go through the guidelines given in the document named “A guide on writing a general lab report.”**

**Safety precautions**

Always wear the safety goggles while you are in the laboratory.
Sodium bisulfite (NaHSO$_3$) is harmful to the skin and releases noxious sulfur dioxide (SO$_2$) gas if acidified. Keep the solution covered with a watch glass when not in use.

Potassium iodate (KIO$_3$) is a strong oxidizing agent and can damage skin. Wash hands after handling the chemical.

Elemental iodine may stain the skin. The stains are generally not harmful at the concentrations used in this experiment but will require several days to wear off. Iodine will stain clothing.

**Reagents and glassware**

0.024 M potassium iodate (KIO$_3$) solution

0.010 M sodium bisulfite (NaHSO$_3$) solution

1.5% starch solution

Distilled water

100 mL beakers 5

25 mL graduated cylinder 1

10 mL graduated cylinders 2

Thermometer

**Procedure**

*Note:* Use clean graduated cylinders for measuring each solution. You can use the same 25 mL graduated cylinder to measure potassium iodate (KIO$_3$) solution and distilled water.

Use 2 separate graduated cylinders for measuring 0.010 M sodium hydrogen sulfite (NaHSO$_3$) solution and starch solutions.

1. Obtain ~80 mL of 0.024 M potassium iodate (KIO$_3$) solution into a clean, dry 50 mL beaker.
2. Obtain ~30 mL of 0.010 M sodium hydrogen sulfite (NaHSO$_3$) solution into another clean, dry 50 mL beaker. Cover the beaker with a watch glass.
3. Obtain ~30 mL of 1.5% starch solution into another clean, dry 50 mL beaker.
4. Obtain five 100 mL-beakers. Rinse them with distilled water and label each beaker as A, B, C, D, and E.
5. Use the 25 mL graduated cylinder for measuring the following solutions. Add 5.0 mL of 0.024 M potassium iodate (KIO$_3$) solution into the beaker labeled as A. Then add 20.0 mL of distilled water into the same beaker.
6. Obtain another dry, clean 50 mL beaker. Mix 5.0 mL of 0.010 M sodium hydrogen sulfite (NaHSO$_3$) solution and 5.0 mL of 1.5% starch solution in the beaker.
7. Measure the temperature of the two solutions prepared in the steps 5 and 6 (make sure to keep separate thermometers for each solution.) If the temperatures differ by more than one degree, wait until the two solutions come to the same temperature.

8. When the two solutions reach the same temperature, prepare to mix them. Have ready a clean stirring rod for use after mixing the solutions. Also, you will need to start the stopwatch (in your mobile phone) as soon as you mix the solutions.

9. Noting the time (to the nearest second) pour the NaHSO₃ and starch solution mixture into the beaker A that contains KIO₃ and distilled water. Make sure to start the stopwatch as soon as you mix the solutions. Stir the solutions for 15 -30 seconds.

10. Watch the mixture carefully and record the time the blue-black color of the starch/iodine mixture appears.

11. Repeat the steps 5 – 10 by mixing the volumes mentioned in the table 1. Each beaker labeled as B, C, D, and E should contain the corresponding volumes of each solution.

12. Follow the steps in analysis of data to analyze your data and determine the order of the reaction with respect to KIO₃.

```markdown
<table>
<thead>
<tr>
<th>Run</th>
<th>Volume of 0.024 M KIO₃ (mL)</th>
<th>Volume of 0.010 M NaHSO₃ (mL)</th>
<th>Volume of 1.5% starch (mL)</th>
<th>Volume of distilled water (mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
<td>85.0</td>
</tr>
<tr>
<td>B</td>
<td>10.0</td>
<td>5.0</td>
<td>5.0</td>
<td>80.0</td>
</tr>
<tr>
<td>C</td>
<td>15.0</td>
<td>5.0</td>
<td>5.0</td>
<td>75.0</td>
</tr>
<tr>
<td>D</td>
<td>20.0</td>
<td>5.0</td>
<td>5.0</td>
<td>70.0</td>
</tr>
<tr>
<td>E</td>
<td>25.0</td>
<td>5.0</td>
<td>5.0</td>
<td>65.0</td>
</tr>
</tbody>
</table>
```

Table 1: volume of each solution that should be mixed in each run.

**Report sheet**

**Note:** You should prepare your own tables when writing the lab report.

Report the starting time and end time (when the blue-black color appears) in the table 2.

```markdown
<table>
<thead>
<tr>
<th>Run</th>
<th>Start time</th>
<th>End time</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
```

Table 2: Time required for the blue-black color to appear

**Analysis of data**

1. Convert the start time and the end time to seconds.
   E.g.: if your start time is 2 min 10 s, convert it to second as shown below.

   \[(2min \times 60s/1min)+10s=130s\]
2. Calculate the time required for the reaction using the formula
   
   Time required for the reaction (s) = end time (s) – start time (s)

3. Create a table as shown below and enter your values.

<table>
<thead>
<tr>
<th>Run</th>
<th>Start time (s)</th>
<th>End time (s)</th>
<th>Time required for the reaction (T) (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3: time required to each reaction in seconds

4. Here, you will determine the form of the integrated rate law by plotting graphs to determine the order of the reaction with respect to KIO₃.

5. Calculate the concentration of KIO₃ in each reaction mixture (from A to E). For example, in the reaction mixture prepared for run A, the volume of KIO₃ is 5.0 mL and the total volume is 100.0 mL (total volume = volume of KIO₃ solution + volume of NaHSO₃ solution + volume of distilled water). Use \( C_1V_1 = C_2V_2 \) to calculate the concentration of KIO₃ in the final solution.

Here, \( C_1 = 0.024 \, \text{M} \)
\( V_1 = 5.0 \, \text{mL} \)
\( V_2 = 100.0 \, \text{mL} \) (might be different according to the volumes that you used)

\[ C_2 = \left( \frac{C_1V_1}{V_2} \right) \]

For the mixture in run A
\[ C_2 = \frac{C_1V_1}{V_2} = \frac{0.024 \, \text{M} \times 5.0 \, \text{mL}}{100.0 \, \text{mL}} = 1.2 \times 10^{-3} \, \text{M} \]

6. Create another table to show the following information

<table>
<thead>
<tr>
<th>Run</th>
<th>Time required for the reaction (T) (s)</th>
<th>[KIO₃] in the mixture (M)</th>
<th>1/[KIO₃]</th>
<th>ln[KIO₃]</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4: Data necessary to plot graphs
Note: Use the ‘LN or natural logarithm’ function to calculate ‘ln [KIO₃]’. You can use the autofill function in MS Excel to perform the calculations for all runs at once.

7. Plot three forms of graphs to find the graph that gives a straight line (please go through your notes for more information.)

   Graph 1 – concentration of KIO₃ in the mixture (Y axis) vs time required of the reaction (X axis)

   Graph 2 – 1/[KIO₃] (Y axis) vs time required of the reaction (X axis)

   Graph 3 – ln [KIO₃] (Y axis) vs time required of the reaction (X axis)

8. If your data points show a linear trend add the trendline and check the boxes for ‘show equation’ and ‘show R-squared value’.

9. Use the R-squared (R²) value to find the most linear graph.

10. Determine the order of the reaction with respect to KIO₃.

**Post lab questions**

Answer these questions at the end of your lab report

1. Why is it necessary to keep the total volume of the mixture constant in all kinetic runs (from A to E) (why was it necessary to add distilled water to make the total volume constant)?

2. In this experiment, you determined the order of the reaction with respect to KIO₃. Briefly explain an experiment that you can use to determine the order of the reaction with respect to sodium bisulfite (NaHSO₃).

**Reference**


**Example 3:** One of the raters said of this assignment that it was a “good problem set for the [selected] dimensions.”

<table>
<thead>
<tr>
<th>Gen Ed Area of Study</th>
<th>Course Name</th>
<th>Dimensions Selected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical and</td>
<td>General Chemistry II for STEM Majors</td>
<td>Analysis of Quantitative Arguments</td>
</tr>
<tr>
<td>Natural Sciences</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Assignment Description:**
Spring 2022

General Chemistry II for STEM Majors

Homework 2
(Due on Monday, March 21, 2022)

Name:

1. Write the expressions for $K_c$ and $K_p$ for the reaction (2 pts)
   \[ 2\, NH_3(g) + CO_2(g) \rightleftharpoons N_2CH_4O(s) + H_2O(g) \]

2. For the reaction
   \[ H_2(g) + Br_2(g) \rightleftharpoons 2\, HBr(g) \]
   
   $K_p = 3.5 \times 10^4$ at 1495 K.

   What is the value of $K_p$ for the following reaction at 1495 K? (1 pt)
   \[ HBr(g) \rightleftharpoons \frac{1}{2}\, H_2(g) + \frac{1}{2}\, Br_2(g) \]
3. Consider the following reaction at a certain temperature:

\[ 4 \text{Fe}(s) + 3 \text{O}_2(g) \rightleftharpoons 2 \text{Fe}_2\text{O}_3(s) \]

An equilibrium mixture contains 1.0 mol Fe, \(1.0 \times 10^{-3}\) mol O\(_2\), and 2.0 mol Fe\(_2\)O\(_3\) all in a 2.0 L container.

a. Write an expression for \(K_c\) for this reaction. (1 pt)

b. Calculate the value of \(K_c\). (1 pt)

4. At 25 °C, \(K_p = 109\) for the reaction

\[ 2 \text{NO}(g) + \text{Br}_2(g) \rightleftharpoons 2 \text{NOBr}(g) \]

If the equilibrium partial pressure of Br\(_2\) is 0.0159 atm and the equilibrium partial pressure of NOBr is 0.0768 atm, calculate the partial pressure of NO at equilibrium. (1 pt)
5. At a particular temperature a 2.00 L flask at equilibrium contains \(2.80 \times 10^{-4}\) mol \(N_2\), \(2.50 \times 10^{-5}\) mol \(O_2\), and \(2.00 \times 10^{-2}\) mole of \(N_2O\).
   a. Write an expression for the equilibrium constant, \(K_c\), for the reaction (1 pt)
   \[2\ N_2(g) + O_2(g) \rightleftharpoons 2\ N_2O(g)\]
   
   b. Calculate the equilibrium constant, \(K_c\), at this temperature for the above reaction (1 pt)
   
   c. If \([N_2] = 2.00 \times 10^{-4}\) M, \([N_2O] = 0.200\) M, and \([O_2] = 0.00245\) M, does this represent a system at equilibrium? (1 pt)

6. A sample of \(S_8(g)\) is placed in an otherwise empty rigid container at 1325 K at an initial pressure of 1.00 atm, where it decomposes to \(S_2(g)\) by the reaction
   \[S_8(g) \rightleftharpoons 4\ S_2(g)\]
   
   At equilibrium, the partial pressure of \(S_8\) is 0.25 atm. Calculate \(K_p\) for this reaction at 1325 K. (1 pt)
   
   Hint: complete the ICE table.