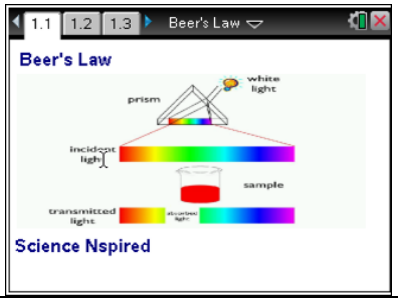
Beer's Law
Student Activity

Name _____

Class _____

Open the TI-Nspire document *Beers_Law.tns.*

In this activity, you will determine the concentration of an unknown nickel (II) sulfate solution using a Colorimeter.



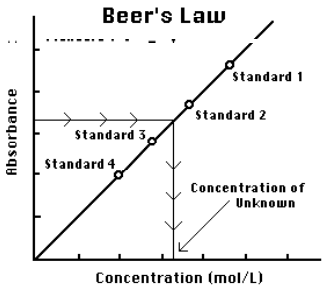
Prelab Information and Questions

Press ctrl ▶ and ctrl ◀ to navigate through the lesson.

As demonstrated by the illustration of a Colorimeter on Page 1.1, red light from the LED light source will pass through the solution and strike a photocell. The $NiSO_4$ solution used in this experiment has a deep green color. 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 either a percent absorbance or a percent transmittance value.

You will prepare five nickel sulfate solutions of known concentration (standard solutions). Each is transferred to a small, rectangular cuvette that is placed into the actual Colorimeter. The amount of light that penetrates the solution and strikes the photocell is used to compute the absorbance of each solution.

When a graph of absorbance vs. concentration is plotted for the standard solutions, a direct relationship should result, as shown in the figure to the right. The direct relationship between absorbance and concentration for a solution is known as Beer's Law.



[1]

The concentration of an unknown $NiSO_4$ solution is then determined 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 (follow the arrows in the figure to the right). The concentration of the unknown can also be found using the slope of the Beer's Law curve.

In this lab, you will:

1. Prepare five (5) $NiSO_4$ standard solutions.
2. Use a Colorimeter to measure the absorbance value of each standard solution.
3. Find the relationship between absorbance and concentration of a solution.
4. Use the results of this experiment to determine the unknown concentration of another $NiSO_4$ solution.

[1] © Vernier Software & Technology.

Move to pages 1.4 through 1.7. Answer the pre-lab questions.

Q1. The wavelength of light used by the colorimeter should be _____ by the colored solution.

Q2. The NiSO4 solution used in the experiment has a deep _____ color.

Q3. For this experiment, the LED of the colorimeter needs to be set to _____.

Q4. A higher concentration of solution absorbs _____ light.

Q5. The relationship between absorbance and concentration is _____.

Q6. The linear relationship between absorbance and concentration is called _____ Law.

Q7. The concentration of the unknown can be determined by using the _____ of the regression line on the graph.

Lab Set-Up and Procedures

1. Obtain and wear goggles.
   CAUTION: Be careful not to ingest any nickel(II) sulfate solution or spill any on your skin.
2. Label five clean, dry, test tubes 1–5.
3. From a burette, draw 2, 4, 6, 8, & 10 mL of 0.40 M nickel(II) sulfate solution into Test Tubes 1–5, respectively.
4. From the second burette, deliver 8, 6, 4, 2, and 0 mL of distilled water into Test Tubes 1–5, respectively.
5. Thoroughly mix each solution with a stirring rod.
6. Clean and dry the stirring rod between stirrings. Concentrations for the trials are: 0.08 M, 0.16M, 0.24M, 0.32M, and 0.40M respectively.
7. Prepare a blank by filling an empty cuvette 3/4 full with distilled water.
   Note: To correctly use a cuvette, remember:
   - All cuvettes should be wiped clean and dry on the outside with a tissue.
   - Handle cuvettes only by the top edge of the ribbed sides.
   - All solutions should be free of bubbles.
   - Always position the cuvette so the light passes through the clear sides.

Move to page 2.2.

The image shows the correct set up for the TI-Nspire, colorimeter and solutions.

Lab Procedures

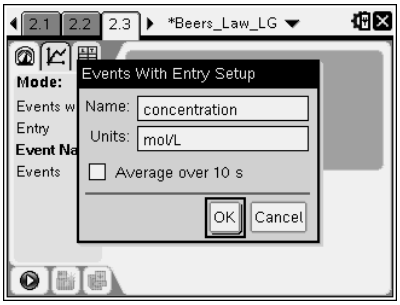
Move to page 2.3 and proceed with calibrating the colorimeter.

8. Following the image shown, connect the Colorimeter to the TI-Nspire Data Collection Cradle, and connect the interface to the TI-Nspire™ handheld.
9. Calibrate the Colorimeter by placing the blank in the cuvette slot of the Colorimeter and closing the lid.
   - 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.

On page 2.3, set up a new experiment.

10. To set up the data-collection mode and change the scale options for the graph, choose **Menu > Experiment > New Experiment** to reset the device.
    - Press **Menu > Experiment > Collection Mode > Events with Entry**.
    - Enter "Concentration" as the **Name** and "mol/L" as the **Units**. Select **OK**.
    - Press **Menu >Options** and **Autoscale Settings**.
    - Change the **After Collection** setting to **Autoscale from Zero**.
    - Click **OK**.

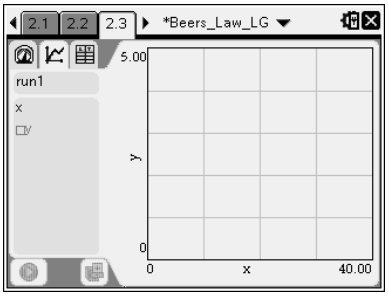
Collect data.



You are now ready to collect data for the five standard solutions.

11. Start data collection by pressing .
    - Empty the water from the cuvette.
    - Using the solution in **Test Tube 1 (0.08)**, 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.
12. When the value displayed on the screen has stabilized, click the **Keep** button, and enter 0.080 as the concentration in mol/L.
    - Select **OK**.
    - The absorbance and concentration values have now been saved for the first solution.
    - Discard the cuvette contents as directed by your instructor.

13. Using the solution in **Test Tube 2 (0.16)**, rinse the cuvette twice with ~1 mL amounts, and then fill it 3/4 full.
    - Place the cuvette in the Colorimeter, and close the lid.
    - Wait for the value displayed on the screen to stabilize, and click the **Keep** button.
    - Enter 0.16 as the concentration in mol/L.
    - Select OK.
14. Repeat the procedure for **Test Tube 3** (0.24 M) and **Test Tube 4** (0.32 M), as well as the stock 0.40 M $NiSO_4$ (Trial 5).
    Note: Do not test the unknown solution yet.
15. Stop data collection by pressing .
16. Click **Table View** to display the data table on the handheld. Record the absorbance and concentration data values in your data table at the end of this worksheet.
17. Display a graph of absorbance vs. concentration with a linear regression curve by clicking **Graph View** .
    - Select **Menu > Analyze > Curve Fit > Linear**.
    - The linear-regression statistics are displayed in the form: $y = mx + b$ where x is concentration, y is absorbance, m is the slope, and b is the y-intercept.



    Sketch the graph you obtained.

Note: One indicator of the quality of your data is the size of b. It is a very small value if the regression line passes through or near the origin. The correlation coefficient, r, indicates how closely the data points match up with (or fit) the regression line. A value of 1.00 indicates a nearly perfect fit.

The graph should indicate a direct relationship between absorbance and concentration, a relationship known as **Beer's Law**. The regression line should closely fit the five data points and pass through (or near) the origin of the graph.

18. Now you are ready to determine the absorbance value of the unknown $NiSO_4$ solution.
    - Select Meter View, **Menu > View > Meter**.
    - Obtain about 5 mL of the unknown $NiSO_4$ in another clean, dry, test tube. Record the number of the unknown in your data table at the end of this worksheet.
    - Rinse the cuvette twice with the unknown solution and fill it about 3/4 full. Wipe the cuvette dry, and place in the Colorimeter.
    - Monitor the absorbance value. When this value has stabilized, record it in your data table at the end of this worksheet.
19. Discard the solutions as directed by your instructor.

Analyze the Data

1. Perform your calculations to determine the concentration of the unknown $NiSO_4$ solution by interpolating along the regression line to convert the absorbance value of the unknown to concentration.
   - Click **Graph View**.
   - Select **Menu > Analyze > Interpolate**.
   - Select any point on the regression curve.
   - Use ▶ and ◀ to find the absorbance value that is closest to the absorbance reading you obtained in Step 18. The corresponding $NiSO_4$ concentration, in mol/L, will be displayed.
   - Record the concentration value in your data table at the end of this worksheet.

Post-lab Assessment. Answer the questions on pages 3.1 through 3.4.

Q8. As the concentration of the $NiSO_4$ solution increased, the absorbance _____ .

Q9. The closer the value of _____ was to zero, the better your data.

Q10. The closer the value of *r* is to _____, the better your data.

Q11. To find the concentration of the unknown, you need to _____ your graph.

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Data Table

Trial	Concentration (mol/L)	Absorbance
1	0.08	
2	0.16	
3	0.24	
4	0.32	
5	0.40	
6	Unknown number ____	

Concentration of unknown	____ mol/L