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

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
Research Question *State your question and why you're interested. Before you collected your data, what did you conjecture would be the answer to your question?*	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.	
Data Collection (n≥30): *Discuss how data was collected, and whether it came from a population or sample. Provide a list of the data.*	Fewer than 30 pieces of data were collected; method of collection not stated; *population vs sample* not discussed; a list of data not provided.	Fewer than 30 pieces of data were collected; method of collection stated; *population vs sample* not discussed; a list of data is provided.	At least 30 pieces of data collected; method of collection not statistically rigorous (convenience sample); *population vs sample discussed*; a list of data is provided.	At least 30 pieces of data collected; method of collection statistically rigorous and explained; *population vs sample* discussed; a list of data is provided.	
Statistical Graphs *Make a Histogram & Box Plot, plus one optional graph*	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.	
Summary Statistics *Compute the Five-Number Summary & Measures of Center (mode, median, mean) and Measures of Variation (range, IQR, standard deviation)*	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.	
Analysis of Data *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?*	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		

Assignment Description:

General Chemistry II (Laboratory)

Spring 2022

<u>Lab Assignment 2: Rates of chemical reactions - The Iodine Clock Reaction</u>

(Due on Monday, February 14, 2022)

<u>Objectives</u>

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

<u>Introduction</u>

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:

$$a\ A + b\ B \rightarrow \text{products}$$

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

$$Rate = k\ [A]^m[B]^n$$

[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

$$5HSO_3^- + 2IO_3^- \rightarrow I_2 + 5SO_4^{2-} + 3H_2O + 3H^+$$

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

$$5HSO_3^- + 2IO_3^- \rightarrow I_2 + 5SO_4^{2-} + 3H_2O + 3H^+$$

takes the general form as shown below:

$$Rate = k\,[HSO_3^-]^m[IO_3^-]^n$$

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 *$[IO_3^-]$ vs time* is linear, the order is 0. If the plot of *ln*$[IO_3^-]$ vs time is linear, the order is 1. A linear plot of *$1/[IO_3^-]$ vs time* suggests that the order is 2.

**** Report your observations as a <u>lab report</u> 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 in to 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 $NaHSO_3$ and starch solution mixture into the beaker A that contains KIO_3 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_3.

Run	Volume of 0.024 M KIO_3 (mL)	Volume of 0.010 M $NaHSO_3$ (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

<u>Analysis of data</u>

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.

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

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.

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 KIO_3.
5. Calculate the concentration of KIO_3 in each reaction mixture (from A to E). For example, in the reaction mixture prepared for run A, the volume of KIO_3 is 5.0 mL and the total volume is 100.0 mL (total volume = volume of KIO_3 solution + volume of $NaHSO_3$ solution + volume of distilled water). Use $C_1V_1 = C_2V_2$ to calculate the concentration of KIO_3 in the final solution.

Here, $C_1 = 0.024$ M
$V_1 = 5.0$ mL
$V_2 = 100.0$ mL (might be different according to the volumes that you used)
$C_2 = ?$

$$C_1V_1 = C_2V_2$$
$$\frac{C_1V_1}{V_2} = \frac{C_2\cancel{V_2}}{\cancel{V_2}}$$
$$C_2 = \frac{C_1V_1}{V_2}$$

For the mixture in run A

$$C_2 = \frac{C_1V_1}{V_2} = \frac{0.024\ M \times 5.0\ mL}{100.0\ mL} = 1.\bar{2} \times 10^{-3}\ M = 1.2 \times 10^{-3}\ M$$

6. Create another table to show the following information

Run	**Time required for the reaction (T) (s)**	**[KIO_3] in the mixture (M)**	**1/[KIO_3]**	**ln[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 [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 KIO_3 in the mixture (Y axis) vs time required of the reaction (X axis)

   Graph 2 – 1/[KIO_3] (Y axis) vs time required of the reaction (X axis)

   Graph 3 – ln [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 KIO_3.

<u>Post lab questions</u>

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 ($NaHSO_3$).

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)

$$2\ NH_3(g) + CO_2(g) \rightleftharpoons N_2CH_4O(s) + H_2O(g)$$

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:

$$4\,Fe(s) + 3\,O_2(g) \rightleftharpoons 2\,Fe_2O_3(s)$$

An equilibrium mixture contains 1.0 mol Fe, 1.0×10^{-3} mol O_2, and 2.0 mol Fe_2O_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

$$2\,NO(g) + Br_2(g) \rightleftharpoons 2\,NOBr(g)$$

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 2.80×10^{-4} mol N_2, 2.50×10^{-5} mol O_2, and 2.00×10^{-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 $[N_2] = 2.00\times10^{-4}$ 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.

Answer the questions in the spaces provided. If you run out of room for an answer, continue on the back of the page. To get credit *show all of your work!* by writing all the steps in order and explaining your reasoning. Good luck and have fun!

Name: ______________________________

Total: 20 points

1. A rumor starts to spread in a small town of 500 people. The number of people who have heard the rumor after x days is

$$h(x) = \frac{500}{1 + 99e^{-.15x}}.$$

   (a) [5 points] How many days will it take before 200 people have heard the rumor?

   (b) [5 points] The rumor is about one of your friends, who is very worried that eventually everyone will have heard the rumor. Are your friend's concerns justified? Give specific support for your answer.

   (c) [5 points] Using your answer for the previous part, please give either the maximum number of people who will hear the rumor or the time it will take until 495 people have heard the rumor. Explain your choice.

   (d) [5 points] A editorial in the newspaper suggests that $f(x) = .05x^2$ is just as good of a model for the spread of the rumor. How will you evaluate their claim? Are you able to make a conclusion with the information you have available?

Assignment: Model of the the Solar System – Part 2

In this assignment, I want you to make and then photograph your scale model of the solar system. This will be a graded assignment.

Part I: Work from Part I *(You should have already completed this work, but if not….)*

To represent the Sun I chose a _______________ and the actual diameter of my 'sun' was _________ mm.

The real diameter of the sun is 1392000 km. The diameter of my model sun is _______ mm so 1mm on my model represents __________km in the solar system. This is my scale factor.

Then copy the data you calculated previously into the table below. When you have determined what the diameters of the planets need to be in your model, see if you can find a household object that is *about* the right size which you can use to model the planet in question. I'm not too worried about it being exact – the intention here is to give us a feel for the scale; we're not looking for precision in the representation. Within 10% is OK. Next week I'll get you to photograph the items & assemble the model.

Name of Object	Actual Diam (Km)	Diameter in my model (mm)	Household Object I can use to model this planet	Actual orbital Radius (km)	Orbital Radius in my model (mm)
Sun	1392000				
Mercury	4878			57,900,000	
Venus	12104			108,160,000	
Earth	12756			149,600,000	
Mars	6794			227,936,640	
Jupiter	142984			778,369,000	
Saturn	120536			1,427,034,000	
Uranus	51118			2,870,658,186	
Neptune	49532			4,496,976,000	

START HERE FOR WORK FOR PART II

Now take two photographs

1. For Photograph 1, place your Sun stand in, Jupiter stand in and the earth stand in next to a ruler and photograph then with your cell phone
2. For Photograph 2, photograph you stand ins for Mercury, Venus, Earth, Mars, Jupiter, Saturn Uranus & Neptune all together in the same picture. Then post them below.

Sun, Jupiter & Earth go here along with Ruler

Above: The objects I used to model the Sun, Jupiter & Earth

Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus & Neptune

Above: My models for Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus & Neptune

Part II: Laying Out the Solar System Model

In the work in part I above you found a scale factor that showed you how many km in space was represented by each mm on your model.

To avoid lots of tedious (and unhelpful) measuring, I want to let you assemble your scale model with minimum frustration. The way I want to do this is to figure out how many km in space is represented by each step you take.

Part II-a- Scale factor for my Step.

Find a convenient space where you can walk about 10 steps (it will need to be 20-40 feet long – a sidewalk or your yard should be good as long as it's fairly flat without any obstacles..

Make a mark on the ground or use a rock or stick to show where you started.

Beginning at your mark, take 10 normal sized steps for you and mark where you finished.

Measure the distance between your starting point and finishing point. It would be good if you measured in Meters, but feet would be OK if that's all you have.
Write that distance here including whether the measurement is in Feet or in meters.: _____________
Remembering that 1 ft = 305mm and 1 meter = 1000mm, How many mm were there in your 10 steps?
My 10 steps = _____________mm.

Now calculate how many millimeters you cover in 1 step: 1 of my steps measures ____________mm

Use the scale factor you used in part I to decide which objects you could choose to model the planets, to estimate how many km in space corresponds to 1 of you steps for your model. 1 step = ________________km.

Now complete the table below to figure out how many steps from your Sun you need to go in order to place each 'planet' in its correct orbit. It will make life easier for you, if work out how many steps it is past 'Mercury' to get to 'Venus' and how many past 'Venus' it is to 'Earth' and so on. Write those values in the last column.

Table IIa

Name of Object	Actual Distance from the sun (km)	No. of my Steps from my model sun	No. of steps from previous planet to this one
Mercury	57,900,000		--------
Venus	108,160,000		
Earth	149,600,000		
Mars	227,936,640		
Jupiter	778,369,000		
Saturn	1,427,034,000		
Uranus	2,870,658,186		
Neptune	4,496,976,000		

Part III- Assemble and Photograph

Having done all the calculations, now it's time to assemble the model and photograph it.

You'll need somewhere flat and level(ish) with plenty of room to lay out your model (A stretch of road ? A trail ? A long drive way or parking lot? - 200 yards would be good !)

Put your 'sun' at one end of your space and pace out the appropriate distance to Mercury as specified in Table IIa above.. Put Mercury on the ground and photograph from Mercury to the Sun. You might want to put your model Mercury (which of course will be tiny) in the middle of a piece of white paper or on top of a rock or other object (short wooden stake??) so that as you move further away, you can still see where 'Mercury' is.

Now pace out how far past Mercury , 'Venus' is. Place that on your marker and photograph from 'Venus'past 'Mercury' to the Sun.

Keep on doing this pacing out to the next planet, putting your planet stand in on its marker and then photographing from the planet to the Sun until you run out of space. (don't worry if you can't get to Neptune – it's a long way away, but try to get to at least Saturn and ideally Uranus as well).

Add your photographs to this document.

Final Reflection:

Write a paragraph reflecting on your observations and what you learned plus any other thoughts you had about this exercise.

Extra Credit.

- Look up the distance to the closest star to us. If, using the same scale, you extended your model to get as far as the next star, how far away would you have to place your model 'neighbor star'?