

## Quantitative Reasoning Sample Prompts

[Click here for the Quantitative Reasoning rubric](#)

### Quantitative Reasoning Dimensions:

Communication and/or Representation of Quantitative Information	Analysis of Quantitative Arguments	Application of Quantitative Models
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### 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.”

Gen Ed Area of Study	Course Name	Dimensions Selected	
Mathematics and Statistics	Intro to Statistics	Communication and/or Representation of Quantitative Information	Application of Quantitative Models

*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).

## Descriptive Statistics Project Rubric

	1	2	3	4	Score
<b>Research Question</b> <i>State your question and why you're interested. Before you collected your data, what did you conjecture would be the answer to your question?</i>	Question topic is qualitative; not appropriate for this project.	Question topic is quantitative.	Question topic is quantitative, plus student explains why topic was chosen.	Question topic is quantitative, plus student explains why topic was chosen and explains what they expected to happen.	
<b>Data Collection (n≥30):</b> <i>Discuss how data was collected, and whether it came from a population or sample. Provide a list of the data.</i>	Fewer than 30 pieces of data were collected; method of collection not stated; <i>population vs sample</i> not discussed; a list of data not provided.	Fewer than 30 pieces of data were collected; method of collection stated; <i>population vs sample</i> not discussed; a list of data is provided.	At least 30 pieces of data collected; method of collection not statistically rigorous (convenience sample); <i>population vs sample</i> discussed; a list of data is provided.	At least 30 pieces of data collected; method of collection statistically rigorous and explained; <i>population vs sample</i> discussed; a list of data is provided.	
<b>Statistical Graphs</b> <i>Make a Histogram &amp; Box Plot, plus one optional graph</i>	One assigned graph attempted, but incorrect	Two assigned graphs attempted, but incorrect or missing labels.	Two assigned graphs drawn correctly; labels included.	Two assigned graphs drawn correctly, plus one optional; labels included.	
<b>Summary Statistics</b> <i>Compute the Five-Number Summary &amp; Measures of Center (mode, median, mean) and Measures of Variation (range, IQR, standard deviation)</i>	Some statistics are computed, but with major errors.	Most statistics computed; some missing or some major errors.	All required statistics computed correctly, or there might be one slight error.	All required statistics computed correctly; some in-depth explanation of computational methods included.	
<b>Analysis of Data</b> <i>Write a paragraph explaining what your data shows, using the statistics from above. Include a discussion of shape, center and spread. Did your original conjecture hold true?</i>	A paragraph is written, but no statistical analysis is included.	Some statistical analysis, but weak; may include only vague ideas about shape, center, and spread.	Analysis is adequate; includes discussion of shape, center, and spread; checks for possible outliers; student adequately compares findings to original conjecture.	Analysis shows in-depth understanding of the relationship between shape, center, and spread; checks for possible outliers with explanation. Student compares findings to original conjecture in an insightful way.	

Rubric scores will be given for each of the five categories (rows) above.

**Example 2:** All the student artifacts that correspond to this assignment prompt were rated “proficient” for both selected dimensions.

Gen Ed Area of Study	Course Name	Dimensions Selected	
Physical and Natural Sciences	General Chemistry II Lab for	Communication and/or Representation of Quantitative Information	Application of Quantitative Models

	STEM Majors		
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*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

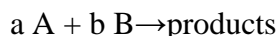
- Examine the effect of concentration of a reactant on the rate of the reaction
- Determine the order of the reaction with respect to a reactant

#### **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:



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

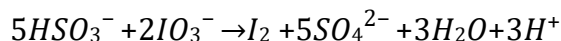
m and n are known as the orders of the reaction with respect to the concentrations of A and B respectively

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.

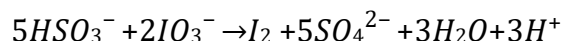
In this experiment, you will study a reaction known as the “iodine clock” reaction. This reaction occurs between potassium iodate ( $\text{KIO}_3$ ) and sodium bisulfite ( $\text{NaHSO}_3$ ) and produces elemental iodine ( $\text{I}_2$ ).

The balanced chemical equation is



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 ( $\text{I}_2$ ) has a color, the time required for the appearance of the color of  $\text{I}_2$  can be used as an indication of the rate of the reaction. However, the light orange-brown color of  $\text{I}_2$  in water makes it difficult to identify the appearance of the color. The presence of  $\text{I}_2$  in the medium can be identified by adding a small quantity of starch into the medium as  $\text{I}_2$  forms a dark blue-black color complex with starch. If starch is present in the medium, the first few molecules of  $\text{I}_2$  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



takes the general form as shown below:

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

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

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

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 ( $\text{NaHSO}_3$ ) is harmful to the skin and releases noxious sulfur dioxide ( $\text{SO}_2$ ) gas if acidified. Keep the solution covered with a watch glass when not in use.

Potassium iodate ( $\text{KIO}_3$ ) 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 ( $\text{KIO}_3$ ) solution

0.010 M sodium bisulfite ( $\text{NaHSO}_3$ ) 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 ( $\text{KIO}_3$ ) solution and distilled water.

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

1. Obtain ~80 mL of 0.024 M potassium iodate ( $\text{KIO}_3$ ) solution in to a clean, dry 50 mL beaker.
2. Obtain ~30 mL of 0.010 M sodium hydrogen sulfite ( $\text{NaHSO}_3$ ) 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 ( $\text{KIO}_3$ ) 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 ( $\text{NaHSO}_3$ ) 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 NaHSO<sub>3</sub> and starch solution mixture into the beaker A that contains KIO<sub>3</sub> 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 KIO<sub>3</sub>.

Run	Volume of 0.024 M KIO <sub>3</sub> (mL)	Volume of 0.010 M NaHSO <sub>3</sub> (mL)	Volume of 1.5% starch (mL)	Volume of distilled water (mL)
A	5.0	5.0	5.0	85.0
B	10.0	5.0	5.0	80.0
C	15.0	5.0	5.0	75.0
D	20.0	5.0	5.0	70.0
E	25.0	5.0	5.0	65.0

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.

Run	Start time	End time
A		
B		
C		
D		
E		

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.

$$(2\text{min} \times 60\text{s}/1\text{min}) + 10\text{s} = 130\text{s}$$

2. Calculate the time required for the reaction using the formula

$$\text{Time required for the reaction (s)} = \text{end time (s)} - \text{start time (s)}$$

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

Run	Start time (s)	End time (s)	Time required for the reaction (T) (s)
A			
B			
C			
D			
E			

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  $\text{KIO}_3$ .
5. Calculate the concentration of  $\text{KIO}_3$  in each reaction mixture (from A to E). For example, in the reaction mixture prepared for run A, the volume of  $\text{KIO}_3$  is 5.0 mL and the total volume is 100.0 mL (total volume = volume of  $\text{KIO}_3$  solution + volume of  $\text{NaHSO}_3$  solution + volume of distilled water). Use  $C_1V_1 = C_2V_2$  to calculate the concentration of  $\text{KIO}_3$  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)

$C_2 = ?$

$$\begin{aligned} C_1V_1 &= C_2V_2 \\ \frac{C_1V_1}{V_2} &= \frac{C_2V_2}{V_2} \\ C_2 &= \frac{C_1V_1}{V_2} \end{aligned}$$

For the mixture in run A

$$C_2 = \frac{C_1V_1}{V_2} = \frac{0.024 \text{ M} \times 5.0 \text{ mL}}{100.0 \text{ mL}} = 1.2 \times 10^{-3} \text{ M} = 1.2 \times 10^{-3} \text{ M}$$

6. Create another table to show the following information

Run	Time required for the reaction (T) (s)	$[\text{KIO}_3]$ in the mixture (M)	$1/[\text{KIO}_3]$	$\ln[\text{KIO}_3]$
A				
B				
C				
D				
E				

Table 4: Data necessary to plot graphs

Note: Use the 'LN or natural logarithm' function to calculate ' $\ln [\text{KIO}_3]$ '. 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  $\text{KIO}_3$  in the mixture (Y axis) vs time required of the reaction (X axis)

Graph 2 –  $1/[\text{KIO}_3]$  (Y axis) vs time required of the reaction (X axis)

Graph 3 –  $\ln [\text{KIO}_3]$  (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 ( $R^2$ ) value to find the most linear graph.
10. Determine the order of the reaction with respect to  $\text{KIO}_3$ .

### **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  $\text{KIO}_3$ . Briefly explain an experiment that you can use to determine the order of the reaction with respect to sodium bisulfite ( $\text{NaHSO}_3$ ).

### **Reference**

1. Experimental Chemistry, Zumdahl, Zumdahl, and DeCoste prepared by John G Little, Cengage Learning, Tenth Edition, Experiment 26

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

Gen Ed Area of Study	Course Name	Dimensions Selected	
Physical and Natural Sciences	General Chemistry II for STEM Majors	Analysis of Quantitative Arguments	Application of Quantitative Models

*Assignment Description:*



**Spring 2022**

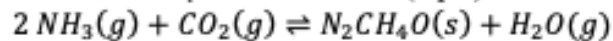
**General Chemistry II for STEM Majors**

**Homework 2**

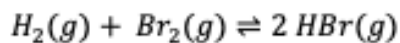
**(Due on Monday, March 21, 2022)**

**Name:**

1. Write the expressions for  $K_c$  and  $K_p$  for the reaction (2 pts)

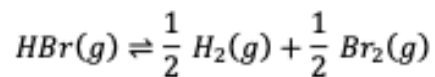


2. For the reaction

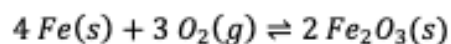


$K_p = 3.5 \times 10^4$  at 1495 K.

What is the value of  $K_p$  for the following reaction at 1495 K? (1 pt)



3. Consider the following reaction at a certain temperature:

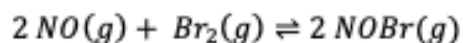


An equilibrium mixture contains 1.0 mol Fe,  $1.0 \times 10^{-3}$  mol  $\text{O}_2$ , and 2.0 mol  $\text{Fe}_2\text{O}_3$  all in a 2.0 L container.

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

- b. Calculate the value of  $K_c$ . (1 pt)

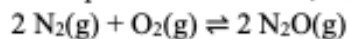
4. At 25 °C,  $K_p = 109$  for the reaction



If the equilibrium partial pressure of  $\text{Br}_2$  is 0.0159 atm and the equilibrium partial pressure of  $\text{NOBr}$  is 0.0768 atm, calculate the partial pressure of  $\text{NO}$  at equilibrium. (1 pt)

5. At a particular temperature a 2.00 L flask at equilibrium contains  $2.80 \times 10^{-4}$  mol  $\text{N}_2$ ,  $2.50 \times 10^{-5}$  mol  $\text{O}_2$ , and  $2.00 \times 10^{-2}$  mole of  $\text{N}_2\text{O}$ .

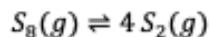
a. Write an expression for the equilibrium constant,  $K_c$ , for the reaction (1 pt)



b. Calculate the equilibrium constant,  $K_c$ , at this temperature for the above reaction (1 pt)

c. If  $[\text{N}_2] = 2.00 \times 10^{-4}$  M,  $[\text{N}_2\text{O}] = 0.200$  M, and  $[\text{O}_2] = 0.00245$  M, does this represent a system at equilibrium? (1 pt)

6. A sample of  $\text{S}_8(\text{g})$  is placed in an otherwise empty rigid container at 1325 K at an initial pressure of 1.00 atm, where it decomposes to  $\text{S}_2(\text{g})$  by the reaction



At equilibrium, the partial pressure of  $\text{S}_8$  is 0.25 atm. Calculate  $K_p$  for this reaction at 1325 K. (1 pt)

Hint: complete the ICE table.