Investigating Chemistry through Inquiry

4th Edition

Experiments using open and guided inquiry approaches

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CHEM-I

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PRELIMINARY ACTIVITY FOR

Beer's Law Investigations

Open Inquiry Version

The primary objective of this Preliminary Activity is to determine the concentration of an unknown copper (II) sulfate solution. You will use a Colorimeter (a side view is shown in Figure 1). In this device, red light from the LED light source will pass through the solution and strike a photocell. The $CuSO_4$ solution used in this experiment is blue. A higher concentration of the colored solution absorbs more light (and transmits less) than a solution of lower concentration. The Colorimeter monitors the light received by the photocell as percent transmittance.

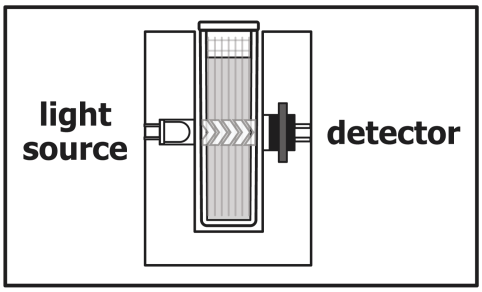

Figure 1

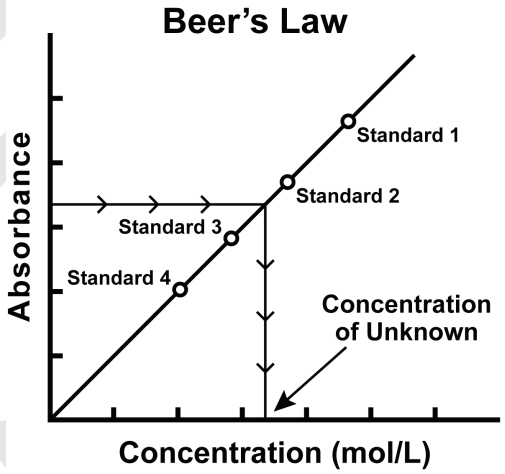

Figure 2

You will prepare five copper (II) sulfate solutions of known concentration (standard solutions). Each solution is transferred to a small, rectangular cuvette that is placed into the Colorimeter. The amount of light that penetrates the solution and strikes the photocell is used to compute the absorbance of each solution. When you graph absorbance *vs*. concentration for the standard solutions, a direct relationship should result. The direct relationship between absorbance and concentration for a solution is known as *Beer's law* (see Figure 2).

You will determine the concentration of an unknown $CuSO_4$ solution by measuring its absorbance with the Colorimeter. By locating the absorbance of the unknown on the vertical axis of the graph, the corresponding concentration can be found on the horizontal axis. The concentration of the unknown can also be found using the slope of the Beer's law curve.

After completing the Preliminary Activity, you will first use reference sources to find out more about solutions, solution concentration, and Beer's law investigations before you choose and

investigate a researchable question utilizing Beer's law technique. Some topics to consider in your reference search are:

- solution
- solute
- solvent
- concentration
- absorbance
- percent transmittance
- Beer's law experiments

PROCEDURE

1. Obtain and wear goggles.

2. Obtain small volumes of 0.40 M $CuSO_4$ solution and distilled water in separate beakers. **WARNING**: *Copper (II) sulfate*, $CuSO_4$: *Do not eat or drink when using this product—harmful if swallowed. Causes skin and eye irritation*.

3. Label five clean, dry, test tubes 1–5. Use pipets to prepare five standard solutions according to the chart below. Thoroughly mix each solution with a stirring rod. Clean and dry the stirring rod between uses.

Trial number	0.40 M $CuSO_4$ (mL)	Distilled H_2O (mL)	Concentration (M)
1	2	8	0.080
2	4	6	0.16
3	6	4	0.24
4	8	2	0.32
5	~10	0	0.40

4. Set up the data-collection system.
   a. Connect the Colorimeter to your Chromebook, computer, or mobile device. Use an interface if necessary.
   b. Set up the data-collection mode for Events with Entry following your instructor's directions. The entry name should be **Concentration** and units should be **mol/L**.

5. Calibrate the Colorimeter.
   a. Prepare a *blank* by filling an empty cuvette 3/4 full with distilled water.
   b. Place the blank in the cuvette slot of the Colorimeter and close the lid.

c. Press the < or > buttons on the Colorimeter to set the wavelength to 635 nm (Red). Then calibrate by pressing the CAL button on the Colorimeter. When the LED stops flashing, the calibration is complete.

6. You are now ready to collect absorbance-concentration data for the five standard solutions.
   a. Start data collection.
   b. Remove the cuvette from your Colorimeter and pour out the water. Using the solution in Test Tube 1, rinse the cuvette twice with ~1 mL amounts, and then fill it 3/4 full. Wipe the outside with a tissue, place it in the Colorimeter, and close the lid.
   c. When the absorbance readings have stabilized, select Keep and enter **0.080** as the concentration. Click or tap Keep Point. The absorbance and concentration values have now been saved for the first solution.
   d. Discard the cuvette contents as directed. Using the solution in Test Tube 2, rinse the cuvette twice with ~1 mL amounts, and then fill it 3/4 full. Wipe the outside, place it in the Colorimeter, and close the lid. When the absorbance readings have stabilized, click or tap Keep and enter **0.16** as the concentration in mol/L. Click or tap Keep Point.
   e. Repeat Part d of this step for Test Tube 3 (0.24 M), Test Tube 4 (0.32M), and the stock 0.40 M $CuSO_4$. **Note**: Do not test the unknown solution until Step 7.
   f. Stop data collection.

7. Determine the absorbance value of the unknown $CuSO_4$ solution.
   a. Obtain about 5 mL of the *unknown* $CuSO_4$ in another clean, dry, test tube. Record the number of the unknown in your data table.
   b. Rinse the cuvette twice with the unknown solution and fill it about 3/4 full. Wipe the outside of the cuvette, place it into the Colorimeter, and close the lid.
   c. Monitor the absorbance value. When this value has stabilized, record it in your data table.

8. Discard the solutions as directed by your instructor.

9. To determine the concentration of the unknown $CuSO_4$ solution, display a graph of absorbance *vs*. concentration with a linear regression curve. Use the Interpolate tool and move along the regression line until the absorbance value is approximately the same as the absorbance value you recorded in Step 7. The corresponding concentration value is the concentration of the unknown solution, in mol/L. cursor

10. (Optional) Print a graph of absorbance *vs*. concentration, with a regression line and interpolated unknown concentration displayed.

QUESTIONS

1. What was the concentration of your unknown solution (in mol/L)?

2. Beer's law investigations involve the absorption of light by a colored species. The species may be colored itself, such as a colorful food dye in a beverage. Alternatively, the species of interest may be colorless, but able to react with an appropriate reagent to produce colored species. Some colorless ions in ground water fit into the latter category. An Internet search using "Beer's law experiments" as the search topic will reveal numerous possible researchable questions of potential interest to you.

3. List at least one researchable question concerning the use of Beer's law technique.

Note: The plan that you submit for instructor approval should list laboratory safety concerns, including chemical safety concerns, and specify how you will address these safety concerns during your investigation.

PRELIMINARY ACTIVITY FOR

Sugar Fermentation by Yeast

Open Inquiry Version

Yeast can metabolize sugar in two ways, *aerobically*, with the aid of oxygen, or *anaerobically*, without oxygen. When yeast metabolizes a sugar under anaerobic conditions, ethanol (CH_3CH_2OH) and carbon dioxide (CO_2) gas are produced. An equation for the fermentation of the simple sugar glucose ($C_6H_{12}O_6$) is:

$$C_6H_{12}O_6 \rightarrow 2\ CH_3CH_2OH + 2\ CO_2 + \text{energy}$$

The metabolic activity of yeast can be determined by the measurement of gas pressure inside the fermentation vessel.

In the Preliminary Activity, you will use a Gas Pressure Sensor to monitor the pressure inside a test tube as yeast metabolizes glucose anaerobically. When data collection is complete, you will perform a linear fit on the resultant graph to determine the fermentation rate.

Figure 1

After completing the Preliminary Activity, you will first use reference sources to find out more about sugar fermentation by yeast before you choose and investigate a researchable question dealing with fermentation. Some topics to consider in your reference search are:

- sugars
- glucose
- fermentation
- anaerobic respiration
- aerobic respiration

- yeast
- enzyme
- substrate
- enzyme inhibitor

PROCEDURE

1. Obtain and wear goggles.

2. Connect a Gas Pressure Sensor and a Temperature Probe to your Chromebook, computer, or mobile device. Use an interface if necessary.

3. Connect the plastic tubing to the Gas Pressure Sensor.

4. Prepare a water bath for the yeast. A water bath is simply a large beaker of water at a certain temperature. This ensures that the yeast will remain at a constant and controlled temperature. To prepare the water bath, obtain some warm and cool water. Combine the warm and cool water into the 1 liter beaker until it reaches 38–40°C. The beaker should be filled with about 800–900 mL of water. Secure the Temperature Probe in the water bath with an Electrode Support and Stir Station as shown in Figure 1.

5. Using a pipette or graduated cylinder, place 2.0 mL of the glucose solution into a clean 18 × 150 mm test tube. **Caution**: *Treat all laboratory chemicals with caution. Prudent laboratory practices should be observed.*

6. Obtain the yeast suspension. Gently swirl the yeast suspension to mix the yeast that settles to the bottom. Using a pipette or graduated cylinder, transfer 2.0 mL of yeast suspension into the test tube. Gently mix the yeast into the sugar solution.

7. Place enough vegetable oil into the test tube to completely cover the surface of the yeast/glucose mixture as shown in Figure 2. Be careful to not get oil on the inside wall of the test tube.

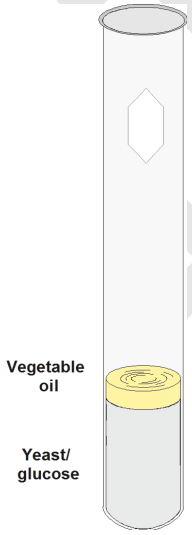

Figure 2

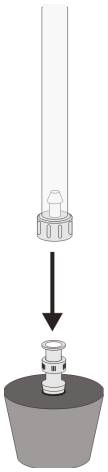

Figure 3

8. Insert the single-holed rubber-stopper into the test tube. **Note**: *Firmly* twist the stopper for an *airtight* fit. Secure the test tube in the water bath with a utility clamp as shown in Figure 1.

9. Incubate the test tube for 10 minutes in the water bath. Be sure to keep the temperature of the water bath constant. If you need to add more hot or cold water, first remove about as much water as you will be adding, or the beaker may overflow. Use a basting bulb to remove excess water.

   Note: Be sure that most of the test tube is covered by the water in the water bath. The temperature of the gases in the tube must be constant for this experiment to work well.

10. When incubation has finished, connect the free end of the plastic tubing to the connector in the rubber stopper as shown in Figure 3.

11. Collect pressure data.
    a. Begin data collection.
    b. Maintain the temperature of the water bath in the 38–40°C range during the course of the experiment.
    c. **Note**: If the pressure exceeds 130 kPa, the pressure inside the tube will be too great and the rubber stopper is likely to pop off. Disconnect the plastic tubing from the Gas Pressure Sensor if the pressure exceeds 130 kPa.
    d. Stop data collection after 100 seconds have elapsed.

12. After you have stopped data collection, disconnect the plastic tubing connector from the rubber stopper. Remove the rubber stopper from the test tube and discard the contents in a waste beaker.

13. Perform a linear fit on the graph. Record the slope of the line, m, as the fermentation rate (in kPa/s).

QUESTIONS

1. What fermentation rate did you obtain in the Preliminary Activity?

2. What is the role of the vegetable-oil layer on the surface of the yeast and glucose mixture?

3. List three common sugars, other than glucose.

4. List three factors that could possibly affect fermentation rates.

5. List at least one researchable question concerning sugar fermentation by yeast.

Note: The plan that you submit for instructor approval should list laboratory safety concerns, including chemical safety concerns, and specify how you will address these safety concerns during your investigation.