

The Beer's Law Lab sim is designed to help students understand the concept of solution concentration and how it affects light absorption and transmittance.

### Concentration Tab

In this tab, students learn about solution concentration, the factors that affect it, and what leads to saturated solutions. More detailed information on this tab is available in the [Concentration FAQ](#).

Shaker and Dropper: You can add solute using the shaker (solid), or the dropper (solution). The maximum amount for each solute is 6 moles. If the shaker or dropper is empty, they will refill after solute is removed from the beaker via the "Remove Solute" button, or the bottom faucet.

Faucets: You can add water (top faucet) or remove solution (bottom faucet). Some students think the bottom faucet only removes water until they notice the concentration stays constant. The maximum volume of the beaker is 1 L.

Concentration: You can change concentration by adding solute, adding water, and evaporating water. Concentration is shown qualitatively by solution color, and quantitatively by the solution meter. To measure concentration with the meter, drag the probe so that its crosshairs are in solution. Because the meter measures concentration of solute, pure water gives a concentration of 0 mol/L.

**ALERT**: The concentration is computed as solute amount divided by *water* volume. The sim ignores the volume of the dissolved solute because the effect is small. The sim does **not** compute concentration as solute amount divided by *solution* volume because different volume changes for each solute could be confusing to students.

Saturation: If you add solute or evaporate water past the solution saturation point, solid solute and a "Saturated!" message (like the example shown here) will appear in the bottom of the beaker. You can also add solute to an empty beaker. The solubility limit values used in the simulation are from the CRC Handbook of Chemistry and Physics 91<sup>st</sup> edition, online: <http://www.hbcnetbase.com/>



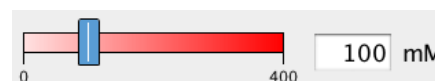
### Beer's Law Tab

In this tab, students learn that concentration, pathlength, and solution type affect how much light is absorbed and transmitted. They also learn that different solutions absorb different wavelengths of light, and that each solution has a different light wavelength for maximum absorption.

**Absorbance and Transmittance:** You can measure how much light the solution absorbs and transmits using the Absorbance / % Transmittance meter. The meter's detector must capture the full beam of light to show the absorbance or transmittance value. (An example of the meter capturing a green light beam is shown here.) The detector can be moved back and forth in the light beam, inside the solution container and to the left of it. Transmittance is shown as a percentage of light that passes through the solution. Absorbance values are in arbitrary units (a.u.) and are not shown.

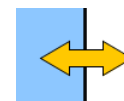


**Concentration:** You can change concentration for a set range using the concentration slider shown here. Solution concentrations are in units of millimoles (mM) or micromoles ( $\mu\text{M}$ ), and are optimized for absorbance values between 0 and 4.



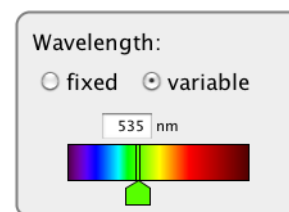
**ALERT:** The intensity of solution color *is not the same* between the Concentration Tab and the Beer's Law Tab. Color intensity was optimized to highlight changes in concentration for the range allowed in each tab. For example, the range for Drink Mix is 0-5.960 mol/L in the Concentration Tab, and 0-0.400 mol/L in the Beer's Law Tab (an order of magnitude difference).

**Pathlength:** You can change the pathlength by dragging the arrow on the lower right side of the solution container back and forth. Pathlength can be changed from 0.5 to 2.0 cm, in 0.1 cm increments, and can be measured using the ruler.



**Molar Absorptivity:** Each solution has a different molar absorptivity value, which can be calculated using the Beer's Law equation,  $A=abC$  (where  $A$  = absorbance,  $a$  = molar absorptivity,  $b$  = pathlength in cm, and  $C$  is solution concentration in mol/L). The molar absorptivity values used in the sim were calculated from experimental data; replicating the experiment may produce slightly different values.

**Wavelength:** You can change the color of light being used by clicking "variable" and adjusting the slider. You can also input a value in the visible range (380-780 nm). The "fixed" wavelength is the experimentally determined point of maximum absorption for each solution. This is the default value in the sim, and each time you change solutions or select "fixed" wavelength, the "variable" value resets to the maximum absorbance wavelength.



### Insights into student use / thinking:

In interviews, students connected saturation to the idea of having "more solute than water can dissolve". The Drink mix example provides a real-world link to this concept to help students connect it to the chemical examples.

In interviews, students who had not yet learned about Beer's Law found all of the controls in the sim and used them to make correct qualitative conclusions about the effects of pathlength, concentration, and wavelength on light absorption. Students who had recently learned about Beer's Law were eager to explore the variables that they could not manipulate in lab, such as pathlength and wavelength.

### Tips for Colorblindness:

The 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. We recommend encouraging students to choose a color of solution that works for them.

### Suggestions for sim use:

- For additional tips and FAQs related to the Beer's Law Lab sim, see the [Concentration FAQ](#) and [Molarity Tips for Teachers](#)
- For tips on using PhET sims with your students see: [Guidelines for Inquiry Contributions](#) and [Using PhET Sims](#)
- For activities and lesson plans written by the PhET team and other teachers, see our [For Teachers](#) page.
- The simulations have been used successfully with homework, lectures, in-class activities, or lab activities. Use them for introduction to concepts, learning new concepts, reinforcement of concepts, as visual aids for interactive demonstrations, or with in-class clicker questions.
- If you are doing a lecture demonstration, set your screen resolution to 1024x768 so the simulation will fill the screen and be seen easily.