

### Concentration Screen

In this screen students explore how the concentration of a solution is changed by varying the amount of solute, solvent, or total amount of solution.

**ADD** water to beaker.

**ADD** solute as a solid or liquid.

**MEASURE** solution concentration.

**REMOVE** water from beaker

**CHOOSE** solute

- Drink mix
- Cobalt (II) nitrate
- Cobalt chloride
- Potassium dichromate
- Potassium chromate
- Nickel (II) chloride
- Copper sulfate
- Potassium permanganate
- Sodium chloride

**DRAIN** solution

Concentration (mol/L): 0.650

Evaporation: none | lots

Remove Solute

Solute: Drink mix

Solid | Solution

Beer's Law Lab

### Beer's Law Screen

Students investigate how the intensity of light absorbed or transmitted by a colored solution changes with solution type, solution concentration, container width (pathlength), or light source.

**TURN** on/off light source.

**SELECT** wavelength of light source.

Wavelength: 641 nm

Wavelength: 433 nm

preset | variable

Wavelength: 433 nm

preset | variable

**VARY** solution concentration.

**MEASURE** transmittance or absorbance of light.

**CHANGE** size of container.

**MEASURE** pathlength.

**SELECT** solution.

29.44%

Transmittance | Absorbance

Solution: NiCl<sub>2</sub>: Nickel (II) chloride

Concentration: 100 mM

cm 1 2

Beer's Law Lab

## Insights into Student Use

- The detector on the transmittance/absorbance meter must capture the full beam of light to show a value for transmittance or absorbance.
- Students who had not been introduced to Beer's Law were able to make accurate qualitative conclusions about the effects of pathlength, concentration, and wavelength on light absorption.
- Yellow and blue solutions may be easier for some colorblind students, but different types of colorblindness may make different solutions harder to see for different students.

## Model Simplifications

- The maximum amount of solute that can be added is 7 moles. The maximum volume of the beaker is 1 L.
- Concentration is calculated as solute amount divided by *water* volume. The volume of dissolved solute has only a small effect on volume, and different volume changes for each solute could be confusing to students.
- The values used to calculate the solubility for each solute were taken from the CRC Handbook of Chemistry and Physics 91<sup>st</sup> edition (<http://www.hbcpNetbase.com>). Drink mix was assumed to have the same solubility as sucrose.
- Sodium chloride is not included on the Beer's Law screen as the solution is clear and colorless and does not absorb light in the visible range to any great extent.
- Color intensity of solution was optimized to highlight changes in concentration for the range allowed in each tab, but color intensity *is not the same* between the Concentration and Beer's Law screens. For example, the range for Drink mix is 0-5.960 M in the Concentration screen but 0-0.400 M in the Beer's Law screen.
- The values for molar absorptivity used in the sim were calculated from experimental data; replicating the experiment may produce slightly different values.

## Suggestions for Use

### Sample Challenge Prompts

- Describe the relationships between the amount of solute, volume of solution, solution color, and solution concentration.
- What happens to the concentration of a solution when the solution volume is decreased?
- Predict what happens to the absorbance of a solution as the concentration of the solution increases.
- Describe the relationship between the width of the solution container (pathlength) and absorbance of light.
- Explain the difference between transmittance and absorbance of light.
- How do you think the preset wavelength was chosen for a given solution? Is this the best wavelength to use for the solution? Why or why not?
- Describe the relationship between the color from the light source, the solution color, and the absorbance of the solution.
- Use Beer's law ( $A = \epsilon l C$ ) to determine the molar absorptivity ( $\epsilon$ ) for a given solution.

## Customization Options

The following query parameters enable options in the "Concentration" and "Beer's Law Lab" sims:

- **showSoluteAmount** – shows the solute amount (in grams) below the beaker in the "Concentration" screen, does not require a value
- **beakerUnits=milliliters** – labels the beaker tick marks using mL (default is L)
- **concentrationMeterUnits=percent** – displays percent concentration in the concentration meter (default in mol/L)

Query parameters are added by appending a '?' to the sim URL, and separating each query parameter with a '&'. Here is an example with all 3 options enabled (this is a single line):

[https://phet.colorado.edu/sims/html/beers-law-lab/latest/beers-law-lab\\_en.html?showSoluteAmount&beakerUnits=milliliters&concentrationMeterUnits=percent](https://phet.colorado.edu/sims/html/beers-law-lab/latest/beers-law-lab_en.html?showSoluteAmount&beakerUnits=milliliters&concentrationMeterUnits=percent)

See all published activities for Beer's Law Lab [here](#).

For more tips on using PhET sims with your students, see [Tips for Using PhET](#).