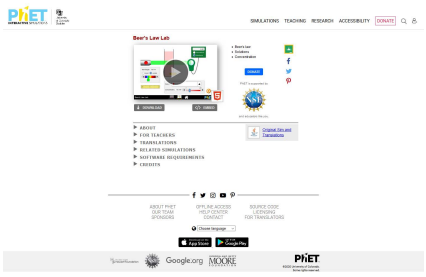
ONLINE Spectrophotometry Simulation/Activity (adapted from Greg Jursich)

This module introduces spectrophotometry and its applicability for quantitative analysis of solutes in solution. The simulation developed by PhET at the University of Colorado will help in understanding the effects of dilution, draining, and solvent evaporation on solute moles and molarity concentration of solutions and demonstrate principles of Beer's Law and its applicability to the analysis of different solutes in aqueous solutions. The simulation is practically orientated. To understand the fundamental principles behind spectrophotometry Chapter 18-1 - 18-4 and 18-6 must be read in the Harris text.

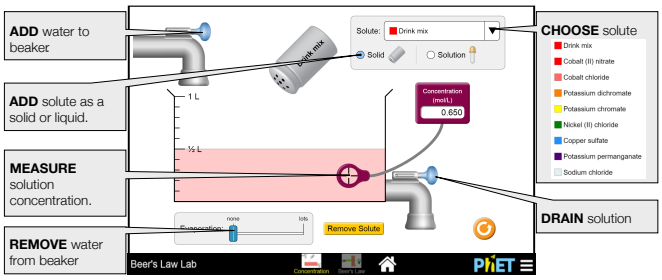
Introduction to the Simulation

Log onto https://phet.colorado.edu/en/simulation/beers-law-lab, the PhET portal for this simulation. Upon entering the portal you will be taken to the main screen of the Beer's Law Lab which has two links you can select from, Concentration or Beer's Law. The simulation has three parts. For Part 1 you will select Concentration and will work on the Concentration Screen and for Parts 2 and 3 Beer's Law will be selected and work will be done on the Beer's Law Screen.

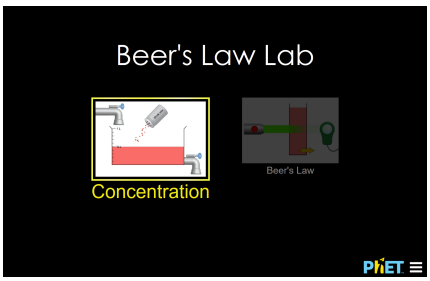
PhET Portal



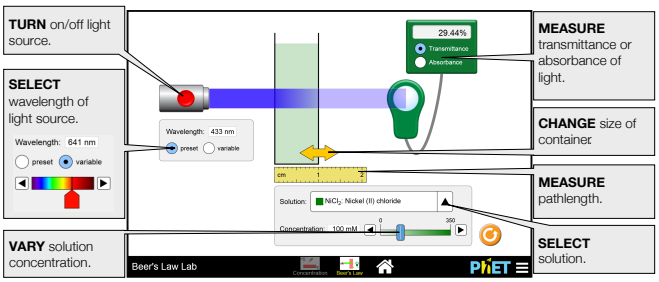
Concentration Screen



Simulation Main Screen



Beer's Law Screen



Procedure for Part 1 - Effecting Concentration

In this part of the simulation activity you will prepare a solution with drink mix and investigate dilution, solution removal by draining, and evaporation. Each time you will need to keep track of and calculate moles of solute and molarity concentration in order to observe how they change from these changes of solution. Before starting prepare a table to report your results.

1. *Preparing a Solution*: Select the Concentration link and move the sensor on the Concentration Screen into the solution. The concentration should read zero since no solute is added. Give the drink mix a few shakes and record the concentration you have for your solution in your notebook. Note the volume of the solution and from that calculate the moles of solute (drink mix) there are in the solution.
2. *Effect of dilution:* Using the faucet add about 200 mL of water and record the sensor concentration. Estimate and record the final volume of solution. Record the concentration. Based on initial and final volumes calculate the concentration and compare with the sensor reading. It should be very close but not necessarily exactly the same due to uncertainty in volume readings. That's ok. Based on the new volume and sensor concentration calculate the moles of solute after dilution.
3. *Effect of draining solution:* Using the drain valve remove about 300 mL of solution and record the new volume and sensor concentration. Note how the sensor concentration did not change. Calculate the moles of solute in the remaining solution after draining part of the solution.
4. *Effect of evaporation*: Using the evaporation panel slowly evaporate solvent to reduce the solution volume to around 250 mL. Record the sensor concentration and new solution volume. Calculate the moles of solute based on the new volume and sensor concentration. Did it change significantly? Why or why not?

Procedure for Part 2 - Demonstration of Beer's Law

Return to the main simulation screen and select the Beer's Law link. Beer's law states that $A = \varepsilon cl$ where A is absorbance, ε is the extinction coefficient which is unique for each compound and dependent on wavelength, and l is the pathlength where light passes through the sample. To demonstrate Beer's law a series of absorption measurements over a range of wavelengths need to be made. Turn on the light source, set the detector to absorbance, and choose $Co(NO_3)_2$.

1. *Obtaining absorbance spectrum of 100 mM $Co(NO_3)_2$:* Set the wavelength of light to 400 nm. Record the absorbance. Make a table of wavelength (nm) and absorbance in your notebook. Then progressively record the absorbance about every 50 nm from 400 to 750 nm. You will see the absorbance reading increase then decrease with increasing wavelength. Near the peak of the absorbance, record absorbance every 10 nm to better define the maximum.
2. *Plotting the absorbance spectrum:* In excel or some other plotting program, plot the absorbance spectrum from 400 to 750 nm. Every compound has its own unique spectrum depending upon the properties of its valence electrons. For this solute the absorbance is coming from the $Co^{2+}(aq)$ ion. Identify the wavelength of maximum absorbance, λ_{max}.
3. *Effect of pathlength on Beer's Law*: Set the wavelength of light to where the maximum absorbance is observed. Then with the same concentration of $Co(NO_3)_2$ (100 mM) vary the pathlength to 0.50, 1.0, 1.5, and 2.0 cm and make a table of pathlength and absorbance. For your lab report, make a plot of absorbance (*y*-axis) versus pathlength (*x*-axis).
4. *Effect of concentration on Beer's Law:* Keeping the pathlength at 1 cm and the wavelength at λ_{max}, vary the concentration of the solute from 50 to 300 mM in increments of 50 mM. Make a table of wavelength (nm) and absorbance for your lab report. Make a plot of recorded absorbance (*y*-axis) versus concentration (*x*-axis) in mM. From the slope of your graph determine the extinction coefficient, ε, in units of $M^{-1}\,cm^{-1}$.

Procedure for Part 3 - Determining Concentrations with Beer's Law

Given the data you collected in Part 2, determine the concentration of $Co(NO_3)_2$ analyzed in the solutions given in the cover sheet.

Questions to be Answered in Lab Report

How does concentration and moles of solute change for a solution undergoing dilution, draining, and evaporation? What is the pathlength and concentration dependence on light absorbance of a solution? How would one rearrange the Beer's Law equation to determine the concentration of a light-absorbing solute?