Beer's Law Lab

Other ideas for the title: (please add yours!)
Concentration and Beer's Law Lab
Concentration and Light / Concentration and Absorption
Solutions and Light / Solutions and Absorption
Concentrated Solutions and Light / Absorbing Light
KP: Solutions and Beer's Law / Solutions, Light, and Beer's Law
EM votes for "Solutions and Light" or "Solutions and Absorption"
Solution Concentration and Beer's Law / Solutions and Light
Beer's Law Lab - chosen title.

PhET Sim Design Document

Design team:
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Thanks to:
Jeffrey Bodwin
CU Boulder Chemistry

Public URL:
https://docs.google.com/document/d/1F7un6uWdG9Nm41IUUjnRazFeNOTAbFIHKDLwgGQS7Qg/edit

Link to Dilutions Google Doc:
https://docs.google.com/document/pub?id=1H9-ZJznqsh_YFwiRTsPGriqbcKo8AfNMRvq_y9m3dHo

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    11/03/11 - PhET Chem Meeting - new design proposal

- 11/21/11 - Chem Team Meeting - discussion of new design
- 11/23/11 - Meeting with KP - discussion of new design
- 12/01/11 - Chem Meeting
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- 12/20/11 - Update Summary
- 01/19/12 - Chem Meeting
- 02/03/12 - Discussion JC, CM
- 02/03/12 - Chem Meeting
- 02/16/12 - Chem Meeting
- 03/01/12 - Chem Meeting
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Online Resources

Interview and Classroom Feedback (see these notes for interview questions)

- Student Interview Notes - Tab 1
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Website for Concentration Flavor

- Sim completion checklist - Concentration

Website for Beer's Law Lab

- Sim completion checklist - BLL

Audience

The principle goal of this simulation is to enhance students' understanding of solutions and the relationships between volume, amount of solute (number of moles), and concentration. This knowledge is important for understanding the concepts of solution concentration and dilution, which is vital for any laboratory course or research that involves solutions. These concepts apply to biology, chemistry, physics, environmental science, and other areas. The target audience is students who will be preparing and using solutions in an educational or research setting, generally undergraduate level students in introductory chemistry courses, though the simulation may also be useful in a high school setting.

KL: The concentration tab could also be useful for middle school students. Emily can check the standards.

KP: It would be great if 1st tab could also be for MS.

EM: I sent Julia the standards relating to this. I would advise not thinking about the first tab

as a middle school sim until development for the HS/UG level is complete. That way we don't complicate development by trying to meet the needs of MS-UG simultaneously.
Here are the Standards:
JC: Thanks Emily! We'll wait on the MS side for now.

Standards
Here's what the new national framework (standards will be out next year based on these) has to say on the topic:

> Changes in matter can also be physical, whereby the molecules do not change, but their positions and their motion relative to each other do change (e.g., the forming of a mixture, a change of state). Such changes are generally easier to reverse (return to original conditions) than chemical changes.

By the end of grade 5.

> When two or more different substances are mixed, a new substance with different properties may be formed; such occurrences depend on the substances and the temperature. No matter what reaction or change in properties occurs, the total weight of the substances does not change. (Boundary: Mass and weight are not distinguished at this grade level.)

Here's what the **Texas Standards (TEKS) say (5th grade)** on this topic:

1. Mixtures of matter can be separated regardless of how they were created; all weight and mass of the mixture are the same as the sum of weight and mass of its parts.

Students should be able to: (D) identify changes that can occur in the physical properties of the ingredients of solutions such as dissolving salt in water or adding lemon juice to water.

Research

Documented student difficulties to guide our design? Very little work in the chemical ed. literature (that I can find). Ideas for resources welcome!

KL: You could use the sim for research. The first semester of general chemistry at CU has a lab called "Determination of Concentration by Spectrophotometry" during week 13. It would also give the sim a deadline.
Additional info from RP: Susan Hendrickson will be teaching Gen Chem 1 in the spring. This is good news for a prospective classroom study with this sim, potentially in the lab section.
2/16/12 Owing to plenty of current research projects and analysis, we will wait to try Beer's Law in class or with small groups of students until Summer 2012.

Learning Goals

After using this simulation, a student should be able to:

- Describe the relationships between volume and amount of solute to solution

concentration
- Explain qualitatively the relationship between solution color and concentration
- Predict and explain how solution concentration will change for adding or removing: water, solute, and/or solution
- Calculate the concentration of solutions in units of molarity (mol/L)
- Design a procedure for creating a solution of a given concentration
- Identify when a solution is saturated and predict how concentration will change for adding or removing: water, solute, and/or solution
- Describe the relationship between the solution concentration and the intensity of light that is absorbed/transmitted
- Describe the relationship between absorbance, molar absorptivity, path length, and concentration in Beer's Law
- Predict how the intensity of light absorbed/transmitted will change with changes in solution type, solution concentration, container width, or light source, and explain why

Model

Equations to use in development of sim functionality:

1. Molarity
number of moles / volume in L = molarity aka moles/V = M, where units for M are mol/L

2. Dilution
(M1)(V1) = (M2)(V2)
M = molarity in mol/L, V = volume in L, 1 = initial solution, 2 = desired/final solution
In this eqn. the number of moles does not change.

3. Beer-Lambert Law (aka Beer's Law)
A = abC
A = Absorbance (sometimes called optical density). Does not have units.
a = molar absorptivity. Units = $M^{-1}cm^{-1}$ (Also called ε or [?][?][?][?], molar extinction coefficient) This is a measure of the amount of light absorbed per unit concentration at a given wavelength. It is different constant value for each chemical substance. The relationship between absorbance and concentration is linear (below the detection limit).
b = pathlength. Units = cm. The container of solution used in spectrophotometers is called a cuvette. The dimension or cross section of the cuvette that the light passes through is the pathlength.
C = concentration. Units = M = mol/L (moles of solute per Liter of solution)

4. Relationships between Absorbance and Transmittance
Summarized from http://teaching.shu.ac.uk/hwb/chemistry/tutorials/molspec/beers1.htm
The amount of radiation absorbed may be measured in a number of ways:

P = Intensity of light that gets through the sample.
P_0 = Initial intensity of the light from the source.
Transmittance, $T = P / P_0$
% Transmittance, $\%T = 100\ T$

Absorbance:

$A = \log_{10} P_0 / P$
$A = \log_{10} 1 / T$
$A = \log_{10} 100 / \%T$
$A = 2 - \log_{10} \%T$

max (lambda max) = Maximum absorption wavelength for a given chemical solution. Usually considered the most accurate wavelength for measuring absorbance at different concentrations because molar absorptivity remains constant (it can drift a little at other wavelengths). For our model, we have experimental data for molar absorptivity at each wavelength, and we will assume that molar absorptivity remains a constant value at each wavelength, across all concentrations and path lengths allowed by the sim.

Model.txt

The model.txt information below was updated on 5/11/12.
The most recent model.txt can be found here.
https://phet.unfuddle.com/a#/projects/9404/repositories/23262/file?path=/trunk/simulations-java/simulations/beers-law-lab/doc/model.txt&commit=64120

Concentration tab:

Concentration of a solution is:
M = min((saturatedConcentration (M), ((amountOfSolute (moles)) / (volumeOfSolution (L))))

When a solution is saturated, the amount of precipitate is:
precipitate (moles) = ((amountOfSolute (moles)) / (volumeOfSolution(L))) - (saturatedConcentration (M))

The number of precipitate particles shown in the beaker is:
numberOfParticles = (precipitate (moles)) * particlesPerMole
where particlesPerMole is specified for each solute.

The solvent is pure water. Solvent can be added to the solution using the faucet in the upper-left corner of the play area. Solvent can be removed from the solution using the Evaporation control.

Solute can be added via either the shaker or dropper. The dropper contains a stock solution, so it adds both solute and solvent. You can measure the concentration of the stock using the Concentration meter. Pressing the "Remove Solute" button removes all solute from the solution.

The faucet in the lower-right corner of the play area is a drain to remove solution (solvent and solute together). This decreases volume with no change to solution concentration.

Displaced volume due to dissolved solutes is ignored in the simulation; it is a small value, but would be non-negligible if we chose to model it. We removed the effect of volume on dissolved
solutes for the following reasons:
(a) the effect is relatively small, since solute particles have a small mass
(b) implementation difficulty in terms of both math and software design
Regarding this latter point, it reduces to a pair of coupled equations:
molesDissolved = f(volume) and volume = f(molesDissolved)

For additional details, consult the class files in package
edu.colorado.phet.beerslawlab.concentration.model.

Beer's Law tab:

Molar absorptivity (a) is in units of 1/(cm*M), and varies with solution and wavelength.
For the solutions in this sim, we measured molar absorptivity for visible wavelengths in the laboratory.
That data is used in the sim, and can be found in Java class MolarAbsorptivityData and file beers-law-lab/doc/wavelength-to-molarAbsorptivity.csv

Path length (b) is the amount of solution that the beam passes through, in units of cm.
It depends on the width of the cuvette and the position of the detector probe.

Concentration (C) is in units of M, and is the concentration of the solution in the cuvette.

Absorbance model: A = abC

Transmittance model: T = 10^A

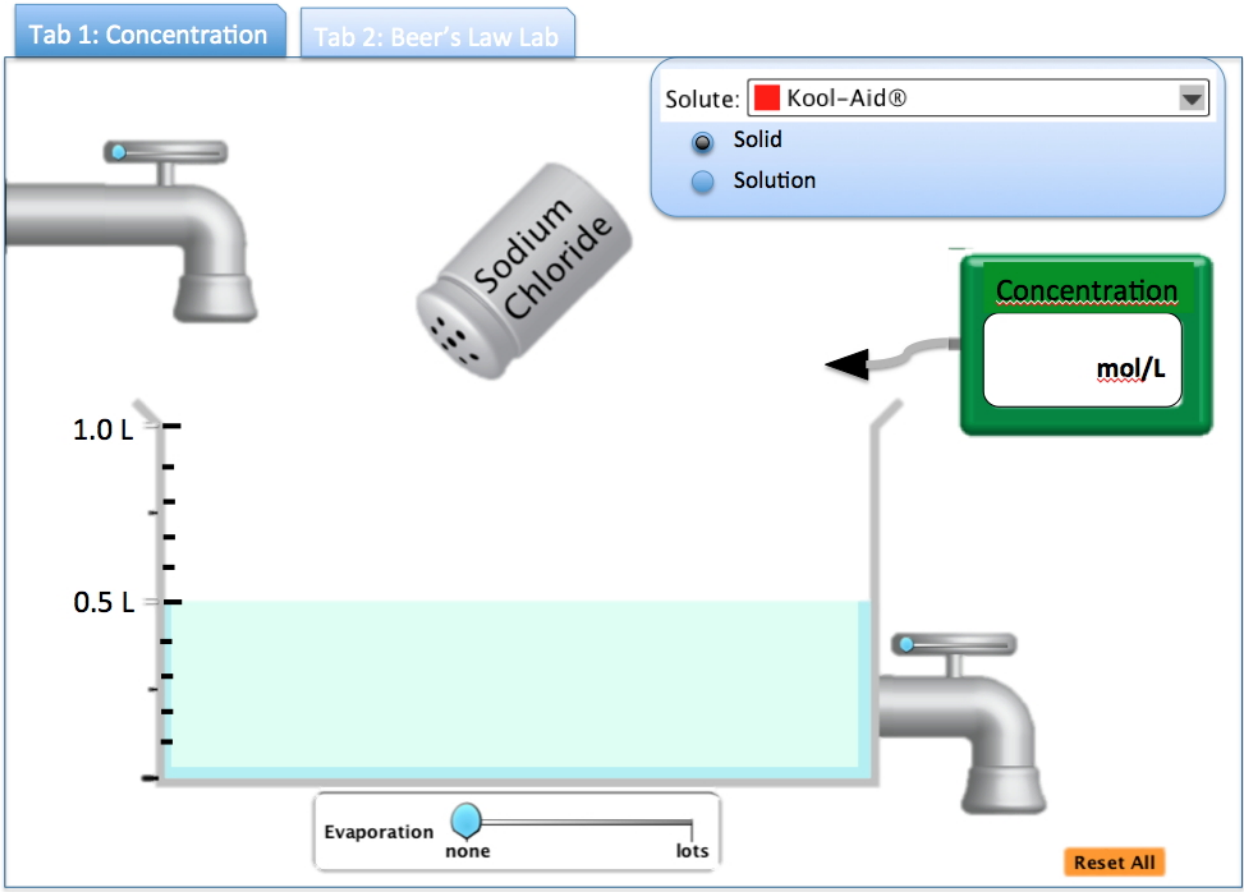
Transmittance varies between 0 (fully absorbed) and 1 (fully transmitted.) Multiplying by 100 gives "percent transmittance".

Mockup

First Tab - Concentration

Modeled after Sugar and Salt Solutions (SSS), this tab will provide a macro view of solute in solution. As in SSS, students can add water from the faucet, remove solution from the drain. In this sim, student can select different chemical compounds from a combo box (drop down menu) and shake the chemicals into the beaker. The chemicals will be different colors, and will turn

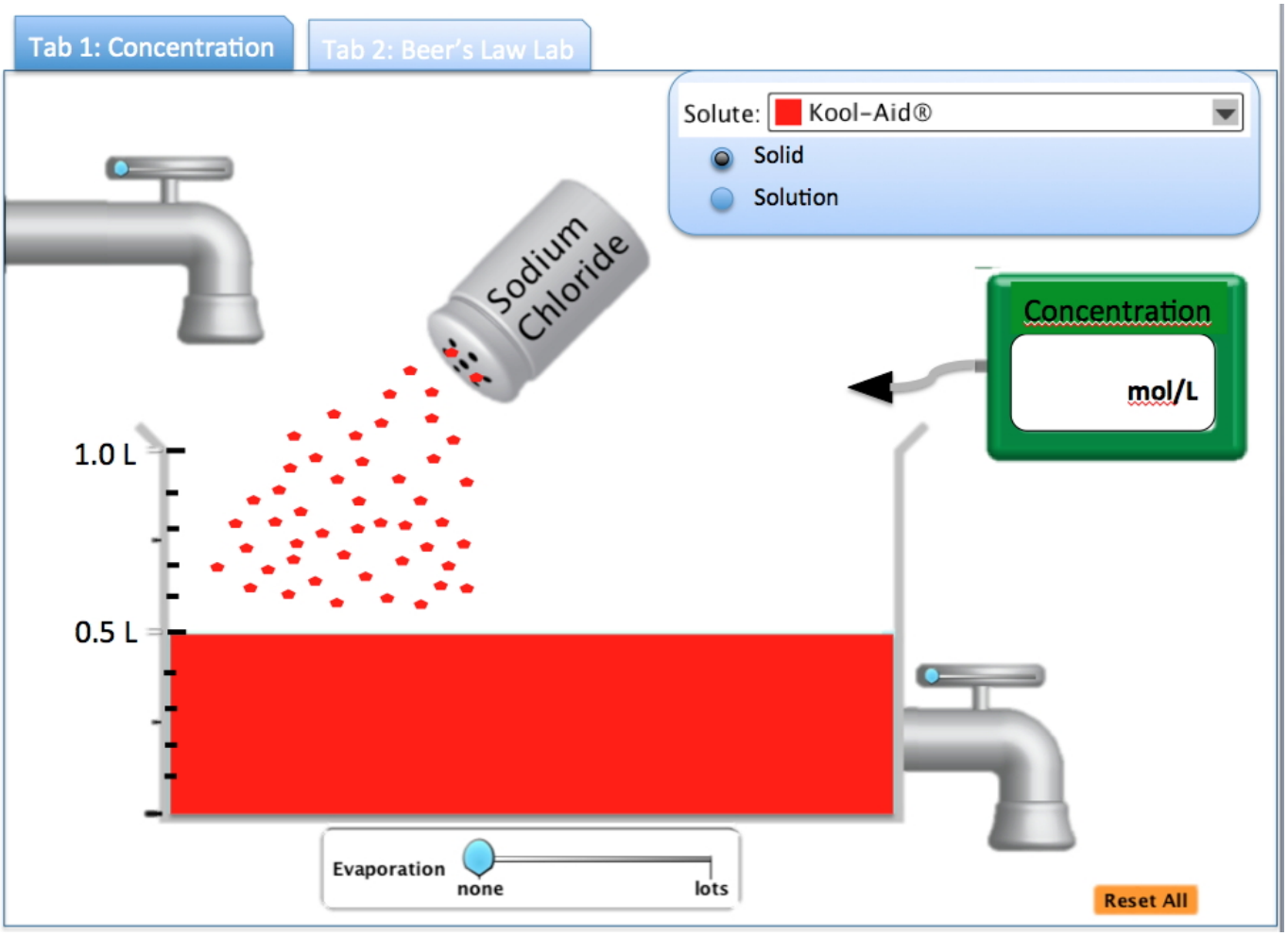
the solution color when they are added. Higher concentrations produce more deeply colored solutions.



Background will be white and water will be lighter in color, as discussed in the previous Dilutions sim. Shaker will read chemical formula (eg, Kool-Aid, CuSO4, NiCl2 with appropriate subscripts).

Faucet graphics will be similar to Sugar and Salt Solutions; CM is going to make improvements to slider thumb size and also potentially make the slider track clickable. Faucet handle will be taller to facilitate easier use.'

CM will include icons next to the "Solid" and "Solution" radio buttons, to strengthen the connection to the shaker and dropper. KP: I second this idea.

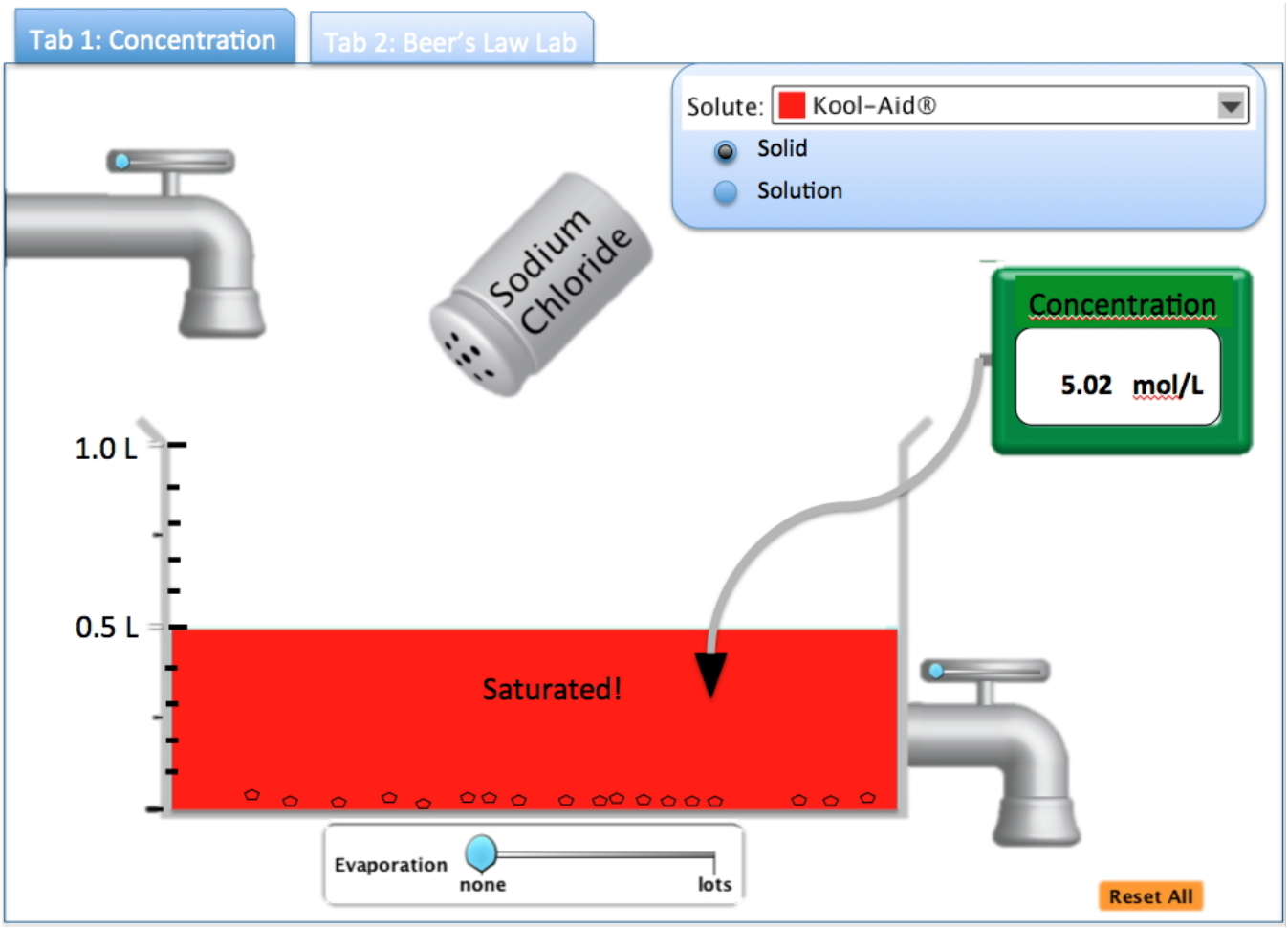


Particles shake out of the shaker (they should be **squares**, unlike the mock up--to match the crystals we show in saturated solutions). The shaker will become empty when the allowance of moles for a given chemical is reached (see table below for values).

Shaker and dropper can both be moved from side to side above the beaker (more fun), however shaken out particles will distribute evenly in the bottom of either a saturated solution or an empty beaker.

Saturated Solutions:
At any point where more moles of solute are present than the solubility limit , the solution will read "Saturated!" and small square crystals will form on the bottom of the beaker, as in the Molarity Tab of the Dilutions sim. The "Saturated!" label will appear when soln. reaches saturation concentration, before crystals start appearing.
(Saturation can occur from a partially filled beaker receiving more solute than it can dissolve, or from evaporating a concentrated solution beyond it's saturation concentration).
When more solid is added to a saturated solution, concentration does not change.
Additional particles shaken into a saturated solution can magically appear in the bottom of the

beaker. They do not need to sink via animation.
Particles added to an empty beaker distribute evenly / randomly at the bottom of the beaker, they do not accumulate on one side.



Concentration Meter
Design still under consideration; current idea is a meter like the Intensity meter in Bending Light (also similar to Absorbance and % Transmittance meter in 2nd tab of this sim). Will be Quantitative -- ie, give a number in M or mol/L. Students can use the concentration meter to find the starting concentrations of the solutions in the dropper, and to see numerical values as they change concentration with the faucet and solute tools.

Concentration meter body is fixed, and probe can be dragged into solution and under the faucets. When the probe is not in solution, it should be blank. If placed under the water faucet, or if dipped in pure water, will read 0.00 mol/L. If placed in drain, will read conc. of solution being drained. If fully submerged, it continues to functional normally (no short circuit) and will read concentration as long as the tip is in contact with solution.
Extremely low concentrations that to below the range readable by the meter will read 0.00, but will still be colored with solute. This is something students and teachers can consider and

discuss while using the sim.

KP: I'm still wondering about whether a bar graph is useful. To make meaning of pure qualitative I see the colors working well for that. But to make meaning of some basic ideas (like ½ as concentrated by doubling water) I think that is where a bar graph could be useful -- you can do it with the pure numeric reading, but it's a higher cognitive load I think than seeing that bar graph went down by ½. I'm just musing about this though and wondering what interviews will show. If we do have a bar graph - the Concentration Meter could have a radio button at the top if it that just shows symbols for bar graph or numbers and you choose your preferred reading mode.

JC: We discussed this at Chem meeting and the issues with a bar graph for concentration meter are the same as the issues for the Molarity Meter in the Dilutions sim. The allowed concentration range for the different solutes is not the same. So, the concentration meter can't be the same for all solutions. It either had to change it's range (invisible to students, or indicated, but possibly not clear to students), or we must keep the same range for all solutions and "grey out" the unavailable area. Since the most soluble solutions are ~6 M, and the least are a ~0.5 M, this difference in range is pretty significant. We discussed other grapical representation ideas (odometer style meter, bar graph indicator, and quantitative read out of numbers) at the chem meeting on 11/21/11. Let's summarize this discussion at the next Chem meeting when all team members are present to contribute their ideas.

KP: A question: how will we handle very low concentrations -- will the meter start reading 0.00001 or will it switch to scientific notation or will it read <0.001 or will it read ~0.00 or will it read too low or will it read 0.00? If it truly is 0, it should certainly read 0.00. I guess after writing this, I'd go with reading 0.00 after it gets down below 0.005. and letting that be a facilitated point of discussion.

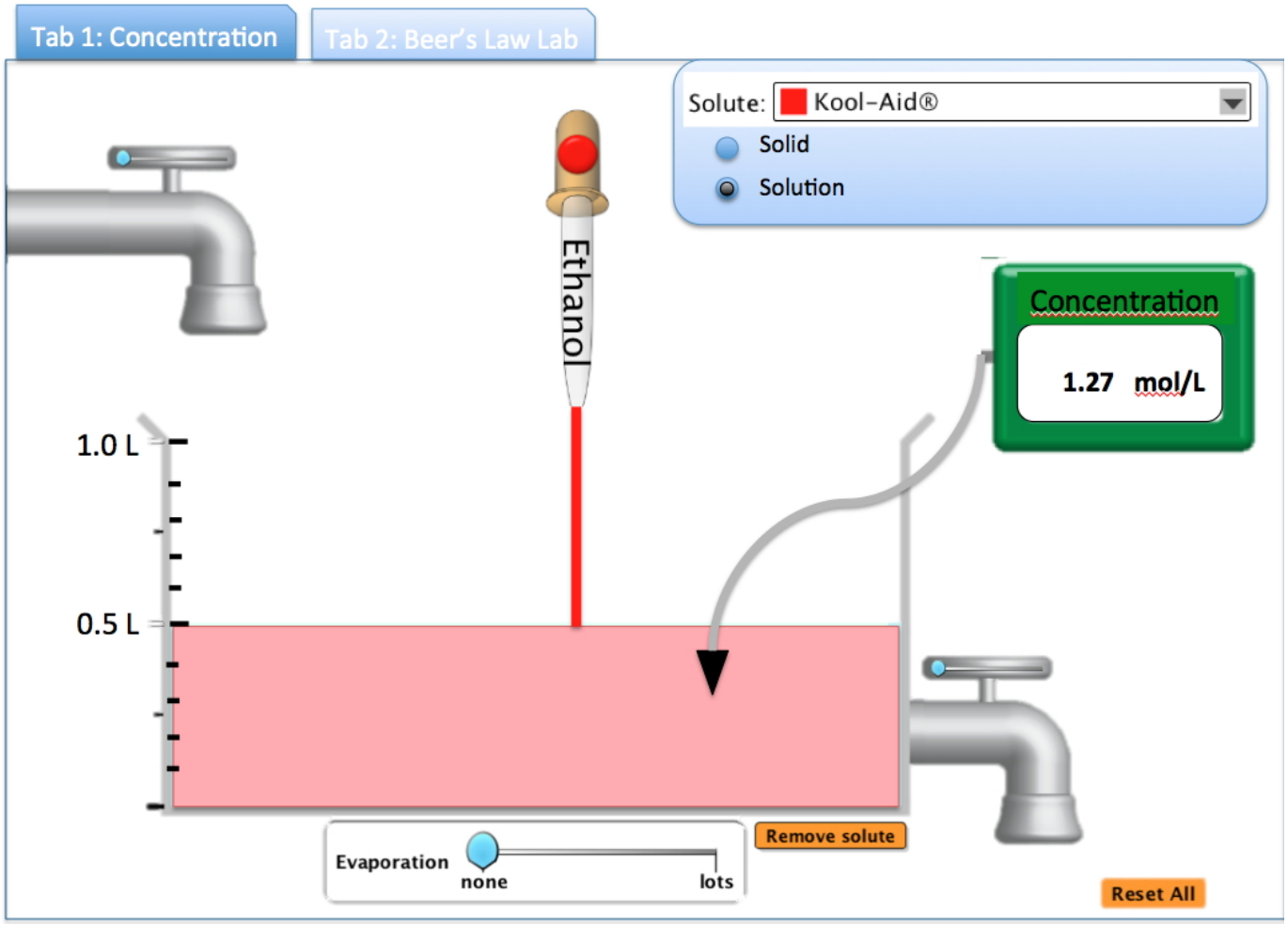
JC: CM comments that the precision of the sim should match the precision of the concentration meter (and vice versa). The < symbol would work well in this situation if needed, and since concentration is decreasing, hopefully students will not misinterpret it to mean >.

Adding Solution:
One (fairly concentrated) solution of each chemical will be available by dropper dispenser (accessed via radio button "solution"). Concentrations given in the table below. Dropper will read chemical formula (not Ethanol in mock up) and may be made wider to accomodate subscripts. The solutions for each chemical will be different concentrations. Colored solution should show in dropper (fixed volume is fine, mostly full or completely full--doesn't change when dropper is used) and is dispensed in a stream of liquid as from the faucet, but narrower max width. Rate of solution dispensing still under consideration. Solution is dispensed from the button on the dropper top. Color of button up for discussion. Red seems fine for all (to me).
KP: For dispensing --- Sam's Fluid and Flow also has another model that uses "drops" which might also work. Either is OK with me, just thought I'd point it out.

Dropper will dispense solution until the limit of moles for the selected solute is reached.
Dropper will refill if beaker is emptied via the drain (thus removing some moles).
Dropper can be moved side to side, but had limits that do not allow liquid to be dispensed outside of the beaker.
KP; I assume that concentration meter will work in the solution mix so you will know what the solution mix is?
JC: my thinking is that students can place the meter in the path of the stream of solution, or they can start filling an empty beaker with the solution from the dropper to determine what it is. It would be fine for the meter to also read in the dropper; that would be more consistent with the meter's magical ability to read concentration of whatever solution the probe is touching.

Evaporation:
Evaporation will have the same effect here as decreasing volume (of water) had in the Dilutions sim. If there is solute in the beaker, the concentration will increase to saturation and then solid granules will be leftover when all the water is evaporated.

Drain:
Drain will empty solution of whatever concentration is in the beaker. Rate TBD; check Sugar and Salt Solutions for ideas on this.
If the drain is used on a saturated solution, only the solution of set concentration is removed; the solid particles remain in the bottom of the beaker. The beaker cannot be fully emptied with the drain. Since the drain is raised a little from the bottom of the beaker, a small amount of solution will remain behind (plus any solid from saturation). Once more water is added, this solid may dissolve.
EM: Might be useful to have an easy way to completely empty, that way you could start over with a new solution. Reset all will work, but another (empty container) option might be useful.
JC: Reset all will return the container to the starting configuration. Remove Solute is a button we need to include. Remove All would be redundant; wait on that feature for now.



Default settings for Tab 1
- Solid vs Solution radio buttons (Solid)
- Solute combo box (Kool-Aid)
- Amount of water in the beaker (0.5 L)
- Amount of solute in beaker = 0 mol (to start)
- Concentration meter in starting location, on the side, with no value displayed.

Remove and Reset Buttons
Similar to Sugar and Salt Solutions. Students will have a Reset All button, which returns the beaker to the above detault settings. There should also be a Remove Solute button to clear all solute from solution. This button appears when there is solute in solution, and disappears when there is no solute in solution (ie, beaker of water.)

Concentrations for different chemicals
The beaker is 1 L, and will have tick marks every 0.10 L, with labels at 0.5 L and 1.0 L.

The total number of moles allowed in the beaker is equal to the moles in 1 L in a saturated

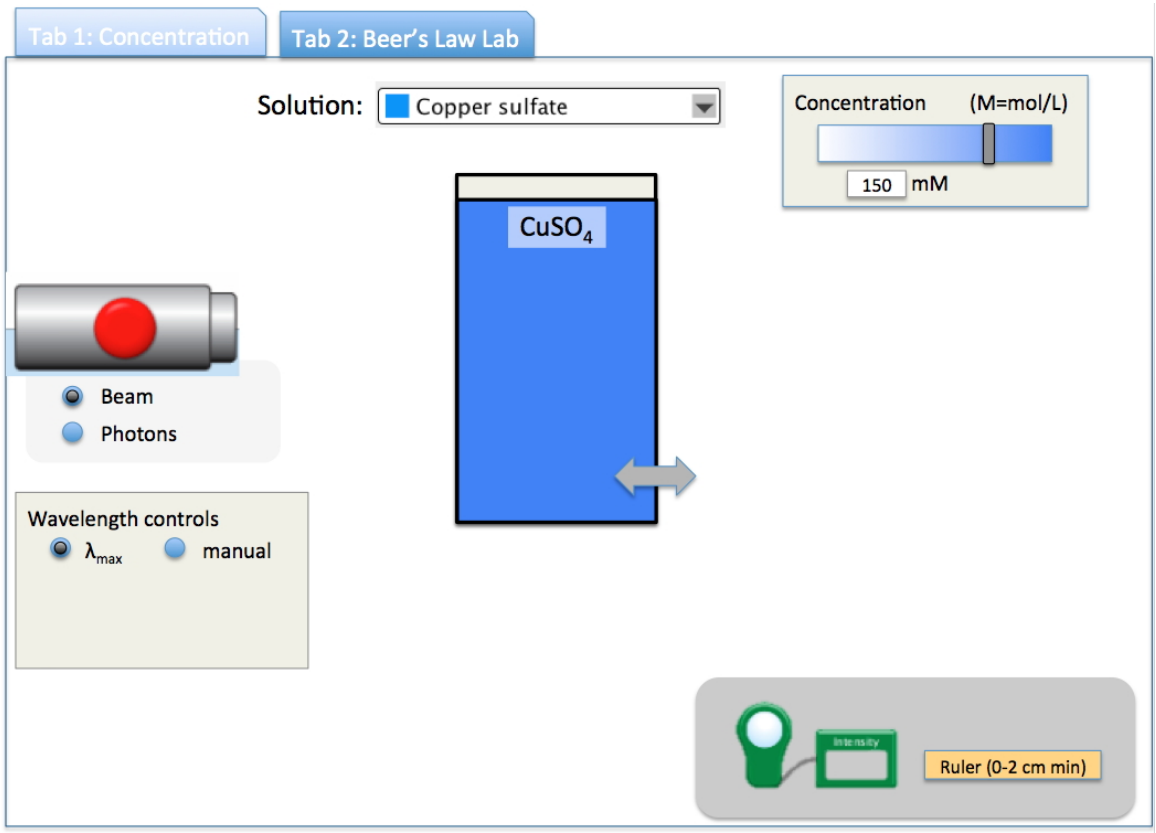
solution. A full beaker with the max allowed solute will not be saturated, and should read the saturation concentration value. Anything more concentrated than this (from evaporation or simply less water to start with) will reflect saturation. Concentration will remain at the “saturation” value, and crystals will appear in the bottom of the beaker in proportion to the number of moles over the saturation concentration. Solution concentration in the droppers will be slightly below saturation concentration, at values possible for concentrated “stock” solutions. Plan to use 2 decimal places for all numbers (internal and the ones showing in the sim on the concentration meter).

Solute	Name	Molar Mass	Color	Solubility in H_2O	Satur’n Conc. = total mol allowed in beaker	Solution Conc. in dropper
Kool-Aid	assume sucrose $C_{12}H_{22}O_{11}$	342.296 g/mol	red	2039.5 g/L (20 C) 5.9583 mol	5.96 mol / L	5.50 M
$Co(NO_3)_2$	cobalt (II) nitrate	182.942 g/mol	red	1032.5 g/L (25 C) 5.6440 mol/ L	5.64 mol/L	5.00 M
$CoCl_2$	cobalt chloride	129.839 g/mol	rose pink	562.3 g/L (25 C) 4.3304 mol/ L	4.33 mol/L	4.00 M
$K_2Cr_2O_7$	potassium dichromate	294.185 g/mol	orange	150.7 g/L (25 C) 0.5124 mol/ L	0.51 mol/L	0.50 M
K_2CrO_4	potassium chromate	194.191 g/mol	yellow	650.2 g/L (25 C) 3.3481 mol/ L	3.35 mol/L	3.00 M
$NiCl_2$	nickel (II) chloride	129.599 g/mol (anhydro us)	green	675.04 g/L (25 C) 5.2087 mol	5.21 mol/L	5.00 M
$CuSO_4$	copper sulfate	159.609 g/mol (anhydro	blue	219.51 g/L (25 C) 1.3753 mol/	1.38 mol/L	1.00 M

		us)		L		
$KMnO_4$	potassium permanganate	158.034 g/mol	violet	75.963 g/L (25 C) 0.4807 mol/L	0.48 mol/L	0.40 M

Tab 2 - Beer's Law

This tab will give students tools to explore the concepts of Beer's Law, including the roles of solution concentration, pathlength, color & wavelength, absorbance, and transmittance.



Similar combo box for solutions as in previous tab (and Molarity sim). **Should forumla name be included in combox box? Problem with including label on cuvette (shown above) is that cuvette can be resized to be too narrow (see Kool-Aid example below)**
Laser and intensity detector (with some modifications) from Bending Light. Wavelength control modeled after Bending Light and Models of the Hydrogen Atom sims with disappearing slider control.

Initial view:
Light beam is off. Students get a container of solution; width of the container (and thus the amount of solution) can be changed using a grey arrow that highlights when moused over. Left

side of container is fixed with enough room to fit the light detector probe in front of it. Right side can be moved to change size. Arrow is bi-directional unless at the low or high limit of slze, in which case it shows only the direction the beaker width can be changed.

Pathlength (container width) range is 0.5 cm to 2.0 cm. Default size = 1 cm.
The ruler tool can be used to meausre the pathlength.
The container will not be labeled with the chemical formula or name. **Will both of these be displayed in the combo box?**

Students can select solutions from the combo box (same chemicals as in Tab 1) to change solution color.

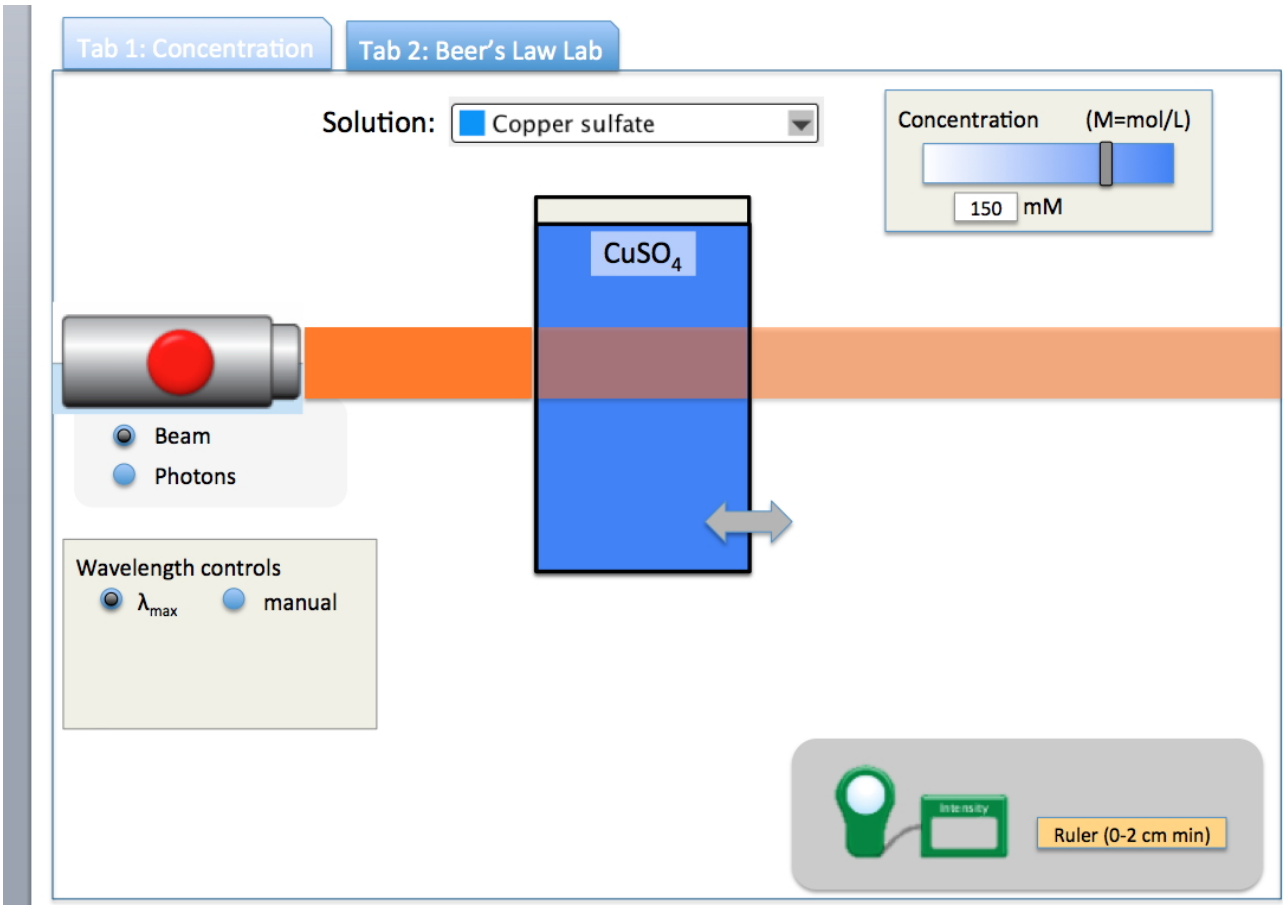
Wavelength default for each solution will be the lambda max value. This can be changed by selecting the "manual" radio button in wavelength control area, which makes the slider appear (see example below) It can also be changed with a number entry box (a spinner would be great on this tool for finding Max Absorbance).

Concentration can be changed with a slider or using the number entry box. Range discussed below, but will be M, mM, or uM.

Light source is fixed (horizontal beam position) and does not rotate or move.

Desired default settings:
- wavelength (lambda max)
- Beam vs Photons radio buttons (Beam)
- container width (1 cm)
- Solute combo box (Kool-Aid)
- Detector and ruler in tool box

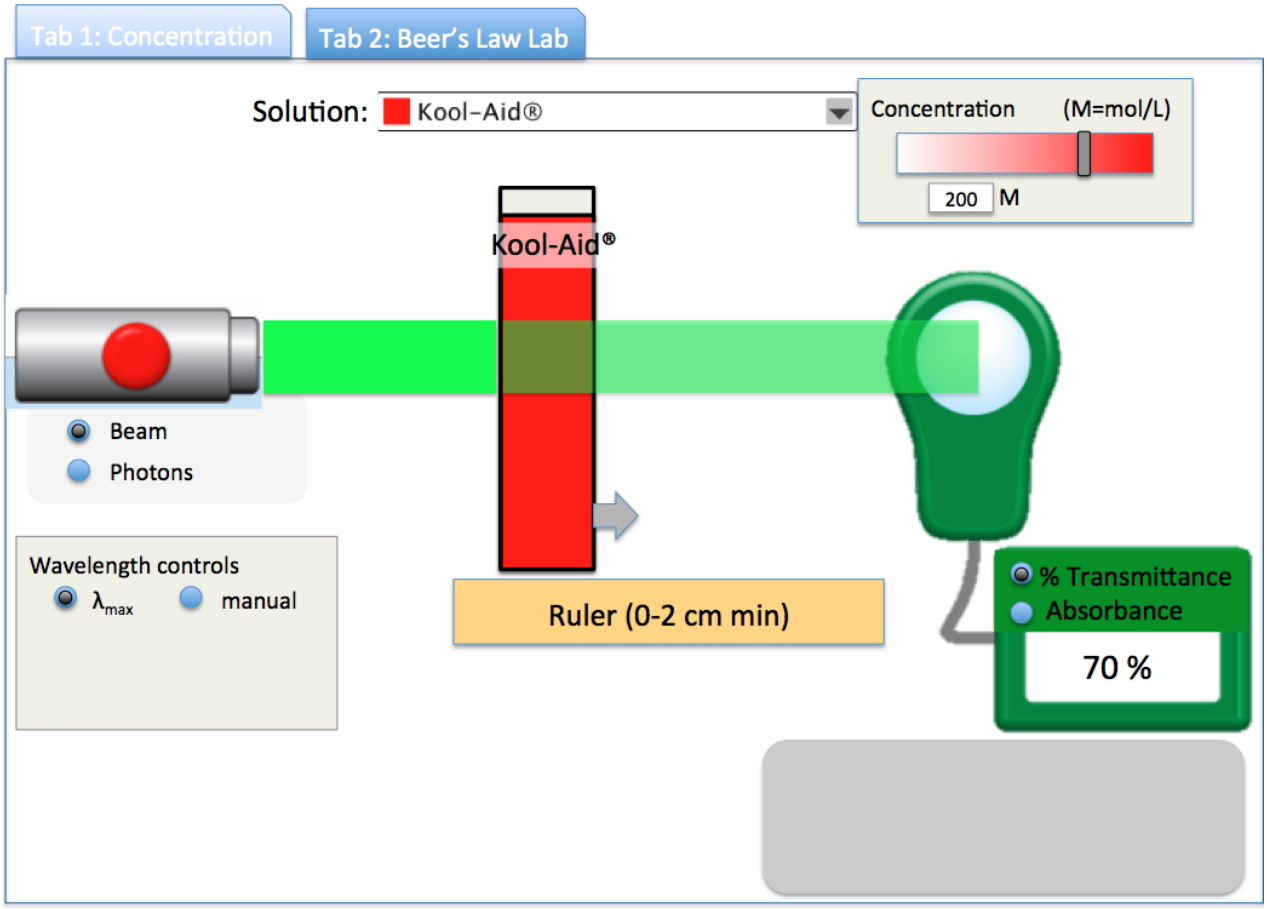
Beam and Photon Views
Students can visualize absorbed light through a beam or through animated photons, some of which disappear as they hit the sample. Plan to use the "standard" PhET photons also used in Models of the Hydrogen Atom and Molecules and Light, etc.
Note: Photon view will not be implemented owing to significant challenges and its not addressing primary learning goals.

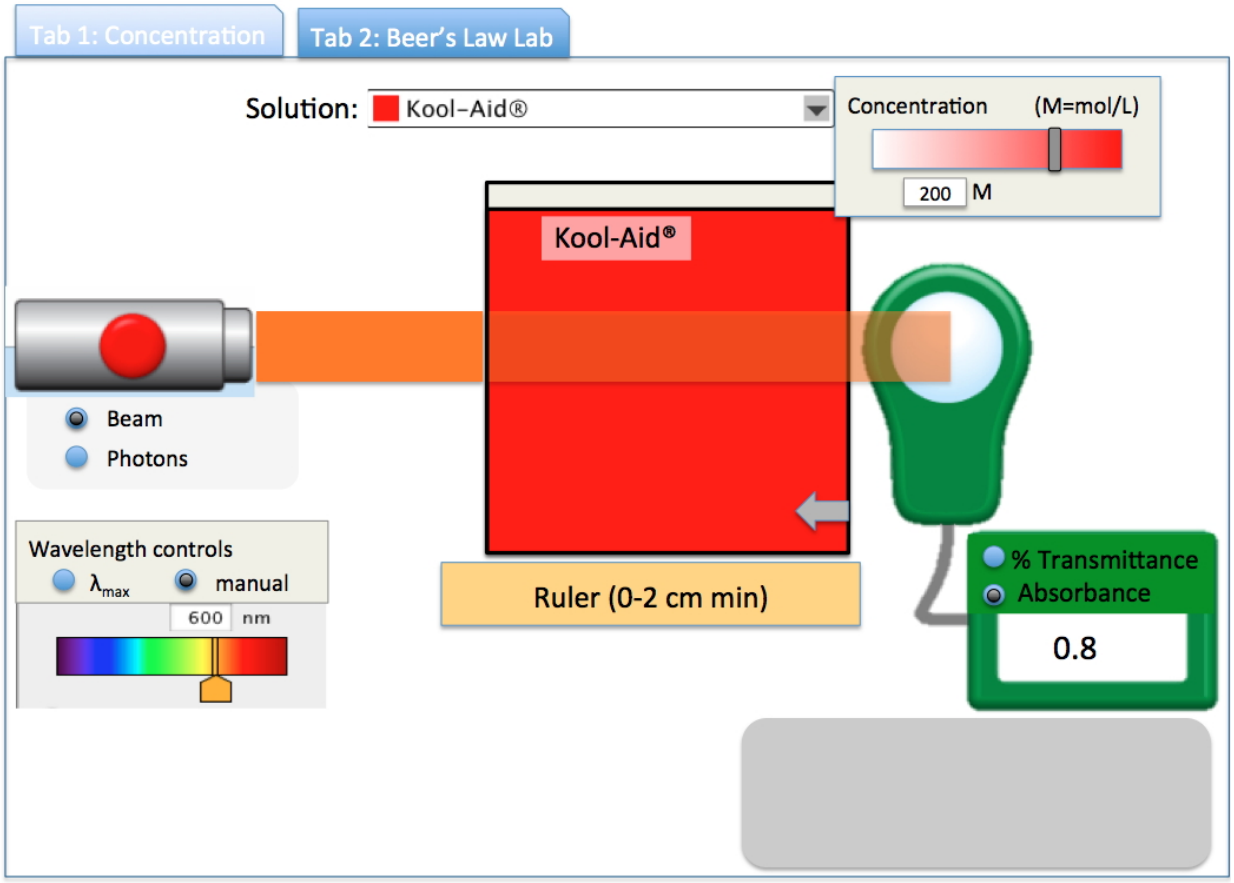


Absorbance and %Transmittance Detector
The detector can be held in the beam or photon stream to measure the amount of light being absorbed or transmitted. If the detector is placed in the beam to the left of the sample, Absorbance = 0 and Transmittance = 100%. Detector cannot be moved into the sample container (the cuvette). If attempted, it bumps up against the cuvette and cannot be super-imposed.

EM: how important is it that students be able to change wavelength. Would it be useful to just change the light setting for each solution to an appropriate value range? If i don't know what i'm looking for, it might be easy to just move the wavelength back and forth too quickly to notice that there are sharp changes at certain points.
JC: Would including the absorbance spectrum help with this possible missing information?

Cuvette size examples:
Should include a quantitative measure of pathlength (cuvette width).
EM: Could you have a readout below the cuvette, so as you change the width, the readout changes?
Current plan to include a ruler tool so students can measure pathlength.


Tab 1: Concentration
Tab 2: Beer's Law Lab
Solution:
Kool-Aid®
Concentration
(M=mol/L)
200
M
Kool-Aid®
Beam
Photons
Wavelength controls
λmax
manual
Ruler (0-2 cm min)
% Transmittance
Absorbance
70 %



Maximum Absorbance Wavelength (Lambda Max)
Lambda max is provided as the default light source for each solution (though not given in nm). Students can use manual wavelength to find Lambda Max using the sim by changing the wavelength of light and watching the detector for max absorbance values.

I would like the sim to show that absorbance depends on the total quantity of the absorbing compound in the light path through the container of solution.

See the Model section of the google doc for relevant equations for this tab.

Data for calculating %T and A:
Pathlength range (b) in the sim is the same for all compounds. 0.5 cm - 2.0 cm.
Concentration should cut off at max absorbance values of 2.0 for the data we are using as our model. This leaves us with pretty low concentration ranges for many of the chemicals.
Consider: "Maxed Out" message for meter so that concentration can go higher.
For Concentration display and input:
Consider: Milli- or micro- molar concentrations (0.001 M = 1.0 mM) -exception of Kool-Aid?
(Better?) Idea: move the number entry box to the right of the decimal point and zeros for numbers with very low concentrations, so as to always maintain the same number of entry digits in the field, but not change units of concentration (M). eg. "0.291 M" and "0.000231 M", where

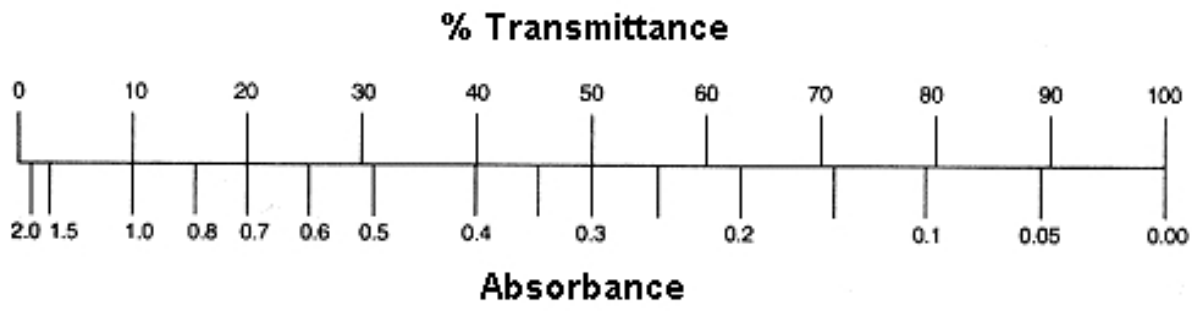
the blue numbers are in the number entry field and the black numbers are fixed.

Solute	Name	Color	Abs. max max (nm)	Conc. A=2.0, b=2	Conc. A=2.0, b=1	Range
Kool-Aid	Kool-Aid	red	511 nm	0.197 M	0.394 M	0 - 400 mM
$Co(NO_3)_2$	cobalt (II) nitrate	red	550 nm	0.212 M	0.424 M	0 - 400 mM
$CoCl_2$	cobalt chloride	rose pink	549 nm	0.138 M	0.277 M	0 - 250 mM
$K_2Cr_2O_7$	potassium dichromate (Cr6+)	orange	394 nm	0.0003 M	0.0005 M	0 - 500 uM
K_2CrO_4	potassium chromate (Cr6+)	yellow	413 nm	0.0002 M	0.0004 M	0 - 400 uM
$NiCl_2$	nickel (II) chloride	green	435 nm	0.188 M	0.377 M	0 - 350 mM
$CuSO_4$	copper sulfate	blue	780 nm in range (real = 300, 850 nm)	0.104 M	0.208 M	0 - 200 mM
$KMnO_4$	potassium permanganate	violet	566 nm	0.0004 M	0.0008 M	0 - 800 uM
H_2O	water	transparent	no Abs.	n/a	n/a	no conc. control

Issues with Chemicals:
Molar absorptivity values are not readily published in the CRC Handbook, the NIST Chemical WebBook, the Combined Chemical Dictionary, PubChem, SciFinder, and Google.
I posted to the Virtual Inorganic Pegagocial Electronic Resource, and asked Laurel Hyde, Alan Foster, and Molly Larsen (who does instrumentation) at CU.
Results: Another VIPEr user collected the spectra in his lab for the chemicals, and I collected Kool-Aid at CU. Data sent to CM in an excel spreadsheet that included wavelengths, absorption values, and calculated molar absorptivity values as a function of wavelength.

Since the relationship between Absorbance and Transmittance is logarithmic and confusing, it may be helpful to include an option to open a window with the following scale, similar to the periodic table window in SSS.
CM: Is this a static picture? I'm not convinced that a static picture is very useful. How about a more sophisticated detector that can show this relationship, and show %T and A simultaneously?
EM: How important is it to show this relationship at all. I don't see it in the learning

goals.

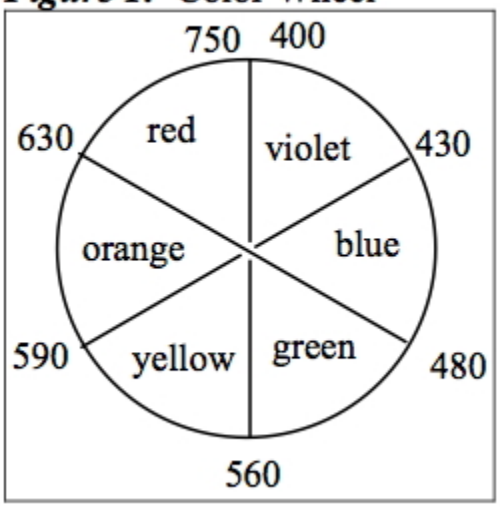


Information on colors
Table and pie chart from https://eee.uci.edu/programs/gchem/RDGVISSpec.pdf

Table 1: Absorbed & Perceived Colors

Absorbed Wavelength (nm)	Absorbed Color	Perceived (Transmitted) Color
400	violet	green - yellow
450	indigo	yellow
480	blue	orange
490	blue-green	red
530	green	purple
570	yellow-green	dark blue
600	orange	blue
650	red	green

Figure 1: Color Wheel



Some info on chemical color, but not lambda max: http://en.wikipedia.org/wiki/Color_of_chemicals

CM: This is a good start for colors. We have common code that converts wavelength to a color. But you'll need to be specific about what you want for qualitative descriptions like "violet" and "green-yellow". As with all sims, colors will be easy to change.

Colors used for solution gradients:

Solute	Color	Conc. for mid RGB color	min RGB=	mid RGB=	max RGB=
Kool-Aid	red				[255,85,0] (?)
$Co(NO_3)_2$	red				

$CoCl_2$	rose pink				
$K_2Cr_2O_7$	orange				
K_2CrO_4	yellow		[255,255,199]		
$NiCl_2$	green				
$CuSO_4$	blue				
$KMnO_4$	violet	0.1 M (?)	[255,235,255]	[255,0,255]	[139,0,130]
H_2O	light blue		[224,255,255]		

Tab 3 - Ideas: Advanced / Custom / Variable Wavelength

A number of features are under discussion that we have decided not to include in the Beer's Law tab. These include:

Variable Wavelength
A wavelength slider so students can see how absorbance is dependent on wavelength from real spectroscopy data, and so they can scan across various wavelengths to find lambda max. Currently this is in the Beer's Law tab and students are making sense of it reasonably well, but not entirely. Another difference in the implemented version is that lambda max is provided to students in the "fixed" wavelength option.

Variable Molar Absorptivity / Custom Solution
Molar absorptivity is at the core of how we are showing Absorbance and Transmittance values in the sim, as well as how we are determining the allowed concentration ranges. I need to think about how we could include a slider on such a core value to make it variable, and what the implications would be. I don't see how to implement variable wavelength with variable molar absorptivity, currently.

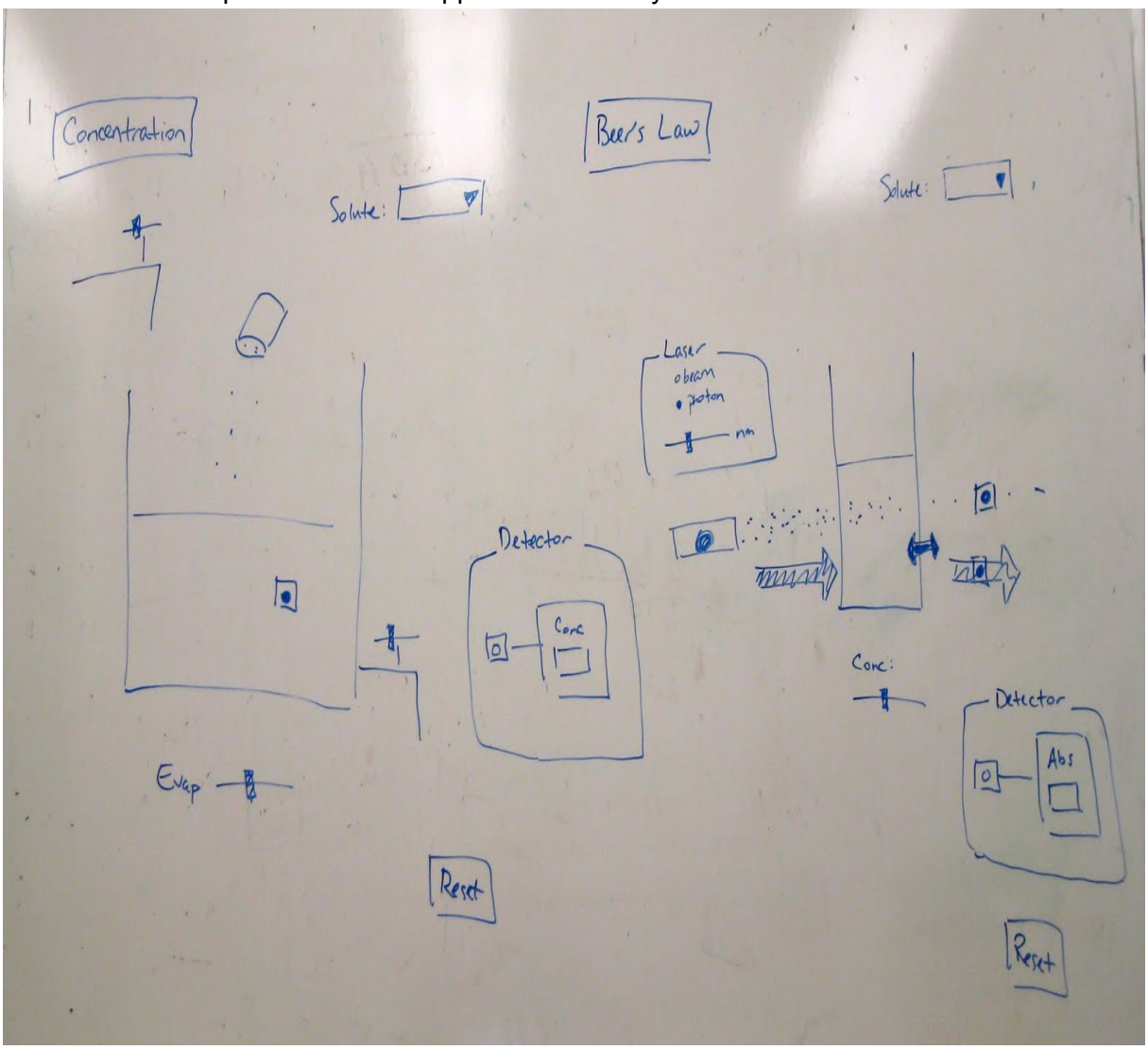
Light beam is what would change to indicate different molar absorptivity.
Molar absorptivity could also be represented via a graph of intensity, but this seems like it opens up a lot of opportunity for misinterpretation.

Unknown Solutions
Could have a tab with unknowns. Could refer back to Beer's Law data, or could be different solutions with 2 or 3 data points provided for known solutions. The trouble with this idea is that it focuses the student on numerical answers and making graphs, which may or may not be what we want to include in the sim. One of our Beer's Law learning goals includes comparing graphs. Do we want to include a graph making tool in a third tab of the sim, or do we want to leave this up to the teacher to have students use pencil and paper, or a program like excel?

Discussion History

11/03/11 - PhET Chem Meeting

Ideas from KL: 2 Tab sim, Concentration and Beer's Law
Same set up as SSS, with a drop down solute combo box.
Pull out tool detector for Concentration (quantitative)
Color of solution will be qualitative conc. display.
Solute could be liquid to add via dropper as well. Maybe different concentrations?



11/17/11 - Meeting with JC, KL

Discussed re-design ideas from the Dilutions sim, questions about design feature ideas. Notes are included in the first set of mockups for this sim.

11/21/11 - Comments and discussion CM and JC

Tab 1:

Background will be white and water will be lighter in color, as discussed in the previous Dilutions sim. Shaker will read chemical name (not Sodium Chloride).

CM: Will the real chemical names fit on the shaker? (Looks like just barely, if they are multi-line, which means small font.) Do you want to show formula, too?

JC: If space and translation are a concern, we could include the formula only on the shaker, and the full name and formula on the combo box.

CM: Putting the label (whose length will vary based on translation) on the shaker (an object whose size is fixed) presents an i18n issue. I suspect that this issue was ignored in Sugar-&-Salt. I intend to scale the label down if it does not fit on the shaker; and scaling down will affect readability. If the shaker is not movable, you could get rid of the label on the shaker, and center the Solute combo box above the shaker so that it serves as the indication of what's in the shaker.

JC: I understand the problem. If putting the formula on the shaker will work, I would like to use that solution. Otherwise, your idea sounds good. Maybe we should do both?

Faucet graphics will be the same as Sugar and Salt Solutions. (Note: some if the design detail got washed out in my image editing--this was not intentional.)

CM: Re the faucets... The slider thumbs on these faucets are unnecessarily small, a deficiency that I raised several times (and eventually dropped) with SSS. These sliders will be unnecessarily difficult to manipulate for younger students, and exceptionally so for users with motor disabilities. We have no constraints in either sim that require these thumbs to be so small, and this would be trivial to correct - simply make the faucet handle taller. I recommend revisiting in this sim, as well as SSS.

JC: I agree. Is there a way to use the slider thumbs that you designed for the original Dilutions sim?

CM: Let's put icons next to the "Solid" and "Solution" radio buttons, to strengthen the connection to the shaker and dropper. And move these radio buttons (and combo box?) closer to the thing they are controlling.

JC: Sounds good! Do you think shaker and dropper icons would work, or would icons representing the "solid" and "liquid" be better? The latter sounds more abstract to me, but might be more helpful to a student if we choose the right images.

CM: Does the shaker eventually become empty, as in Sugar-&-Salt, or does it contain an infinite supply of particles?

JC: It eventually becomes empty. I have molar limits in mind (see table below) for each chemical, but I need to think about how many particles this would represent, and how that would look for the different compounds.

CM: The shaker can be shaken. Can it also be moved, or is its position fixed? If it can't be moved, then (when saturated) all of the particles will end up at the bottom of one side of the beaker.

JC: It is OK for particles to evenly distribute in the bottom of the beaker even if the shaker is shaken on one side. If this looks weird when the beaker is empty, we can discuss alternatives.

CM: Does this section [Saturation] apply to both solids and solutions? Unclear...

JC: Yes, this applies to any time that the conditions make the solution saturated.

CM: What happens when you shake into an empty beaker?
JC: solid granules appear in the bottom of the beaker. I envision these looking like the solid granules in the saturated case.
CM: If the particles need to animate from the shaker to the surface of the solution (do they?), then it's a trivial amount of work to make them animate to the bottom of the beaker when the solution is saturated. That's if we do it initially - if we decide to add it later, it's slightly more expensive. I suspect that you're ultimately going to want to see them animate to the bottom of the beaker, so I recommend that we start with that requirement. On the other hand... Animating to the bottom of the beaker means that particles will cluster below the shaker, they will not be uniformly distributed across the beaker's bottom.
JC: Good points. I would like to not have the problem of all the solute being on one side of the beaker, so I think it's OK for the partlcles to not animate through the solution. My current vision is that when they hit the top of the saturated solution (or the bottom of the beaker, when empty) they will contribute to the appearance of randomly distributed particles on the bottom of the beaker.
CM: Why does nothing happen [to the concentration meter] when fully submerged? As long as the tip is touching solution, shouldn't the magical meter display concentration?
JC: Sorry -- I mostly meant that it still functions completely when submerged (unlike a conductivity meter).
CM: What is the motivation for putting the concentration meter in a toolbox? There's only one of them (correct?), and it could just as easily be left in the play area, where we have plenty of room. If the issue is that the word "Concentration" (toolbox title) doesn't fit on the meter, then let's design a better meter (which I think we should do anyway.) As soon as the user drags the meter away from the toolbox, the association between the meter and the toolbox title is certainly weakened, and perhaps lost.
JC: I have been thinking about this too, and I think a more fun looking meter without a tool box would be good.
CM: Does the dropper contain an infinite supply of solution?
JC: Each chemical will have a molar maximum allowed in the beaker at once. The dropper and the shaker will both run out when the number of moles in the beaker hits this amount.
CM: Is the dropper movable, or is its position fixed?
JC: Could be either. I don't currently see moving it as giving the user any affordances. Stationary might be better to cue the use of the red button.
CM: There are 2 issues with putting the label on the dropper as shown in the mockup. (1) The chemical names you've provided won't fit on the dropper, and there's no room for multi-line labels. (2) The length of the labels will vary based on translation, and since the dropper is a fixed size, labels will need to be scaled down (impacting readability) if they don't fit on the dropper. I recommend making the dropper as wide a tolerable, or (as I mentioned for the shaker) consider moving the Solute combo box above the dropper so that it serves as the indicator of what's in the dropper.
JC: Let's put the formula label on the dropper, and make it wider as needed. I think this will solve the problem.
CM: Evaporation control was never discussed. What does the user see when all of the water is evaporated?

JC: Evaporation will have the same effect here as decreasing volume (of water) had in the Dilutions sim. If there is solute in the beaker, the concentration will increase to saturation and then solid granules will be leftover when all the water is evaporated.

CM: What are the desired defaults for:
- Solid vs Solution radio buttons (Solid?)
- Solute combo box (Kool-Aid?)
- amount of water in the beaker (0.5L?)

JC: Yes to all of these.

The beaker is 1 L, and will have tick marks without labels for full, three-quarters, half, one quarter, and empty (as in SSS).
CM: If the concentration meter is quantitative, why aren't the beaker ticks labeled?
JC: The idea was to place less emphasis on the quantitative aspect of the beaker, but you bring up a good point. In order for students to calculate how many moles are in solution, quantitative beaker labels would be needed.

Tab 2:
Initial view:
Light beam is off. Students get a container of solution with a handle to change width of the container (the pathlength). In the mock up this is a black handle--it will need mouse-over arrows or some better indicator that it's a tool.
CM: Recommend that using the handle makes the container width change in both directions (+x and -x) so that the container remains centered. Use a left-right arrow cursor (see power control in Optical Tweezers.)
JC: Sounds good to me.
CM: Does the container have a non-zero minimum size? What is the internal range and units for the container width?
JC: Yes. I'm currently thinking that minimum container width would be 0.5 cm.
CM: Should the container be labeled "Solution"? Being new to the concept, I had no idea what this was supposed to represent when I first viewed the mockups.
JC: I will think about this. Designing the container to have a little bit of room in the top might help. Let's discuss with the team.
CM: Does the concentration slider need to be in a control panel, or can it be in the play area, ala the Dilutions sim?
JC: all of the controls in this tab are up for rearrangement for better design and use of space. Putting the concentration control in the play area seems OK, but let's see what we decide to do with the other controls and keep it internally consistent.
Location and placement of tools and objects is up for discussion--currently it looks a little disorganized.
CM: Organization looks basically OK to me. I would center the "Solute" combo box above the container.
JC: Great.
CM: Is there any need to label the container with what it contains? Probably not if we center

the Solute combo box above the container. But if so, how does this work when the container is resized?
JC: I would like to not label the container, since the student will need to observe what's going on inside of it when the light passes through.
CM: Does the laser move or rotate?
JC: No. It is fixed.
CM: What are the desired defaults for:
- wavelength (JC: will depend on default solution. For now, let's use 600 nm as show in the mock up).
- Beam vs Photons radio buttons (Beam?)
- container width (1 cm)
- Solute combo box (CuSO4)
- Detector location (lower right, below beam) (Not sure, seems reasonable right now).
CM: What visual representation of photons are we using? the "standard" we created for "Models of the Hydrogen Atom"?
JC: Yes, I think this would look good, and would be consistent across sims.
Detector cannot take a measurement inside of the sample--if moved onto this space, it reads blank as if in front of / on top of the sample space.
CM: As with the concentration meter... Why put the detector in a toolbox? There's no need for a toolbox, just leave it hanging out in the play area, there's plenty of room to move it in/out of the beam.
JC: I'd be fine with this. Does it need a label?
CM: "%T" and "A" are sufficient labels for the radio buttons, and they don't belong on the detector's probe. Move controls to the detector's body (where the value is displayed), and make their labels more verbose.
JC: OK. In the mock up the detector shows the full name of whichever is selected. I was trying to save on space, but if this isn't clear enough we should redo as you recommend.
CM: Not clear to me how "students can find Lambda Max" when only the wavelength and detector are quantitative.

11/21/11 - Chem Team Meeting - CM, RP, KL, JC - Discussion of new design
Agenda and Questions to address:
New project name? (Ask KP)
Tab 1 Quantitative beaker labels? (Yes)
Tab 2 Is Qualitative Concentration slider OK in Beer's Law tab? No, make quantitative like the wavelength slider.

Notes:
Agree that formula on the shaker is good, chemical name and formula in combo-box.
Yes to CM's suggestion for icons next to Solid and Solution (shaker and dropper)
Yes to KL's suggestion to have all solute controls in one box.
Dropper and shaker will both move back and forth across beaker (more fun).
CM will change faucets to make larger slider thumb with click-on-track functionality (not only

grab and drag).
Tick marks on beaker at 0.1 L intervals. Labels at 0.5 and 1.0 L.
Have 2 decimal places for concentration meter.
Ask EM: when do student learn decimal notation?
Rearrange combo-box and solid/solution options to be more centered, whatever looks good.
Conc meter will have a body and probe that move independently, like the light meter in the second tab.
Change look of detector to look more perpendicular. Make it so it cannot overlap with the container, like a real object.
Question of being able to see A and %T at the same time. Will students realize that 1 goes up while the other goes down? (good interview question)
Detector should work like in Bending Light, absorbs the light (no light passes through detector). Need to update the mock up to show this.
Also see in interviews which one students use more / make more sense of (%T or A).
Need a reset button for wavelength? Or just reset solvent?
Current plan: when solute is changed, wavelength and concentration will change to optimal values. Both will be quantitative with similar layout of number and slider.
Second tab combo box label should be “solution” not “solute”.
Light up arrow for cuvvette resize tool.
Initial setting for probe is out of beam path.
Need to know what the beam will look like coming out of the source, going through solutions, and coming out of the beaker.
Second tab should include Water as an option to measure a “blank”. Would be last option in solute menu. Hide the slider for water.

If we want to include the model of solid adding to solution volume, Jonathan may have a way to calculate this. Read over design doc for a discussion on this topic and the complexities to calculate saturation point. (Start in discussion section of SSS)

11/23/11 - Meeting w. KP
Tab 2: Maybe make 2 tabs, Beer’s Law intro and Beer’s law lab
First is simpler, one solution, limited wavelenths (max and one other maybe) for students to familiarize and explore the relationships here. 2nd tab will have different solutions, variable wavelength, etc.
Allow meter in solution (no problems with this)
Could use Ruler for pathlength. If so, consider using a toolbox for ruler and meter.
Need relationships of a and mavelength for all compounds.
Possibly some mystery solutions would be useful. Conc would not be movable, it would be the goal...
Idea that how much light gets through is conc and a (and pathlength). Could let students interact with absorptivity coefficient directly, and show how that relates to absorption and transmittance. Custom solution could build this in. Should this be included in the intro tab? Or later.
Maybe options in intro tab for a solution (set. Koolaid?) and then the custom solution. Koolaid

wouldn't have a slider, just a readout. When they switch to custom molecule they could move the slider down and up from wherever Koolaid was starting. Since they range is so dramatic (we think) just make the "a" slider a "higher' and "lower" qualitative.
Another visual to help understand absorbance? Consider measures of optical depth that show changes as concentration is changed.

12/01/11 - Chem Meeting
Agenda:
Decide on a name for this sim
Tab 1:
Bar Graph idea as an additional cue for concentration change (could test in interviews)
Very low concentration values with the meter -- will this be OK?
Drop dispensing for solution - see KP comment on Fluid Pressure and Flow
Beer's Law:
Resources for molar absorptivity as a function of wavelength
2 Tabs Idea - Beer's Law intro w/ fewer parameters to change + Beer's Law lab w/ chemical solutions.
Tools:
Ruler tool to quantify pathlength?
Allow the meter in solution--we are going to need to visually model photon absorbance anyhow, so allowing students to measure it in solution is OK. Q: what about the absorbance of the cuvette? Can we "idealize" this and make it zero?
Ideas for a "custom" solution where a can be changed.
Ideas for "mystery" solutions with given a and unknown C.

Meeting Notes:
Name choice: EM: tabs could be separate. Does this help us choose a name?
T1 = Solution Concentration
T2+ = Beer's Law
Name of large sim = Beer's Law Lab. (sub sims will be named later)
email titles will be "Beers"
RP = consultant, EM = team member.

Bar graph: potentially complicated because of differing concentrations in each solute. Similar to Molarity in dilutions.
EM: this would make sense only if it can be standard across solutions; it could still be hard for students to parse because of this.
CM: scale 6 max and 0.5 min is a problem for a small bar graph. Wouldn't be relevant for all choices. Zoom buttons and more controls could be just more confusing.

Conc. Meter precision: meter needs to match what students can do. Meter could switch to a lower concentration range, but this might be complicated (ppm).
KL: let's start with the 2 decimal places and see what the functionality looks like.
CM: meter could read < for values below 0.01 M.
On molar absorptivity as a function of wavelength.

KL: these are in water, which does absorb in the visible region. The more accurate you try to be, the more trouble you run into.

Wavelength range 380-780 (consistent in other sims)
KL: another options is to not allow wavelength to be varied for some compounds. We could allow this only for the custom solution.
RP: Standard / actual chemical solutions the wavelength would be fixed at max abs. Custom solution they will get to change wavelength and molar absorptivity.
EM: This would minimize their options with the real chemicals; is this what we want.
KL: if molar absorptivity is changable, what changes? How does this work?
CM: if they can't change the wavelength for stock solns, how will they know to change it for the custom soln?
KL: Custom soln could be a color, which would define where it absorbs. When they move the wavelength slider it will
KL: Want students to see that solutions absorb in some wavelength and not at others.
RP: custom soln kind of buries "a". Real solns can have multiple absorption peaks in different combinations to give the same color...
JC: for purposes of sim, assume all chemicals absorb best at a single wavelength
CM: 2 ways we're using color in the sim: 1 is to indicate concentration, the other is to indicate what color of light the solution absorbs.
EM: could work to not have custom and let students choose from a range of given solutions. If you have a color dependence, students may think that's the goal to learn.
What are the benefits to the **custom solution**?
JC: Think about how to build in the tools we want (variable wavelength, color relationships) without custom soln.
Allowing probe in soln: Would students realize this changed path length?
EM: in this case the tool would interfere with the measurement. Would students think that 'it's just different in the container?"
KL: Probe in solution would be same as changing pathlength.
CM: As we change solutions in the Beer's Law tab and change wavelngth, will students realize we are setting this for the peak of the curve.
KL: could try some middle wavelength and let students find max.
CM: **will students see there is a curve without direct visualization?**
KL: you could see this if you could vary wavelength.
JC: Possibility for 2 Tabs on Beer's Law, an intro, and the "Lab" to break up the cognitive load.
KL: 2 tabs on BLL could be a big change.
EM: There are more features in bending light T1 than in Beer's Law. Cognitive load OK.
JC: Can see in interviews, and can see how sim development of this tab goes and how many features there end up being.

12/09/11 - Chem Meeting
Agenda:
Tab 1
- Graphical representation for concentration meter.

- Remove buttons (remove solute, remove all, remove water?)
(Reset All button will return the beaker to its original (half full) configuration)

Meeting Notes:

Graphical representation of conc meter:

KP: no autoscale. Goal was semiqualitative associations like ½, etc. Ok to start with just numbers and see how students do.

Graphical representation would be nice here, but the difficulty of scale between solutions leads us to start with the quantitative meter and think about a semi-quantitative representation if students need something like that to help them make sense.

KL: remove solute from solution will remove moles solute, leave water from the solution that was added.

12/20/11 - Updates Summary

- Included "Remove Solute" button in the 4th mockup panel of Tab 1 (the one with the dropper)
- Added concentration ranges to Tab 2 table of info. Need to discuss concentration units and number display; I have some ideas (described above and shown in mock up).
- Included tool box, ruler, curve graph and Kool-Aid in Tab 2 mock up.

1/5/12 - Chem Meeting (did not have meeting)

Agenda

Tab 1

Remove solute button: stay put, or appear only when solute is present? KL: or disable when no solute is present

Ideas for space for shaker mobility and dropper graphics?

Beaker tick marks: R or L side of beaker wall?

KL: how many decimal places are needed for concentration?

1/19/12 - Chem Meeting

Agenda

Tab 1:

- A "too low to read" notice for the concentration meter? See Tab 2 note re: meter max-out.

Tab 2

- Concentration ranges are variable and very small for some chemicals (see table). Should we broaden the allowed range and have a "maxed out" message for the concentration meter when solution is too concentrated? (%T = 0)
- Light detector in solution vs. not. How does this represent pathlength? Pros: More interactive, can change (and measure) pathlength to the detector using the ruler in solution.

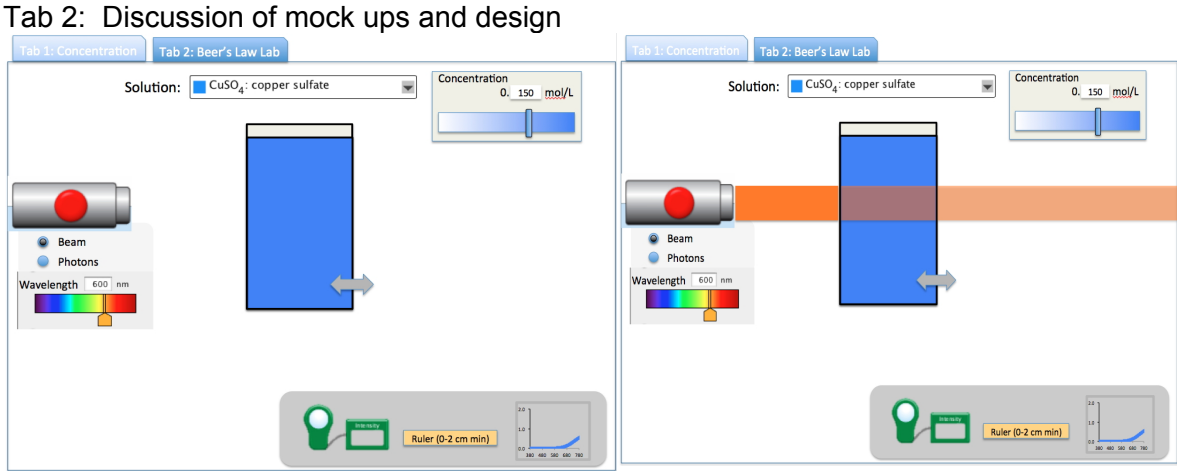
Cons: need to model smaller pathlengths than 0.5 cm. With what increment of precision can the meter probe be moved?

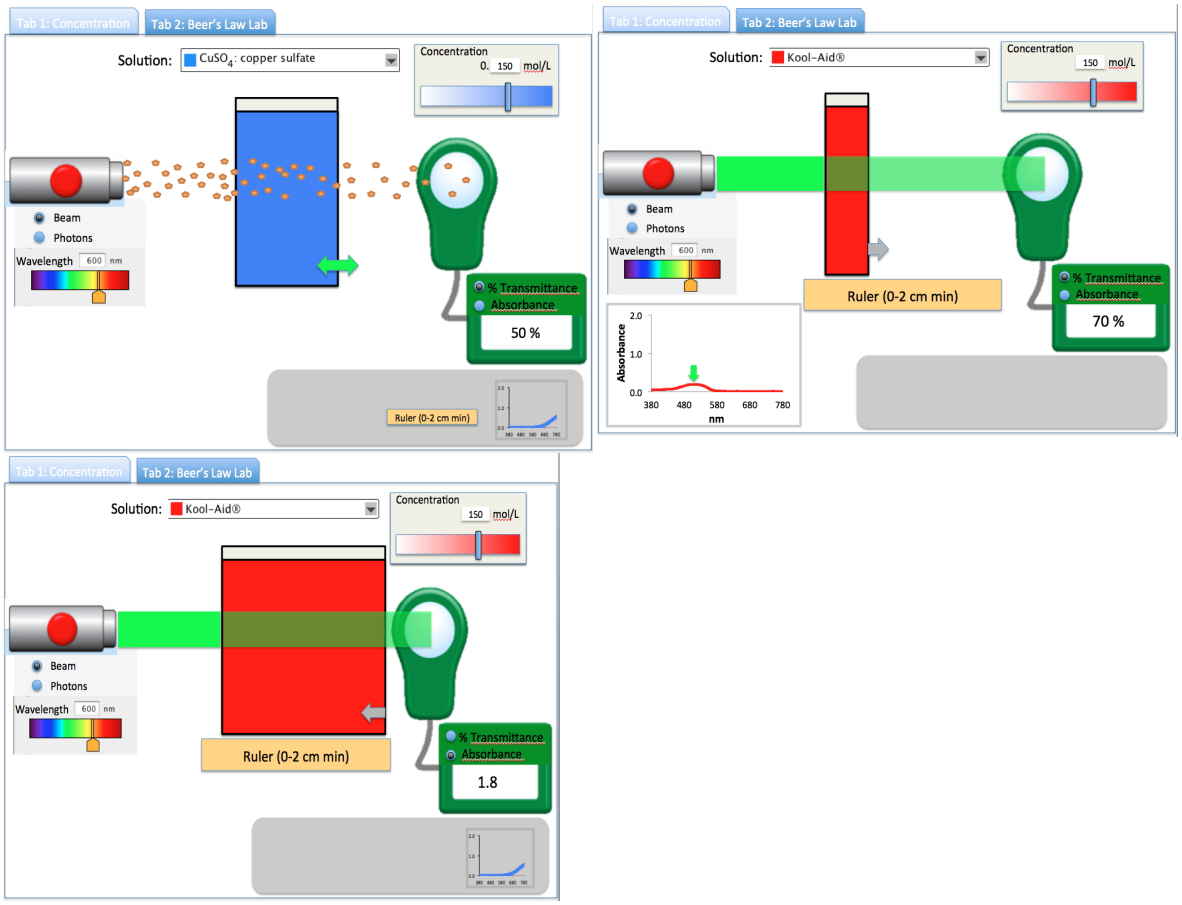
- Curve display option? (graph tool in mock up) KL: seems a bit like sim creep
- Ideas for a "custom" solution where "a" can be changed? What does this feature buy us and what difficulties does it introduce? "a" is wavelength dependent, so we can't vary "a" and wavelength at the same time.
- Ideas for "mystery" solutions with given a and unknown C.
- Should wavelength be variable?

- Should there be a Reset button for wavelength to max absorption?

Meeting Notes
Tab 1:
KL: black line for water helps. Could we put this outline on the faucet output for water (and drain too?)
RE: maxed out / conc too low notification.
TL: how have we done this in other sims?
EM: it makes sense that it reads 0.000 M. Let's leave as is and see if this is confusing for students.
JC / Team: sounds good.
EM: likes how intensity meter has a curvy connector.
KL: See if students firgure out to move it. If not, we can make it look more like a loose cord, more interactive.
KP: this would look nice, but isn't high priority.
KL: sometimes hash mark doesn't read value with the connectivity meter.
TL: I like the remove solvent button.
KP: look of meter: don't have a strong feeling about it. It reads where the plus sign is.
EM: could it start reading where the white part starts?
KP: no strong preference. It's not a gradient reader, so...
KL; we cna see how students use it in interviews.
KL: this is nearly ready for interviews. Could do this tab and Molarity sim.

Tab 2: Discussion of mock ups and design





Solution to different ranges in concentration is to put text entry box in scientific notation.
KP: may be a problem with sci notation eg. 400 x 10^-3 isn't scientific notation.
KP: maybe have the slider only allow you to go in increments of 10 so that you can get to the value you want just using the slider, and helps focus on significant differences.
EM: yes. Increments will mean something, students will notice the change when slider is moved. May help them think about what happens when it's 2 times as much, etc.
KP: if there is a readout with the slider, how would the readout look? Scientific notation still is tricky here. Maybe the decimal point (0.00005 eg) expansion is the way to go for the readout.
KP: should we have a non-quantitative version of this tab?
EM: for a non-quantitative version, which numbers would be hidden?
KP: you'd need different kinds fo readouts for A and %T like bar graphs...
EM: How would I play with this without numbers, without a ruler. Hm. Would this make me want to double and half things, or would it makes me want to try to figure out the relationships. I'm not sure.
TL: Bending light example is a nice example of how the light intensity changes visually.
EM: so you'll be able to see how the light changes in either mode, regardless of using the quantitative tools. KP seems to be suggesting having a non quantitative version.
KP: just an idea, I don't feel strongly either way.
TL: maybe this would be so that you don't have the tools for tne non-quantitative mode.
KP: tools are burried at start up in the tool box, so that helps.
KP: We can stick with quantitative for now and see how students interact with it.
Discussion of range issue:

EM: maybe we should use milli and micro.
KL: if they don't notice the scale change it probably won't impact what they get out of the sim.
KP: don't they need to know this if they do calculations?
EM: Yes
KL: it's all relative though.
EM: I vote for micro and mili symbols. Students need to be familiar with these and know hwo to read them.
TL: yes. This is an advanced sim. Needs to be a large enough font that they notice it.

On putting the meter inside the cuvette:

EM: I don't think that helps us in this sim.
TL: think that this will be weird when compared with Bending light (where there is no absorbance)
KP: thinks this is powerful to see more is absorbed as you move through soln.
EM: I think this is less clear than the idea of changing the pathlength by changing container size.
JC: for now, let's have it not allowed in the beaker, and see how this works.

On Absorbance curve

EM and KL: this gives away the point fo the sim. Don't include!
JC: OK, won't include and will see how students interpret this.
KL: so, when they choose solution, will it default to max absorption wavelength? Will this be the default?
KP: isn't it easy to find the max wavelength?
EM: this seems like a lot to do simultaneously. Pathlength and concentration relationships without knowing about wavelength max... is wavelength max equally important as these other things? It coudl be helpful for them to get to jump to where they will see the most signal for the beers law relationships.
KP: idea for intermediary tab there wvelength is fixed, one solute, explore just changing pathlength and concentration, not wavelength yet. This is my motivation for suggesting an intermediary tab where this is more constrained.
EM: intermediate tab sounds good, Not sure why only 1 solute is needed. Finding the max is important...
KL: wavelength seems to be the hicup.
KP: if you just constrained it to 1 and made a generic case, you could have 1 solute so students focus on concentration and pathlength.
EM: would this give the signal that you're trying to get to the last tab, when really both are equally important. If you constrain it too much it seems less advanced, like only a stepping stone.
KP: the other aspect for the middle one was to have a concentration slider and a slider for custom solution where "a" molar absorbtivity of solution can be varied. So students get the sense that this is the parameter of a chemical that changes what gets absorbed.
KL: this seems more advanced, even, and would be the last tab.
TL: could be set wavelengths for each solution...
KL: in chem labs, wavelength is set, you don't get to play around with it. Could just set this, and that all you need to know is that different solutions require different wavelengths of light.
KP: wavelength slider seems like a useful learning goal, but it's making this complicated for teaching beer's law.
EM: I think it's useful. I remember wondering as a student, this would be neat to include.
KP: if this is the only thing that's changing... Could you call the third/other tab "absorbance

spectra" Or, another option is to keep it in one tab but hide the wavelength slider.
JC: Manual wavelength will be a differnt option.
KL: a check box below the beam that says …
KL: "custom wavelength"
JC: Yes, and default will be the max wavelength for each solution.
KP: can see how this goes and play around with it based on interview feedback.
KP: So, shall we have a third tab for custom solutions?
RP: we should move forward with this and see.
KP: As it's set up right now, nowhere in this do students get to develop a definition of molar absorptivity. If they had it as a parameter to play with they could learn about it.
RP: it's not a prominent concept in gen chem.
KP: then, what are the main goals of beer's law?
KL: usually it's to find the concentration of an unknown.
KL; what would changing molar absorbtivity show? How would it show up in a 3rd tab?
KP: tell CM it;s a possibility that we'll make a 3rd tab with these options for a custom solution.
KP: how about unknown solutons?
JC: would be easy to make unknown soln concentrations (mystery soln) with unknown concentration and let students use to do the beer's law exercise of finding the unknown.
KL: let's think about that more. For now, let's see how engaging the sim is and what students do with it.

Discussion with CM on 2/3
Will change meter color in Tab 1 so that meters in T1 and T2 are different colors (to indicate different functions).
Ruler needs to measure up to 2 cm. No other specifications / needs. Can be "standard" PhET.
Lambda Max should not be given, see if students try to find it using variable wavelength control.
Discussed look of cuvette.
Combo box labeled solution.
Discussed label position for chemical forumla - on cuvette, or over cuvette. Will try over cuvette first.
Combine the solution controls combo box and concentration slider.
CM may start w/o tool box, and determine if we want to include it later.
CM will explore meter usability for cuvette constraints.
Water option in Tab 2 will say "none (pure water)" in the solute combo box.

02/03/12 - Chem Meeting Notes
Agenda for Chem Meeting on 2/3
Tab 2 Chemical formula: in combo box or on cuvette?
Should I collect log files for the features CM has already outfitted? Plan is yes.

KP: Meter could read question mark when over the cuvette.
Discussion of where to put formula name.
KP likes it on the cuvette. EM not sure it's necessary.
Will start with chem forumla on the drop down menu and see if the label is desired.
CM: This is all straightforward. The biggest issue will probably be the meter implementation and usability.

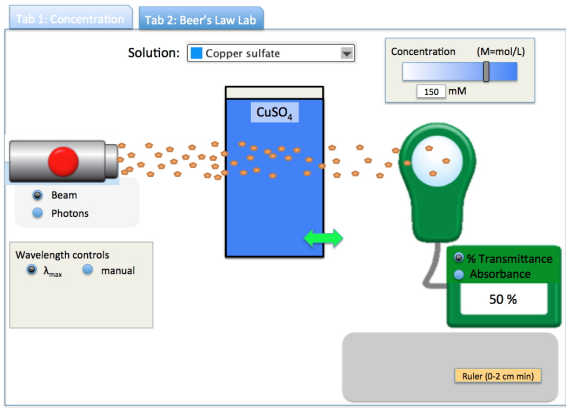
Other things:
- What will the beam look like going through the solution? (use absorbance data to model performance) Can %T be a guide for beam fading as it passes through soln?
- Decimal places in Abs and %T reading - See what kind of precision makes sense based on the significant figures (and precision available) from the other numerical inputs.

2/16 Chem Meeting Notes
Tab 1 looking good. Interviews show mixed engagement, but positive responses. Keep as is. (Get interview notes from EM)
Ideas for wavelength learning goal: hide it in teacher menu. Or, perhaps better is a 3rd tab that cues this learning goal (EM, CM, KP)
KP: intro tab could really focus on changing pathlength and concentration, without multiple chemicals. Then the next tab allows exploration of various chemicals (and wavelength?)
EM: rank the different learning objectives for this.
JC: pathlength and concentration more important than wavelength variation.
KL: if we take out wavelength variation, this tab really just about pathlength and concentration.
EM: agree with KL,
CM: maybe a tab just on absorbance?
KP: could hide variable wavelength.
Plan currently: remove wavelength slider / change options from the Beer's Law tab and think about ways to include in a third tab.
KP: what about the molar absorptivity idea to have a slider to understand what this mean?
KL: in another tab with wavelength change, maybe you wouldn't change concentration or pathlength, but maybe yes for molar absorptivity control. Could call this tab Advanced.
KP: Let's build this and see how it interviews with conc and pathlength variable, for the list of chemical solutions.

3/1/12 Chem Meeting Notes
Agenda:
Interviews on tabs 1&2 next week?
Implementation of variable wavelength.
Mtg notes:
Lightest color issues: Need to re-select min and max
Options: make lightest color lighter.
Try a 2 gradient scale with pink to white on lower end to test behavior.
Trouble with white as the lower bound is that adding blue water to white is confusing.
Send CM a new lower bound color for $KMnO_4$. (all solutions would be good)
CM will do a developer control to change color, will also do linear vs log gradient interpretation. (Just for Concentration tab).
Checkbox idea to make the wavelength variable slider more hidden / less discovered first.
CM will work on:
Photon view, wavelength slider feature, detector probe look in cuvette, detector function in cuvette, 3 color range for solutions in tab 1, and linear vs log color range.

3/7/12 Notes

Photon view is problematic to implement for numerous reasons (time delay of photons traveling across screen, resolution possible for the number of photons we can fit in the beam space, how photons react when other aspects of the sim are changed). Because photons address a secondary learning goal about molecules and light, we will remove it from this sim and focus on the macro view, and the learning goals we can address with variable wavelength.



4/26/12 - Chem Meeting Notes

Tab 1 Concentration Meter

Some students (3/5) had difficulty getting the meter into solution. Thoughts on design?
More inviting probe? Start meter in soln.
Change tickmarks to ¼ and ¾ (no labels) to encourage comparisons of half relationships. Or, just remove the ½ label so that there are 10 tick marks and a 1 L label only. Or, leave as is.
Ask Noah P for a more fun looking conc meter probe design, more handle on the circle.

Tab 2 Concentration Units

mM seems better than mmol/L. Since units are not as important for comparing concentrations in terms of half or twice as much, and not a big focus of the sim, it is OK that not all students understand mM units.

Variable Wavelength

A wavelength slider so students can see how absorbance is dependent on wavelength from real spectroscopy data, and so they can scan across various wavelengths to find lambda max. Currently this is in the Beer's Law tab and students are making sense of it reasonably well, but not entirely. Another difference in the implemented version is that lambda max is provided to students in the "fixed" wavelength option.
Interviews are showing that students do use this a lot and try to figure out the relationship, but they do not get distracted by it and led to unproductive play. Most students try variable wavelength to see what it does, and then set wavelength to fixed and change other variables to see what they do. Some students identified that fixes was the max absorbance wavelength. Since the sim resets to the max absorbance wavelength each time the solution selection is changed, students can't accidentally end up looking at non-absorbing wavelengths. We decided to keep the feature in Tab 2 as is.

Variable Molar Absorptivity / Custom Solution

Molar absorptivity is at the core of how we are showing Absorbance and Transmittance values in the sim, as well as how we are determining the allowed concentration ranges. I need to think about how we could include a slider on such a core value to make it variable, and what the implications would be. I don't see how to implement variable wavelength with variable molar absorptivity, currently.
For fixed concentration, light beam is what would change to indicate different molar absorptivity. Molar absorptivity could also be represented via a graph of intensity, but this seems like it opens up a lot of opportunity for misinterpretation.
Understanding molar absorptivity is not a primary learning goal for Beer's Law or in general chemistry. We will not include it as a variable in this sim.

Unknown Solutions
Could have a tab with unknowns. Could refer back to Beer's Law data, or could be different solutions with 2 or 3 data points provided for known solutions. The trouble with this idea is that it focuses the student on numerical answers and making graphs, which may or may not be what we want to include in the sim. One of our Beer's Law learning goals includes comparing graphs. Do we want to include a graph making tool in a third tab of the sim, or do we want to leave this up to the teacher to have students use pencil and paper, or a program like excel?
We agree that we don't want the sim to make graphs for students. The sim could provided a lab like scenario with stock solutions and an unknown in a game format, to try to get to the application side of Beer's Law, but the best parts of the sim are it's conceptual representations. For now, we will not yet build the game / collection of solutions tab with unknowns. This is a possible future tab, depending on how use goes, what users request, and whether we get any good ideas of how to implement.

Changes: Remove ½ L tick label on Tab 1 (optional). Revert changes to mM units (JB).
Ask NP for a more fun, grabbable handle for the concentration probe.
KP will ask JB for a code review.
Include new meter graphic.
Publish and Post-Mortem date after CM gets back.

05/10/12 - Meeting w/ CM
Notes

Online Resources

http://terpconnect.umd.edu/~toh/models/BeersLaw.html
Information about Beer's Law and deviations observed in laboratory instrumentation, as well as discussion of min/max concentrations affects on Absorbance, max absorbance values (above 2) etc. Good resource!

Colors in Triplet and Hex: http://web.njit.edu/~kevin/rgb.txt.html

A Beer's Law Tutorial, dealing mostly with absorbance and % Transmittance relationships.

http://teaching.shu.ac.uk/hwb/chemistry/tutorials/molspec/beers1.htm

These links have simulations that show the absorbance process (photos absorbed into the colored solution), and that can be used to calculate a calibration curve and measure an unknown. Definitely examine further before building Tab 3.
http://www.chm.davidson.edu/vce/spectrophotometry/EffectOfConcentration.html
http://www.chm.davidson.edu/vce/spectrophotometry/beerslaw.html
http://www.chm.davidson.edu/vce/spectrophotometry/UnknownSolution.html

Spectroscopy data collected by Jeffrey Bodwin at Minnesota State
"I felt like doing some productive procrastination yesterday, so I ran most of the UV-Vis spectra you were looking for. We don't have AuCl3 on the shelf, and the CoCl2 solution was just a tiny bit cloudy, but I ran the rest of these samples. Data is at http://www.drbodwin.com/research/phetuvvis01.xlsx and I took a picture of the samples http://www.drbodwin.com/research/IMG_0469.JPG . Oooo, pretty...

I calculated out extinction coefficients in each data set. A couple notes...
1. I recorded 190nm-1100nm, the data around 200nm might not be the most rock-solid, but it's probably OK.
2. After I got all the samples ready, I found out that we have a gremlin in our instrument; there's something funny happening between around 590nm and 600nm. I mathematically smoothed the data in this range. For most of the specta, it's not a problem, but it takes a bite out of the lovely multi-line peak in KMnO4. Arg, we need to have a service call to fix that.
Any questions about them, let me know."

From http://23b-cthruchemistry.blogspot.com/2007/02/colours.html
The Rainbow Colours

Red --- Adding Universal indicator to Hydrochloric Acid (HCl). (n/a)
Orange --- Potassium Dichromate (K2CR2O7). (very toxic)
Yellow --- Iron(II) Chloride (FeCl2. (good option)
Green --- Adding distilled water to Universal indicator. (n/a)
Blue --- Copper(II) Sulphate (CuSO4. (good option)
Indigo --- Concentrated Potassium Permanganate (KMnO4).
Violet --- Adding distilled water to Potassium Permanganate (KMnO4).

FeSO4

Nickel (II) Nitrate:

Interview and Classroom Feedback

Questions for interviews:
Tab 1
Do students try to compare relative solubilities of different solutions?
Do students want a periodic table when they use the different chemical solutions?
Tab 2
Do students make more sense of %T or A? Which detector read-out do they use more in the

sim?

Student Interview Notes - Tab 1

Student 1DD
Interview 02-06-2012
1. Beer's Law Lab Tab 1 v.0.00.08
2. Molarity v.0.00.18
3. Gene Expression Basics 0.00.13

Background info - 1DD
Ecology and Evolutionary Biology major.
Freshman at CU, took IB in high school.
Currently taking: Intro Chem 1021, Ecosystem ecology.
Previous college science: Principles of Ecology, Astronomy, Sustainable Bio Design
High school science: IB Biology 1 and 2, Honors Bio, Earth Science
(no Chem, no Physics)
Previous Sim use: none.

Beer's Law Tab 1 v.0.00.08 - **1DD**
Start 3:41 (20 sec into camtasia)
First clicked Concentration meter probe, but it didn't move .
Tried second tab after 2 min.
Notices you can't mix chemicals.
Didn't figure out shaker at first. Got it 4 min into play.
Used dropper, menu, faucet, drain, evaporation, and reset (everything).
Tried many but not all solutes.
Described saturated as "too much Kool-Aid"
Explains drain takes away all liquid chemicals but not solid chemicals.
Thinks maybe the chemicals react with water.
Commented that he thought it would be useful to use the concentration meter if he could figure out how to get it to work. He used it when the liquid level was high enough to reach probe, commented later that he "doesn't know where the concentration number went"
Tried the help menu, didn't find it helpful for activating the concentration meter.
Is curious t see how concentration changes
Finished after 7 min (3:47) (7 min into camtasia)
Thought shaker was confusing, recommended a button on the shaker like the dropper.
Went to tab 2 pretty early, I had to say it wasn't finished, but T1 was.
Later in the "what do you think about" part, he did find how to move the concentration meter on his own. Didn't really use it to explore different chemicals and compare them, but did use it to see what does and doesn't change concentration.
Talked about concentration in terms of a ratio.
Explains that draining doesn't change concentration, but evaporation gets rid of water alone.
Total time on BLLt1 = 13 min. (closed sim 13 min into camtasia)

Summary
Clicked on everything, used many solutes, faucet, drain, and evaporation.

Went to 2nd Tab after 2 min.
Figured out the shaker after 3 min.
Explored around, tried all features but wasn't vocalizing questions; seemed more interested in figuring out how to operate the sim than what he could learn.
Finished with after 7 min.
Didn't figure out how to move concentration meter probe until Q&A after play.
Noticed the difference between evaporation and drain.
Total time with sim (including my questions) = 13 min.

Student 2AP
Interview 02-06-2012
1. Molarity v.0.00.18
2. Beer's Law Lab Tab 1 v.0.00.08
3. Gene Expression Basics v.0.00.13

Background info -2AP
Sophomore Physics major bur Freshman at CU (has science credits from HS)
Currently taking: Gen Chem 1, Experimental Modern Physics, various math classes.
Previous college science: Took Intro Chem at community college during HS.
High school science: AP Bio, 3 years HS physics, including Mechanical and E&M. AP Environmental Science.
Sims: Yes, used lots in physics. CCK, Photoelectric Effect, John Travoltage, a trajectory / launching sim, and The Ramp are ones she remembers using.

Beer's Law Tab 1 v.0.00.08 **- 2AP**
(Used Molarity First)
Start 5:07 (13:00 camtasia)
Says she doesn't know anything about this should be interesting.
First evaporates all water.
Initial impression is that it's annoying to reset each time after using the drain. Thinks the drain and evaporation goes too fast. Later reconsiders and says it's OK.
Moves the concentration meter.
Selects dropper. Adds Kool-Aid.
Scans the solution with the probe for concentration in various locations, sees that concentration is the same in each area.
Shakes in some solid. Notices conc doesn't change within soln in different places.
Notices that evaporation makes it more concentrated.
Thinks instructions on the shaker might be good, but she did get it with ease.
Uses faucet to fill beaker at 5:09 (2 min into play). Comments that it's like a real faucet. Likes it's interface/speed better now than before.
Seems to be focusing more in interface than on learning.
Says the evap knob is "jumpy".
Keeps scanning solution concentration with probe for different solutions. She is trying to find an exception or something with different behavior.
Says she wants to see something new.

Spent 5 min on Tab 1.
5:12 Opened the 2nd tab, I told her it's not finished, went back to first tab.
Says that the drain has concentration stay the same, adding water changes it, and adding solute changes it.
Comments that solute and solution seem the same because they both make the concentration increase.
Done at 5:13 (19:00 camtasia). Played for 6 min with BLL sim.
Q&A
Likes the colors, but that's all.
Likes Molarity better. Wants different sliders in Beer's so that she can use the slider and watch what's happening more easily.
Doesn't think solid and solution do much different.
Wanted some irregularly concentrated solutions.
Recommends a "shake" cue for the shaker.
Says she learned that you can make dilutions and concentrated solutions by adding and removing water
Done with sim at 5:18 (24:00 camtasia)
Total time with Beer's: 11 min.

Summary

Commented that faucets operate like "in real life"
Noticed concentration relationship to adding water, evaporating, draining.
Looked for and wanted to see different concentrations in different areas of a beaker of soln.
Thought it wasn't very interesting that for all solns, concentration was the same throughout the beaker.
Tried Tab 2 after 5 min.
Played for 6 min. with Tab 1.
Liked Molarity better than BLL.

Student 3ML - KL Interview

Beer's Law Lab
02/07/12 v 0.00.08

Did *Molecule Shapes* first
Shakes in solid, adds water, uses all obvious controls
Selects different solute, saturates
Evaporates all water, says you are still left with it
Fills to top with solution, says you can't overfill it
Notices concentration readout, but did not move probe
Shakes in solid, says it gets darker with more concentration, but it also has a max, so you know how soluble it is
Clicks on 2nd tab, tell her it's not ready yet
Selects different solute, adds water to get it up to probe

Shakes in solid until saturates, compares to solution form
Removes all "water" with faucet and fills with solution up to probe
Says if add water, it (concentration) goes down
Says $CoCl_2$ does not evaporate
Selects different solution, evaporates all water, says it all becomes solid; compares solid & solution evaporation
Selects different solid ($NiCl_2$), says you have to add a lot for it to become "full"
Thinks liquid solution is less concentrated than solid
Removes solute, adds water "to the green line," compares solid & solution forms; says maybe solution is more concentrated than solid
Tries to see how dark she can make kool-aid with solid, then solution; says it takes less water with solution than solid
Resets, likes that you can do things you can't do in lab
Moves probe (idly), puts back in place, wants to see what happens if heat up
Likes that you can control amount, says most programs use fixed amount
Done after 12 mins
KL: what do you think about concentration probe?
Says not sure if measures concentration at that point, or if that is when it starts measuring
Says can tell with less water, concentration is higher, more water = lower
Thinks it (probe) includes "what's down here" because it jumped to a value
Tell her you can move the probe
Moves probe, says it starts measuring at the bottom; also moves probe out of solution
Really *likes* this sim

Student 4MB
Interview 02-08-2012
1. Beer's Law Lab Tab 1 v.0.00.08
2. Molarity v.0.0018
3. Gene Expression Basics v.0.00.14

Background info - 4MB
Freshman MCDB and Spanish major.
College science classes: Gen Chem 1, Principles of Genetics, E.Bio
High school /other science classes: Physical Science, Bio, Chem, Physics
Sim use: used sims in E-Bio.

Beer's Law Lab v. 0.00.08 **- 4MB**
Start 3:32
First action is to shake the shaker and evaporate.
Seems to be trying to figure out Beer's Law. Is very fixated on the title of the sim.
Says it's hard to know how much solid you'll drop with the shaker.
Easy to get as much solution as you want / the right amount of liquid.
Moves meter all around.
Reads meter on dropper and on shaker (fix this —shaker shouldn't read for a solid)

(Note: CM fixed, shaker doesn't read conc now.)
Looks at whether different solutions have the same concentration.
Says concentration is only the liquid. Can't evaporate solid.
Says that the point of Kool-Aid is more simple, it's just water and sugar.
Notices you can mix solutions with solids.
Says meter measures concentration with solid and solution [together], but with only a solid [ppt], it doesn't measure it.
Says maybe it's just measuring solution, not the solid.
Wonders out loud how you could test a solution not on the list.
Measures the concentration of solid mixed with water.
Tries mixing different chemicals and says that you can't.
Removes meter from solution a lot, rarely leaves it in for an action.
Tries solution + solid, then evap.
Says that concentration doesn't count water. Says it's a "solute concentration" meter.
Asks "Why do solute solutions start at different concentrations?"
Says the evaporation rate is the same for all.
Solid automatically mixes with water.
Fills beakers with crystals, fills beaker with solution. Saturation goes away. Says she's not sure on why this is. Says maybe it depends on how much solid you put in.
3:52 Says maybe Koo-Aid is just different.
Wishes it didn't reset to water each time soln is changed.
She repeatedly starts with an empty beaker.
Says that the soln won't dissolve all solid if there aren't enough liters.
Realizes that if you evaporate the solution, "the particles come back".
Thinks it's good to show the color change with dilution with water.
Thinks that $KMnO_4$ color doesn't really look diluted when you add water. Says the other solutions do look dilute when water is added.
Wonders why we used Kool-Aid instead of something else, like coffee or lemonade.
Says you can only use remove solid/solute when it's in the solution.
Says that the concentration meter reads how much you've put in, since you can't read it on the shaker or dropper dispensers.
Comments that you can't mix the solids either.
Done at 3:58, spent 26 min playing with BLL.
Q&A
Point of the sim? "Not how solutes react! Maybe it's how concentration changes with solids vs. solutions.
What did you feel you learned? "Solids can't evaporate! – just kidding. That different substances have different concentration even with the same volume.
How can you change concentration? "Add liquid with the control, add solid…" mentions precision, how much it changes.
Difference between evaporation and the "pipe" (drain)? Tries the two. Says that "evaporation is the opposite of diluting" and that "the pipe gets rid of everything."
Why do you think there are different solutions? "Different molar masses? That might affect concentration. You can try different ones."

Likes: Well made, easy to figure out, likes the dropper, easy to control.
Dislikes: that you couldn't mix the solutions.
Confusing: Why start with water every time?
Recommendations: Not start with water every time. No other recommendations.
Done with sim (including Q & A) at 4:06. Total time = 34 min.

Summary

Student was initially very concerned about not knowing what Beer's Law was (based on sim title); relaxed and explored everything in detail after I told her Tab 1 wasn't about Beer's Law. Used all tools in the sim, wondered about how you could measure a solution that wasn't on the list. Tried mixing chemicals. Wondered why we used Kool-Aid instead of coffee or lemonade. Determined that the concentration meter only measured solutions, not solids; noticed that color change indicates concentration change; learned that different solutions have different concentrations even with the same volume.

Student 5HL

Interview 02-08-2012

1. Beer's Law Lab Tab 1 v.0.00.08
2. Molarity v.0.0018
3. Gene Expression Basics v.0.00.14

Background info – 5HL

Freshman psychology major, but might change major.
College science classes: Bio 1, Bio 2 (current), Intro Chem 1021 (current)
High school / other science classes: Physics, Chem, Bio, Physical Science
Prior PhET or sim use: Doesn't think she's used PhET, but she used a sim in HS chem about atoms (her description sounds just like BAA)

Beer's Law Lab v. 0.00.08 **– 5HL**

Start 4:48
First thing student does after opening sim is ask to have "something explaining what is going on, because it's kind of confusing." Student turns and looks at me for explanation. I say I can't explain it to her, but that she can explore everything, can take as long as she wants to, and that there's no right or wrong way of doing it.
First click = dropper radio button.
Adds soln., then adds water.
After 15-20 seconds said she "is good now" meaning she understands the sim.
I ask "what do you now understand?"
She says she now understands that she's making a solution and are doing evaporation condensation, going from different phases.
Asks for confirmation, they reminds herself that I cant' say anything.
I give general reassurances that she's doing great, has made a great start.
Switches to NiCl2 shaker.
Can't get shaker or concentration meter to work by clicking.
Adds soln with dropper.
Says it's about how different things are concentrated, and how concentrated they are.

Clicks on Tab 2 after 2 min. I explain it's not done, but she's welcome to explore if she wants to. I say that the first tab is complete, she switches back to it.
Asks if shaker is supposed to click. I say she can keep trying different things.
Tries shaker and dropper again.
Says she thinks it's about the larger effects on what they have.
Isn't sure what else she's supposed to be doing.
I say anything she wants, do whatever she feels like.
4:52 Gets conc meter probe to move, moves it all over. Takes a reading in soln.
Looks at how conc changes for different solutions.
Gets shaker to work by dragging. Says it's cool to read conc and use shaker.
Says "obviously adding solid makes it more concentrated."
"Evaporation makes it more concentrated as well. That would make sense."
Adds water from faucet.
Says different solutes "show different …I think it's 'combustions', or different make- ups and how concentrated they are." [I think she means compositions].
Says that when it evaporates is gains concentration, but when you use "this" [points to drain] it doesn't gain or lose concentration."
Makes a saturated soln. Says "there's too much."
Adds water to unsaturated.
"I'm not 100%, but it's showing when… it's still… when it's obviously it's not saturated… when it's equal…"
4:54 Says you have to use a lot more solution to get the same number of concentration than if you were to use the solid.
Compares solid to solution and says that yes, with solid it "goes up way faster."
Comments that you can't mix solutes.
Done with play at 4:55, explored for 7 minutes (7:30 in camtasia file)
Q&A
Q: What did you think was the point of the sim?
A: To see concentration, when there's less, it becomes more solid and the molecules come closer together. And then when it gets wider it becomes more like a gas, and in the middle it's more like a liquid.
Q: What do you think you learned?
A: That having a solid has more of an effect [on concentration] than the solution does.
Q: What are all the ways you can change concentration?
A: Evaporation, adding solid or solution, add water (hesitates, tries it to confirm, then says yes it does), but not by getting rid of water [indicates the drain] and by changing to different … what, combustions? Compounds? Yeah.
Q:Is there a difference between this [point to drain] and evaporation?
A: yes, evaporation makes concentration more, whereas when you lose water it doesn't do anything. (Tries it to confirm)
Q: What did you personally think was the point of having different compounds?
A: To see which oens were more… like, this one makes it saturated faster. To see which ones were more strong, to make a bigger difference using the same amount. So having more is probably going to make a bigger effect.

Likes: Different colors. Says she thinks the concentration meter probe is clear but says it was confusing at first. Liked how clear the effect of evaporation was. Liked different examples, and being able to use both solid and solution.
Dislikes: That is was a little confusing. Says the shaker was confusing.
Confusing: Conc meter at first, shaker operation.
Recommendations: Instructions, how to move things back and forth, tips telling you what to do to make it more clear how to use the sim, something explaining what you can do.
Done with Q&A at 5:00. Total time with sim was 12 min.
Note: During Molarity she commented that "we haven't done a lot of this stuff yet " [in class].
After using Molarity she said that Beer's Law tab 1 "would be better if I understood it."

Summary

Student wanted directions at the start and asked me for an explanation.
Found all controls through exploration.
Described what was happening in the sim in comparisons to solid, liquid, gas, and condensation during play.
Said that adding solid had a greater effect on concentration than adding solution.
Described saturation by saying "there's too much"
Described the function of the drain as making the solution "lose water".
When asked she effectively determined all the ways to change concentration and that drain has no effect on concentration.
Thought the point of the sim was to see concentration and compare solutions.
7 min play, 12 min total.

Student Interview Notes - Tab 1 & 2

Student 1RP
Interview 03-20-2012, 10am
Beer's Law Lab v.1.00.01

Background info – 1RP

Freshman MCDB major
College science classes: taking Gen Chem 1 now, Genetics. Took MCDB 1 in fall.
Highschool / other science classes: biology, physical science, chemistry
Prior PhET or sim use: Maybe. Doesn't remember ever using PhET. Dad is a chemist and he has played with 3D models. Says visualization software also used in Gen Chem class sometimes.

Interview Notes – 1RP
(note: have not reviewed Camtasia file; want to re-listen for some discussion around 10:37 am)

First year student, in Gen Chem 1.
Played with the sim for 22 minutes.
Start 10:03 (my watch)
Tab 1:

Shook in salt first.
Commented that they just covered molar concentrations in class.
Tried nearly all the solutes, going down the list during play.
Clicked concentration meter repeatedly (0:45), used other controls, clicked it again several times (1:25). Said “I’m not sure how to use this thing” at about 1:40, clicking on it again. Used other controls. Tried clicking it again at 2:05, 2:25, 2:30.
Clicked on Beer’s Law tab, looked at it. Clicked back to Tab 1 and clicked on concentration meter at 2:40. Selects solute, shakes in, evaporates. Tried concentration meter again at 3:10, drags it and says “Oh, OK.”
Commented that evaporation makes it more concentrated, drain does not.
Says that the saturation is different for each solution and named examples using solutions and molarities from the sim.
Used evaporation to saturate faster than shaking in solute with $NiCl_2$, to compare saturation concentration; liked the speed of the evaporation.
Used all tools in Tab 1.
Wanted a more precise way to enter in solution volume.
Tab 2:
Moved the detector into the cuvette solution first.
Then turned on light beam.
Changed concentration.
Looked carefully at Absorbance values while changing pathlength.
Compared variable wavelength to %T and says they didn’t learn about that in class.
Measured pathlength with ruler, commented “that’s why it’s there”. (referring to the ruler)
Changed pathlength a lot and looked at effects on light beam, %T, A values.
Wasn’t sure why wavelength changed for each solution. Thought it might have to do with different elements.
Said the sim is useful, would make a good prelab to help students understand the lab he just did in Gem Chem.
Wants an introduction about light and solutions to help understand wavelength control.
Noticed that light gets dimmer with increasing concentration. Says this is helpful.
First impression of tab was that it would be good to have a fixed detector in the beam, then changed his mind and said it was nice to move the detector out of the way to see the changes in the light beam.
Thinks the sim is more efficient and lets you do stuff you that would be hard to do in lab.
Flipped back and forth between tabs several times.
Wanted fixed wavelength setting to give you the value in nm.
Used all controls, looked at each solution.
Said the sim would be helpful even after lab as a review with follow up questions.
Finished playing after 22 minutes. (10:25 by my watch)
Answers to questions:
Q: What did you learn or what could someone learn from the sim?
A: As Transmittance goes up, Absorbance goes down. Could help someone understand this. For the first tab, could learn that evaporation makes s solution more saturated, solution is thicker. The faucet dilutes. It shows the saturation point.

Q: What are all the ways you can change concentration?
A: Add water decreases concentration; add solute increases concentration; add solution… I think solution is solute and water. Dumping it out (drain) doesn't change concentration. Using the solution increases concentration to a certain point, but I'm not sure.
Tries NiCl2 solution in empty beaker and says "Oh, it's exactly 5"
Q: How do you think the tabs are related?
A: They both show how concentrated this is. Light vs. solution (10:37)
Q: what do you think is the point of having different solutions (your opinion)?
A: You can test saturation level. I think they're different. The liquid can't make any bonds when it's saturated (Isn't totally sure about this)
Q: What do you think affects Absorbance and Transmittance:
A: They work similarly. The concentration of solute makes Transmittance decrease because light is blocked. Pathlength. It could be size of concentration of each solute that determines how much it absorbs.
Q: What do you think about the "variable" control? (wavelength)
A: Not sure. (student notices trends, says he thinks reading about it would help.) Maybe it corresponds with different solutions. (Notices that each have a different wavelength.) Says he thinks this wavelength is probably either most or least for absorption.
Q: If you had to pick one (most or least), which would you say?
A: (Tests some examples with the sim and says the fixed wavelength absorbs most for corresponding solutions. Used flipping back and forth between fixed and variable to reset for the wavelength.
Likes/Favorite part:
Beer's Law Tab. Says it helped him understand the lab a lot. It was more helpful than the Concentration Tab. Liked that is shows both %T and A, liked Concentration control.
Dislikes:
Water volume control in the Concentration tab, wanted a number entry box to type in a value in liters. Says maybe instructions would be good for using the concentration meter.
Confusing:
Concentration meter control (how to use it). Wasn't sure about the ruler at first, but then got it. Says the meter cord in Tab 1 helped him know how to use it in Tab 2.
Recommendations:
More control over water, and instructions. But, says it doesn't need too much instructions.
End of interview: 10:47
Total time: 44 minutes.

Student 2SC
Interview 03-20-2012, 2pm
Beer's Law Lab v.1.00.01

Background info – 2SC
Sophomore I-Phy (integrated Physiology?) and Psychology major
College science classes: taking Gen Chem 1 now, took Intro Chem last semester, Gen Bio 1 and 2, Gen Astronomy, Social Psychology, Cognitive Psychology.

Highschool / other science classes: AP Psychology, biology, physics
Prior PhET or sim use: Used sims in Intro Chem last semester. Thinks is was something about pressure? Releasing pressure maybe was shown in class (isn't sure), also remembers different solvents, solutions, and sugar (did sugar and salt solutions lab study Fall 2011) She tries really hard to remember, so I tell her it's OK that she can't remember exactly.

Interview Notes – 2SC
First year student, in Gen Chem 1.
Played with the sim for 43 minutes.
Start: 2:01 pm
Tab 1:
Shakes in drink mix first, then adds water.
Says she's not sure what she's supposed to be doing.
Lets water out (the drain), says concentration stays the same.
Uses concentration probe, sees concentration change and stay the same for different actions.
Says adding drink mix is more moles per liter.
Says Evaporating increases concentration.
Tries dropper, says it's liquid of the same thing.
Tab 2:
Selects $KMnO_4$ solution. Changes pathlength. Turns on light.
Puts the detector in solution.
Says %T changes when you take the probe out of the cuvette. (may not have used those words)
Tests how much is absorbed. Keeps probe in cuvette, then takes it out.
Uses wavelength control. Say it transmits more with red light than with blue.
Not sure why it's different (transmittance) in solution and not in solution (the probe).
Says they just learned about this in class.
Says %A is how much a solution absorbs, %T is how much light transmits.
Notices %T decreases as she moves the probe back (to the right) through the solution.
Looks at Absorbance. Says "I know how to calculate absorbance, but I don't know what those numbers mean."
Says smaller transmits more light, bigger transmits less (cuvette size / pathlength)
Says a longer pathway means more chance for light to scatter.
Tries $Co(NO_3)_2$ and sees the mM units. Isn't sure what that means.
Says different wavelengths transmit different amounts.
Places the ruler under the beam to measure, then moves it to right below the cuvette.
Says that 2 cm transmits less than 1 cm, but absorbance is higher.
"I know blue or purple is the shortest wavelength. I guess that's why A gets higher? But maybe that's just for cobalt nitrate.."
Tries K_2CrO_4. Notices that A increases around blue/purple, decreases around red.
Says it matters what the wavelength is , and how concentrated.
Notices that absorbance for $CoCl_2$ is "really high compared to the others."
(2:10) Says " there are a lot of factors for absorbance and transmittance."
Names the factors: Light, width or pathlength, solution, wavelength, concentration.

Returns to Concentration Tab and observes:
To make more concentrated, evaporate.
To make less concentrated, add water.
If you release solution (drain) it stays the same.
Concentration is the same throughout the solution.
When you add more [solute], concentration increases.
Concentration is in Molarity. So if I want to make 3 M, I need to add more water. If I want 6 M, Ill have to evaporate. (tries it). Saturated! Saturated means…
(thinks about it) I wonder why it says saturated. I guess it's as concentrated as it's going to be. Yeah.
So no matter how much drink mix I put in, it will be 5.90 (gives the number from concentration meter).
(2:13) Selects $KMnO_4$ again. Shakes in solid.
"Once it's saturated, the solute won't dissolve any more. Same concentration no matter how much I put in, which I didn't know. Potassium permanganate has a much lower saturation than drink mix."
Changes to $CuSO_4$, shakes in solid.
"I can add as much solid as I want and solution level won't go up. So if I want to get rid of that solution, I have to empty some out and add water, or remove solute, or reset all."
Adds with the dropper. Then tries $NiCl_2$.
Notices that the beaker is full and says "so I have to empty some out."
"Nickel chloride has a higher concentration than the last one. The solution makes volume increase, but the solid doesn't do anything to volume."
"Nickel chloride is saturated at 5.210. Maybe it increases as you go up the list. The solid is fun to use."
Tries some more examples.
"I guess M doesn't increase as you go up the list. $K_2Cr_2O_7$ has a low saturated point. I wonder why you can't get a solution more concentrated. Maybe there's not enough water molecules.
I won't know how many of these things is a mole (I think she's referring to the particles), but M is moles per liter, so if I decrease the liters, molarity should increase. So I guess I don't understand this term (saturation)."
Explores saturation for different solutes.
Doesn't know where the number comes from (saturation limits).
"Does excess solute not bond with anything? Once I put in more water it goes away."
Uses drain to remove, then gets rid of saturation.
"Water dissolves solute. If there's not enough of it you can't dissolve unlimited amounts."
Thinks about what would happen if she had a larger container. Wonders if the saturated concentration would be the same. Then says that she thinks it would. Says "I never thought of it this way before."
(2:21) Selects $Co(NO_3)_2$
Says "these are all polyatomic ions mixes with a transition metal, or a metal, or an alkali metal, which is interesting because drink mix can have…
(finds saturation concentration for Drink Mix) … 5.960. I guess there's not enough water to dissolve all the sugar."

Realizes that she can't add liquid to a full beaker, switches to solid.
Maxes out the moles of drink mix (no more solid comes out), doesn't know why this happened.
Evaporates and still can't add more solid.
"I geuss it's completely saturated. It gets darker as it's more concentrated, then really dark, then saturated."
"Each solute has different maximum molarities. I thought you could have any amount of moles per liter; no one told me there was a set limit. I feel that's important."
(2:26) "If I wanted the same M, I'd add different moles per liter. In class yesterday we discussed how to get 0.4 M to 0.6 M with liters. You couldn't make the same M, but you could make the same moles."
Beer's Law Tab:
"We did this last week in lab with a spectrophotometer."
Looks at the probe and says, "I guess this is a detector of a spectrophotometer."
"We only used fixed wavelength. We measured %T. 2-log%T was A. But this sim would have helped. There was a question on the post lab about doubling the size and the effect on T or A. Many people didn't understand. I guessed that for 2 times the size, T would decrease. (uses sim) It seems to decrease a lot."
Says that pathlength should be consistent for an experiment.
Says the lab assignment asked why looking at transmittance is easier.
"A is just a number. I don't know the units. I feel like A is what is not transmitted."
"If we would have tried different wavelengths, we would see shorter wavelengths absorb more than longer wavelengths, especially for this solution"
"Purple is 3:80, 780… But some [solutions] don't follow that rule. Potassium permanganate has high absorbance at purple, then goes down, then back up, then decreases at red."
Looks at %T for $KMnO_4$ and varies the wavelength.
"Blue transmits most, solution isn't absorbing much. It goes down at yellow, that's around fixed. Transmittance goes down."
"I feel like blue light scatters most so it should transmit least. It should be…"
"Maybe it has to do with the color of potassium permanganate. It transmits a lot of red. This makes sense because in sunsets, blue light scatters and the red light is leftover as the sun goes down."
(2:35) Tries yellow solution. "I don't know if color has to do with solution, but I'm guessing they do. We used blue drink mix in lab"
Explores wavelength variation fo different solutions.
"Red transmits 98%, isn't absorbed by K_2CrO_4. Purple barely transmits any. Yellow transmits a lot of light, maybe because it's the same color. Red transmits too. Blue doesn't, neither does purple. So wavelength is fixed a purple. Strange. (looking at pathlength) I wonder why it only goes to 2 cm. Maybe it wouldn't transmit light if it was more. When it's closer to 0, it gets higher and higher" (comparing pathlength of cuvette to the amount of light transmitted.)
(2:38) Looks at the solution list, sompares K_2CrO_4 and K_2CrO_7. Says that they have the same color for the fixed wavelength, but one has it brighter.
"I don't know if it's complementary colors. It might be."
Looks at $CuSO_4$ and says "I don't know about blue and brown."
Says again that they used drink mix in lab.

“So, dichromate transmits a lot more, it should absorb less. I know if Transmittance is more, Absorbance is less, but I don’t understand the units on that number.”
“As concentration goes down, Absorbance goes down. As Concentration goes up, Absorbance goes down and Transmittance goes down a lot.”
“There are different factors for Beer’s Law. Type of solution, concentration, mM, wavelength fixed or variable, pathlength/container width, where the detector is located.”
“Transmittance increases more inside because light hasn’t passed all the way through, so pathlength would be shorter.”
(2:41) Puts meter at the edge of the container, increases path, compares %T.
Says “1 cm equals 1.95 A, 2 cm is almost 4, so it doubled. But T is o.2 and… T doesn’t double.”
(2:44) Done. Played with sim for 43 minutes.
Questions
Q: What did you learn or what do you think someone could learn from this sim?
A: Learned about pathlength, had had a hypothesis from lab. Could also learn why there are different wavelengths for each solution, and how detector is different inside and outside the container.
Concentration as well. That was what the lab got at. This is faster and more clear.
For the first tab (question about what you could learn)
There was a question about how to a low molarity higher. Sim would help show evaporation. That concentration doesn’t change when you pour some out. (did this in lab, partner thought it would affect C).
How different solutes have different max molarities. Maybe how solutes were chosen. They all dissolve in water. And the solute doesn’t add volume.
Q: do you think that’s the case?
A: I think that after a while it should increase volume, because you are increasing the mass.
Wants Molarity for the Beer’s Law Tab, doesn’t know what mM is, and would like to see mol/L.
Q: What did you think was the purpose of different solutions?
A: Show max molarity, show adding different amounts and transmitting different levels with different concentrations (in tab 2).
Likes: Solid shaker. Likes control of sliders. Says you have less control with the shaker.
Says a label on the detector would be good in T2. And to put more familiar units for Concentration.
Done with interview at 2:54 pm.

Student 3SL
Interview 03-21-2012, 3pm
Beer’s Law Lab v.1.00.01

Background info – 3SL
Freshman engineering major
College science classes: Physics, Intro Chem. Took “College Chem” through UC Denver while in high school and got college and HS credit.
Highschool / other science classes: Integrated science, honors chem, college bio, human

anatomy, plus “college chem” mentioned above.
Prior PhET or sim use: Yes, he thinks his intro chem prof uses them for class. (confirms when opens sim).

Interview Notes – 3SL
Intro chemistry student.
Played with the sim for 40 minutes.
Start at 3:05 pm
Starts by describing what he sees and what he thinks it does.
Clicks on dropper, adds solution. Says you can add water to change molarity, use the concentration meter, drain, and change solute.
Says it could be used to model molarity and mixing chemicals.
Tries different solutes.
Clicks concentration meter a few times and can’t get it to work. (gets it later in play)
Goes to Beer’s Tab after 2 minutes.
First think he clicked was the “variable” radio button.
Then solute menu, NiCl2.
Mouses back and forth between wavelength control and solution controls before clicking fixed, the variable, and then changing concentration to most concentrated. Turns on beam. Says it shows the density of thickness of the solution , that it makes sense. That different colors go through differently.
Confirms that there are just 2 tabs in the sim that there isn’t more.
Goes back to Tab 1 and starts explaining how the two tabs are related.
Switches to the manual mouse, get the concentration meter into solution. Drains beaker, fills with CuSO4.
Says it tell you how concentration changes.
Resets, shakes in Drink Mix, drains all, puts in solution dropper, says this is more efficient (than shaker).
Notices that “it doesn’t seem like you can mix [solutions], which would be fun.”
Goes to Beer’s Law Tab.
Puts the detector into the solution and changes the wavelength.
Moves the meter to varying distances outside of the cuvette and notices %T doesn’t change.
Says it seems to take into account that light is transmitted no matter what when it’s not going through solution.
“Keeping wavelength constant I can’t decide… certain solutions ability to pass light…”
He tries keeping wavelength the same and compares different solutions with the same wavelength (resetting it to the desired number of nm each time).
Says he is comparing the reflection/transparency of light.
Says that making it shorter / smaller allows less or more (referring to pathlength).
Concentration Tab
“You can evaporate out.”
Adds nickel chloride solid, adds water, adds solution.
Evaporates all and looks at solid. Looks at the saturated solution.
“When you mis solution with solid, it doesn’t dissolve unless you mix in water, which changes

molarity."
(3:15) Says that with a little solution and solid at the bottom it has a higher concentration than if you just add solution.
"Hm. Can't get to 5.2 filling it up with the dropper."
Changes to yellow, dropper, shaker, remove solvent, then Cobalt chloride.
"When I start adding solution, it always puts it to the half liter mark."
"I can only use 1 at a time. Concentration of water is 0, which means it's water."
"You can start with water, then add solution, then evaporate to get solid solute."
Beer's Law Tab
Chooses $KMnO_4$, changes wavelength and looks.
"The spectrum kidn of follows a high, low, dips up…" (describes the trend he's seeing in the numbers)
Says this is understandable because different colors reflect differently with different solutions.
"The chromates are about the same. Differences in them illustrated…"
Compare the chromates at the same wavelength.
Uses ruler to measure container width.
(3:20) "I would guess cutting the diameter in half should reduce the absorbance by half. So if it's 0.07 at 1 cm, double it should be 0.14" (confirms with sim but doesn't seem to notice that it doubled instead of decreasing)
"If there's no concentration, it will be 100% transparent"
"Each solute has different max values of concentration, which affects the %T possibility.
Concentration Tab
Looks at the cobalt II solution, then changes tabs.
Beer's Law Tab
Looks at cobalt II solution. Says he can't tell what the volume of the container is in this tab.
Goes back and forth between tabs a few times.
Says that concentration is in moles/L, and is not sure how to correlate the concentrations in the Beer's Law Tab to the Concentration Tab.
Thinks that the micro symbol means "nano".
Doesn't think that you can reproduce concentration between the two tabs. He seems to be saying this with a comparison in mind. He says "even if I put the concentration all the way up, it's still not as yellow as this one" about K_2CrO_4.
Changes pathlength and looks at beam.
Notices that you can't change the levels of the light beam. (maybe he means intensity?)
Puts the detector at the left most edge of the cuvette and moves is back through the solution, looking at Transmittance.
"Judging… if you probably created a table or a trend with a fixed probably diameter and known solution you could judge the molarity based on the transmittance and the absorbancy of the light."
Says you can use the concentration tab to represent how molarity changes, for 7 compounds and drink mix.
Puts ½ L water, plus ½ L solution and guess the #.
Then evaporates all the water, then adds back in ½ L, says you get double, which makes sense.
Says the only way to adjust solute at the bottom is to remove it all. You can't remove half of it

without adding water.
Flips to Beer's Law tab, then back to Concentration tab.
Looks at the numbers given.
Beaker is at ½ L, then evaporates. Says that using all 6 or 7 compounds and testing molarity could help guess what drink mix is composed of. Compares it to Co(NO3)2.
Says drink mix is soluble. "I don't exactly know how much solute I have."
(3:29)
Compares saturation concentrations.
Thinks drink mix has the highest molarity. Was assuming that it would fall near one of the 7 solutes.
"Based on this I don't think I can identify what's in it."
Compares stock solution concentrations.
"I know potassium is an alkali metal. Nickel is a transition metal, copper transition metal…" names various elements in the solutes and whether they are transition metals or alkali metals.
Says chromium is a transition metal and chloride is just chlorine. Goes through nomenclature.
Puts in ¼ liter of water (counts to the half-way between tick marks)
Shakes in solute and says "one shake is 4 little solutes."
Makes a 0.035 really dilute grey colored drink mix solution.
Beer's Law tab
"If I put everything at full concentration and fixed wavelength…" he sets the nm then returns to fixes radio button. "Transparency is about 1% of drink mix at full molarity. It's more for copper…" compares all solutions %T at full molarity and fixed wavelength.
"When I select different solutions, wavelength doesn't stay fixed like I thought it would. I'm not sure what that means."
(3:34) Compares all solutions at 780 nm (far right of wavelength slider). Compares the %T values.
Thinks it would be hard to decide what Drink Mix is because different colors pass through differently. Says the top three might help you decide, since they are reddish.
Moves the meter through the cuvette.
Concentration Tab:
Says he's "pretty sure copper has a charge… a negative charge. Which means that solution… the charge of the overall solution is based off of molarity."
Adds solution to saturation, then dilutes, then removes solvent.
Put the concentration meter at the ½ L mark. Fills to ½ to see exactly ½. Then fills to 1 L, sees that concentration doesn't exactly cut in half.
Evaporates, then fills to 0.25 using the meter.
I ask for clarification on what he's doing.
(3:40) Says if you put half water L it has a 1.5 molarity for a full 1L.
Says that when it's filled just with water it should be the same… no, higher.
Says it's roughly2 times as much. When you cut the volume in half, molarity is doubled.
Says it's hard to tell exactly where the ¼ mark is on the beaker.
Empties beaker, fills to ½. Says it's difficult to measure exactly how much volume.
Says "saturated means the highest molarity you can get, the highest this compound can be, even if I keep adding solute. Makes sense."

(3:44) Sees and says it makes sense that adding a small amount of water to lots of solid says “saturated” and gives the same concentration.
Beer’s Law Tab:
All solutions I’m given are homogeneous throughout. Eg, moving the light around would be the same.
Concentration Tab:
Except for the solute at the bottom, concentration is homogeneous for all parts of the beaker.
Done at 3:45. Played with the sim for 40 minutes.
Questions:
Q: Clarification on what he meant by “the same” for the chromates earlier in the interview.
A: he meant that they have the same elements, that the chemical formulas look “roughly the same”.
Q: What did you learn, or what could someone learn from this sim?
A: Could understand how molarity is based on how many atoms. Talks about comparing Kool-Aid and the flavor of it when strong or dilute. Could understand evaporation leaves behind the solids. Says he understood before that light passes differently through solutions, but the sim is good for providing facts and numbers. Could speculate before, but this gives numbers.
Q: What did you think was “the point” of the sim?
A: Properties of solutions are affected by light, for example hydrogen peroxide has to be stored in brown bottles because light affects it.
Says the sim would be good for showing this in lecture.
Q: What are all the ways you can change concentration?
A: Add solution to increase molarity, add water to decrease molarity. Could mimic high and low with large and small amounts of solute and water. It’s all about the dilution of solutions with water.
(4:50) Q: What did you think about the variable wavelength control.
A: Didn’t pay attention and though light was staying the same, then realized it was changing. Thinks it roughly gives you the same answer for each solution. Whereas variable shows you how it changes.
Sums up by saying that light passes through different solutions differently.
(5:52) Ran out of time because the room was reserved at 5pm.

Student 4KH
Interview 04-24-2012, 10am
Beer’s Law Lab v.1.00.01

Background info – 4KH
Freshman Integrated Physiology major
College science classes: Bio 1 and 2 at CU, Intro Chem currently.
Highschool / other science classes: Chem, Bio, Physics, and Physical Science.
Prior PhET or sim use: Yes, says she has used a sim to look at molecules and the electron and molecular geometry (Molecule Shapes). No mention of RPAL or sims in lecture (may have interpreted “have you used sims” to mean you personally).

Interview Notes – 4KH
Intro chemistry student.
Played with the sim for 37 minutes.
Start at 9:59 am
Concentration tab
Student clicks on shaker, then drags it and solute comes out.
Clicks on concentration meter probe and drags it into solution.
Says the drain takes water out.
Says you can add water to dilute.
Evaporate water to concentrate it.
Clicks remove solute, fills the beaker to 1 L.
Changes solute. Sees and uses the solution dropper. Lowers volume to ½ L.
Using CoCl2 says out loud "Is there a limit to how much I can add?"
Adds solid, then evaporates. Says "Saturated. Oh! What does that mean?"
Tries to measure the concentration of the solid at the bottom of the beaker.
Removes solute, fills to ½ L with water.
Selects KMnO4.
Says that different substances have different concentrations.
Says "that one got concentrated really fast."
Evaporates all water. Adds just solution.
10:02 Clicks on Beer's Law tab.
Turns on light, then selects variable wavelength.
Says "Transmittance. What does that mean?"
Slides the wavelength slider back and forth.
Says "as the wavelength gets smaller, it transmits less. OK, that makes sense."
Changes pathlength and measures the width with the ruler.
Selects different solutions from the menu.
Says that each solution had a different color that transmits more or less.
Returns to fixed wavelength, changes concentration and changes solutions.
Clicks on Absorbance, selects Drink Mix, and changes the wavelength.
10:08 says "Can transmittance ever be zero?" drags the wavelength slider until the transmittance value is lowest, continues dragging and transmittance starts to go up again.
Says "Not quite."
Says that different solutions transmit differently.
Says that the more solution there is, the less it transmits.
Says the more concentrated it is, the more it absorbs.
Says the color of the light correlates with the solution. The same color absorbs less.
Compares drink mix to other solutions.
Went back to Tab 1 and summarized the relationship between tabs for herself.
Then back to Tab 2 for a little bit.
Tab 1: Says that saturation is the maximum it can concentrate.
Looks at concentration and compares between different solutions.
Then switches to the Beer's Law tab to see if it correlates.
(Student used the word correlate a lot in the interview.)

Mouses over mM units and says “What is this? Moles times molarity? Or is it just molarity?” pauses to think some more, then says “what is that unit. Why isn’t it just molarity?”
Changes between different solutions and comments that the max concentration is different between solutions.
Goes back to Tab 1, says “How do you know how many moles you’re putting into solution?”
Tab 2 Looks at the different solutions and says she thinks that CuSO4 has the lowest max concentration in Tab 2. Asks if maybe it takes less to saturate. Goes to Tab 1 and looks at the saturation concentration of CuSO4 and says it makes sense that CuSO4 has a low max concentration in Tab 2, and that this is justified by the saturation point in Tab 1.
In Tab 2 says that the fixed wavelength is max absorbance. “Oh that makes… OK. So the fixes is…”
Selects each solute down the list. Ends on KMnO4, changes pathlength.
Selects CuSO4, then Co(NO3)2.
Moved the detector probe. “Oh, does that do anything?”
Looks at %T for the system with the probe in front of the cuvette and inside the cuvette.
Says “It’s basically the same concept except moving this around.” (Clarification at 10:38 after student finished play indicates that she meant that changing cuvette size and moving probe through solution had the same effect on transmittance.
Says that hitting “reset” moves the concentration sliders back to 100.
Says that mM could be moles per molarity.
Says (looking at solute list in Tab 2) “so these aren’t necessarily in order of how much they can transmit.”
Looks at Tab 1, then back to Tab 2. Looks at each solution going down the list.
Ends on KMnO4 and sees that it’s concentration range is 0-800. (Does not know or notice micro molar units.) Says “KMnO4 can have a higher concentration. Is it the strongest?”
Goes to Tab 1 and selects KMnO4, “It takes the longest to saturate…” saturates KMnO4 and says “No, I have this backwards.”
Wishes she could go straight to saturated solution instead of having to do it separately for each one.
Compares saturation concentrations for different solutes in Tab 1. “Why does that [Co(NO3)2] take longer than this one [KMnO4]? Why does each solution have a different color? Is it the wavelength, or the color?
Compares wavelength numbers in Tab 2. “They kind of bounce all over the place.”
Tab 2: “Is there an equation that goes along with this, so I’d be able to calculate what the wavelength is, or the Transmittance?”
Says red solution seems like one of the strongest ones. She compares its absorbance values to the absorbance of KMnO4 and says “they are all around the same area.”
10:24 Tab 2, looking at Co(No3)2 “Is this one completely saturated? 400…”
Goes to Tab 1 and saturates Co(NO3)2. “How do I know how many moles are in here?”
Compares saturation concentration in Tab 1 to concentration slider range in Tab 2 and says “I guess that means there’s about 80 moles?” Looks at Tab 2 solution. “I don’t know if this is saturated or not.”
Tab 2 “For zero concentration it’s water, so light passes completely through, it doesn’t matter what wavelength.”

“KMnO4 confuses me most because I feel like it should be the strongest.”
Changes the pathlength with water. Says water doesn’t do anything at all.
Looks closely at KMnO4 in Tab 2. Changes the wavelength, looking at the area around the max absorbance. Moves the probe in solution and asks if it matters where it is. Compares it to changing transmittance with pathlength. Says “It [moving the probe] changes transmittance, but I can just move this [cuvette size control].”
Goes to Tab 1 and asks “What’s in the Drink Mix? Am I supposed to be able to guess that?”
Fills to 1L and looks at the concentration meter. Says “moles per liter”.
10:28 Asks “Did I break it?” The Tab 2 drop down menu won’t open when she clicks the button. JC says “oh, maybe so!” tells her to try a different control and then try it again. Student changes the concentration slider, then clicks the drop down and it opens fine.
Tab 1 “What does saturation mean?” Wants to click on a definition to read about it.
Tab 2 “I would think that if the wavelength was high, it would transmit less, but I guess that depends on the actual solution.”
10:31 “I guess there’s just an equation that calculates that based on… huh.”
‘How would you know which substance would work with which light? Is it color, or do you calculate it based on grams per mole?
Tab 1: Looks at dropper. “What’s the concentration of the solution? Is it saturated?”
Empties the beaker and fills with solution from dropper for 2 different solutions. “That one’s 1. That one’s 4. Why are they different?”
Looks at KMnO4 “Oh, that one’s 0.4. Does that correlate with the max concentration on the other tab?”
Looks at yellow solution on Tab 1 “This is 3.” Then looks on Tab 2 “Here it’s 400.”
Tab 1 “What about the drink mix? 5.5. Is that close to …” Tries the dropper. Compares saturation concentration to the solution concentration in the dropper for several solutions. Wonders if it has anything to do with color, or if it’s the actual substance.
Tab 1: Green and Red have the same concentration in the dropper. Do they have the same saturation? “ tries it and say “No.”
10:36 Goes to Tab 2 and says “what about here?” Compares green and red solutions, Co(No3) 2 and NiCl2. “They are two very different colors.” Compares wavelength absorbance for red and green.
Student says “I’m not sure what else I’m supposed to do”.
Done at 10:36. Played with the sim for 37 minutes
Q & A after play.
Q: What did you think was the point of the sim?
A: To understand concentration and how it works. I’m not sure about saturation. Wavelength and how light goes through each solution, and that each solution has a maximum absorbance. I feel like there is an equation on this. I’m not sure if it’s the color, or something you have to calculate to figure out absorbance and transmittance.
Q: Whad to you think you learned from the sim?
A: I didn’t know what the words meant, like Saturation. I didn’t know different substances transmit more or less to different colors of light. I would have thought wavelengrh size was a factor but I saw in the sim this isn’t the case.
10:41. Tab 1.

Q: What are all the ways you can change concentration?
A: Increase water to dilute, decrease water no change to concentration (points to the drain), evaporating increases concentration. Solution was more dilute than the solid. There were different molarities for each. I'm not sure why.
Q: (JC points to screen) Is there a difference between this (drain) and this (evaporation control)?
A: Yes. There is not change to the solution when you use this (the drain), but evaporation only removes water. You can't do this in lab, it would take too long.
Q: What did you think was the point of having different solutions?
A: TO compare them and see that they each have their own concentration. I don't think it correlates with color. You can compare saturation points, like Potassium Per… I can't pronounce that … anyway, it took less time to saturate. It's stronger.
Tab 2
Q: How did you think this is related to the first tab?
A: Comparing concentrations, what's harder to transmit through. Comparing concentration points to the amount of light transmitted. You can compare concentration with absorbance—how much solution, how concentrated it is, the tybe of light and wavelength. % transmittance is the same concept as absorbance. The more absorbance, the less transmittance The more concentrated, the less transmitted. It's inversely related. If you could graph them, as one goes up, the other goes down.
Q: What do you think the wavelength control could be used for?
A: I don't know why some wavelengths work better, there's not really a pattern to follow between solutions. Each solution has a point where it absorbs more, and wavelength correlates to the actual substance.
Likes: Lots of things to change, lots of opportunities and factors to manipulate.
Dislikes: Wants a "saturate" button.
Confusing: Light and how it correlates to the solutions.
Recommendations: Maybe have the equation so I can see the relationship.

Summary:
Intro Chem Student
Took chem in HS. Says she has used a sim about molecule shapes (PhET), doesn't mention any other sim use.
Played for 37 minutes.
Tab 1
Used and made sense of all the tools.
First action was to click and shake the shaker.
Her second action was to click and drag the concentration probe into solution.
Said the drain "removed water", but said the drain doesn't change concentration where as evaporating water means the solution becomes more concentrated.
Said that evaporation is something you can't do in lab because it takes too long.
Wasn't sure what "saturation" meant.
Compared the saturation concentrations between solutions in Tab 1, and between tabs for individual solutions.
Compared saturation concentration to solution concentration in the dropper for several

solutions.
Noticed that Co(NO3)2 and NiCl2 had the same dropper solution concentration, then did an experiment to see if they had the same saturation concentration.
Said that different solutions have different concentrations, some get concentrated faster.
Wondered if she was supposed to try to figure out what was in the Drink Mix.
Tab 2
Used all the tools and features.
First actions were to turn on the flashlight and select variable wavelength.
Initially said “as wavelength gets smaller, transmittance is less.”
Later said that absorbance and transmittance are “based on the actual substance, not wavelength.”
Said that the fixed wavelength was at maximum absorbance, and that moving the meter through the solution to measure transmittance was “the same concept” as changing the size of the container.
Said Beer’s Law was probably based on an equation that would calculate wavelength or transmittance.
Said if you graphed absorbance and transmittance, one would go up as the other went down because they are inversely related.
Was confused about the concentration units on Tab 2, thought they might be moles per molarity, but wondered why they were not molarity.
Tried comparing concentrations between tabs, but could not figure out the units in Tab 2. Was particularly confused by KMnO4, which has the lowest saturation concentration in Tab 1, but the widest concentration range in Tab 2 (0-800).
Said she liked all the options and controls the sim provided.
Wanted a button to automatically saturate the solution.
Wanted a link to a definition of what saturation meant.
Wanted the sim to show the equation so she could “see the relationship”.

Student 5JH
Interview 04-25-2012, 4pm
Beer’s Law Lab v.1.00.04

Background info – 5JH
Freshman E-Bio major
College science classes: Intro MCDB, Genetics, Marine Bio (abroad), E-Bio 2, Intro Chem currently, Statistics.
Highschool / other science classes: Chem, Bio, Physics, Physical Sci, Statistics.
Prior PhET or sim use: Yes, says he used a PhET sim in lab last week (RPAL). Doesn’t think he’s used any others. Says a lot of his homework is online, also has used videos in the Mastering Biology series, but they are not very interactive.

Interview Notes – 5JH
Intro chemistry student.
Played with the sim for 18 minutes.

Start at 3:57 pm
Tab 1: Concentration
First action: Adds water with the faucet. Removes water with the “hose”.
Clicks on DM, adds some to solution. Evaporates a little.
Says “I’m not sure if I’m supposed to be accomplishing something”.
Changes to Co(NO3)2, lets a little out the drain, adds water.
Clicks on concentration probe and moves the probe around in the space below the meter (does not move into solution).
Says “It seems like it should change as I change solution concentration” while mousing over the meter.
Adds some more solid Co(NO3)2, adds water, drains solution./
Selects dropper, Co(NO3)2 and adds solution.
Selects drink mix, adds solution. Selects CoCl2, switches to shaker, back to dropper, adds solution, then hits “Remove Solute”.
Says that the solution has water mixed in, and the solid doesn’t.
Wants to see if the solution gets darker with more solid added. Tries it by adding solution, then shaking in solid CoCl2 to darken the solution. Says “Yeah.”
Tab2: Beer’s Law
Clicks on Beer’s Law tab after 3 minutes of play.
Says “Yeah, I don’t know what this is.”
Selects Co(NO3)2 from the menu, turns on the light beam.
Predicts that less light will get through when there is more concentration, then tests and confirms his prediction.
Changes wavelength.
Selects the yellow solution, changes wavelength. Says it doesn’t change color.
Selects the red solution, changes wavelength to red. Selects Absorbance and changes the wavelength. Says “Absorbance changes if I change the color.”
Tries to describe absorbance as it relates to wavelength (high and low). Says that low wavelengths have different absorbance than high wavelengths for light colored solutions.
Changes pathlength, describes it as “more thickness”.
Says it is “as if I was making the beaker bigger, and absorbance changes.”
Tries making absorbance zero. Changes concentration to zero (water), then changes container width, no change in absorbance.
Says he can change concentration in micro moles per liter.
Says Beer’s Law might be that wavelength passing through depends on the color of the solution, not on the wavelength.
Selects fixed wavelength. Says it depends on color and concentration; says that concentration is basically the color.
Switches to Tab 1, back to Tab 2, hits Reset.
Says the drink mix option is interesting, maybe it’s for someone who doesn’t understand solutions.
Says he’s only using color, not really what in the solution.
Goes to Tab 1. Says “It doesn’t matter to me what chemical, only that it’s red.”
Adds solid CuSO4.

Moves concentration meter in at 4:05 (9 minutes into play).
Adds more solid $CuSO_4$ to saturation, says he can add up to 1.3 concentration.
Changes solute to $KMnO_4$, says it holds a different amount because it's saturated. Let's some solution out the drain, adds water and says that $KMnO_4$ "absorbs some."
Choses $NiCl_2$. Asks "How much nickel chloride can it hold?" Shakes in solid and passes $KMnO_4$ saturation point, says "More."
$Co(NO_3)_2$ shakes in solid. Says "It can hold a lot." Shakes in solid until solution saturates.
$CoCl_2$, selects dropper. Fills beaker most of the way.
"When I add solution it is changing concentration, but at a slower rate, so I guess there's water in solution. It doesn't become saturated with solution."
Saturates $KMnO_4$ using solid, then adds water so it isn't saturated any more.
Clicks Tab 2.
Changes concentration up and down for $Co(NO_3)_2$ for fixed wavelength.
Says the ruler must be for measuring the solution because it goes up to 2 cm.
Aligns ruler to middle of cuvette. Changes pathlength.
Changes concentration.
Selects $CuSO_4$, then $KMnO_4$ and changes wavelength.
Selects $Co(NO_3)_2$ and changes wavelength.
Says "the transmittance has a bigger range. Wavelegth introduces more variability in how much the solution takes out of the light."
Wonders if there are any solution where pathlength doesn't matter. Goes down the list testing each one by changing pathlength. Says "it always matters."
Clicks Tab 1, then clicks Tab 2.
Moves the detector into solution. Says it seems the same as moving the width of the solution.
Clicks Tab 1, Tab2, Reset. Tab 1, Reset.
Done at 4:14, after 18 min of play.
Questions and Answers
Q: What do you think was the point of this sim?
A: We've been trying to understand concentration in class. The first tab shows the relation in adding solvent, how much solute water can hold, how variables affect concentration.
Q: What are the variables that affect concentration?
A: Amount of solvent, which is water. Amount of solute that you put in. Make up of the solute, like whether it's a solid or solution or different molecules. Evaporation… Student says he knows it would remove water, but not sure how it would affect the solution. Thinks it would concentrate the solution. Tries it with the sim. Says evaporation does show ow only H_2O evaporates, not Drink Mix.
Q: Is there a difference between evaporation and this (JC points to drain)?
A: "Yes, there is a difference. The hose lets out both, the whole solution. Evaporation is only subtracting water. There's no way to remove only the solute. But, there's a magic button for that."
Q: What do you think is the point of having different solutions?
A: There is a different saturation for each. Some have saturation, given the same amount of water. The different colors seemed to help you remember different solutes.
Q: What do you think someone could learn from the sim?

A: That evaporation only removes water, not the solute. For example if you evaporate salt water, the salt stays. Also, a solid will concentrate a solvent faster than a solution. I'm not sure if adding enough solution can saturate. I don't think it can. Someone could learn the variables that affect concentration, and what you can do to increase or decrease concentration.
Q: What do you think was the point of the Beer's Law tab?
A: Show how different colors and concentrations can take out light being shown through. More concentration removes more light. Also how different wavelengths affect it. Variables that affect this are: Concentration. Says that if it was clear, I don't know if it would affect it, but since these are colored they do. JC asks him for an example of a clear solution. He says a clear fluid could be H2SO4, and that the light would shine just as brightly on the other side.
More variables that affect this: Concentration; width of solution, how long the light shines through; wavelength; and Different solutions – as far as I can tell, only color matters.
Q: How do you think the two tabs are related?
A: Tab 1 shows that the more concentrated it is, the darker it is. Tab 2 shows that when it's more concentrated, it takes out light more efficiently. In the second tab you don't make your own solution like you do in the first one though.
Q: What do you think affects Absorbance?
A: Concentration, width. I think wavelength, higher or lower has to do with solution color.
Q: How about Transmittance?
A: It measures how much light comes through. Absorbance gauges how much the solution takes up. I'm not sure what the absorbance units are. It can't be %.
Fixed wavelength helps you isolate variables so you know it's not changing.
Concentration is in "m" moles. I'm not sure what "m" moles per liter is. Some unit of molarity.
Q: If you had to guess what "m"moles means, what would you think?
A: It might be micro, or milli. Some number of moles.
Q: How do the units between the two tabs compare?
A: T2 is a different scale. Says it can't be the same scale as T1 because 160 mol/L is super concentrated.
Q: Which tab do you think is more concentrated?
A: They could be the same.
Q: Do you think the range is the same?
A: Maybe. I don't know. Since you can make the same color, I think the range is similar.
Q: What do you think this (JC points to wavelength control) could be used for?
A: It's part of Beer's Law because wavelength has an affect on Absorbance and Transmittance.
Likes: Tab 1 drain for continued play (you don't have to reset to keep using it), solid and solution to add, evaporation control. Tab 2 was interesting. I think I got the general concept of concentration and absorbance.
Liked the interface, easy to figure out.
Confusing: The dropper button, at first. Thinks it was because it's red like the solution. Says the concentration probe was tricky
Dislike: Wanted to solve a problem, not just play.
Recommendations:
Wants an equation with real numbers. Says in Tab 1 you can't get the concentration exact, but in Tab 2 you can enter numbers so you could use them in an equation.

Says the concentration probe was tricky. Recommends starting the probe in water, or don't have the probe, only the read out (except thinks that might be weird). Thinks starting in solution would be better than no meter.
Confusing: Not sure if the chemicals mattered, or if only the color mattered.
Anything else: Wondered if he was supposed to solve a problem while playing. That was his main question.
Interview over at 4:44pm, 48 minutes total.

Summary:
Intro Chem Student
E-Bio Major, had HS chemistry, used RPAL last week in lab.
Played for 18 minutes.
Tab 1
Added water and removed water using the faucets first.
Said "I'm not sure if I'm supposed to be accomplishing something".
Clicked on concentration probe within the first minute and moved it around in the area below the read out.
Said he thinks the meter should change as he changes solution concentration.
Put probe into solution 9 minutes into play.
Described saturation as "how much it can hold."
Said since solution changes concentration slower than solid, there's water in solution.
When asked, said the drain lets out the whole solution and evaporation removes only water.
Said there isn't a way to remove only solute from a solution, but in the sim "there is the magic button."
When asked the purpose of the different solutions, said that the different colors help you remember different solutes.
When asked what someone could learn from the sim, said that evaporation removes only water.
Gave salt water as an example where evaporation would leave behind the salt.
Recommended the concentration probe start in solution.
Tab 2
Opened the Beer's Law tab and said "Yeah, I don't know what this is."
First action was to select Co(NO3)2, turn on the light.
Predicted that there will be less light with more concentration; tested and confirmed prediction by changing concentration.
Said that "with fixed wavelength it depends on color and concentration, which is basically color."
Said that it doesn't matter what chemical he's using, only that it's red.
Dragged the ruler to the cuvette and said it must be for measuring the container.
Tested changing the pathlength for each solution to see if it affected all of them.
Says moving the detector into the solution seems the same as changing the width.
When asked what affects absorbance, said solution concentration affects it for colored solution.
Said that he thinks for a clear liquid, concentration would not affect absorbance. Gives H2SO4 as an example.
Wasn't sure what "m"moles was. When pressed, said it could be micro or milli.
When asked about comparing concentration between tabs, said the were probably different

scales, since the value on Tab 2 was in the 100s, which would be “super concentrated”.
When asked which was more concentrated, said they could be the same, since the colors are about the same.
Wanted an equation in Tab 2, to use with the numbers in the tab.
Overall
Said that Tab 1 shows how to make concentrated solutions and tab 2 shows how they absorb light.
Liked the interface.
Wanted a problem to solve, not just play.

Website for Concentration Flavor

Main Topics
solution, concentration, molarity, moles, volume, solubility, saturation

Keywords
solute, solvent, solution, concentration, mole, liter, compound, dilution, molarity, moles, volume, solubility, saturation

Categories
new sims, chemistry, general chemistry, high school, university

Credits

- design team
Julia Chamberlain (lead)
Chris Malley (developer)
Kelly Lancaster
Emily Moore
Kathy Perkins

Description
Watch your solution change color as you mix chemicals with water. Then check molarity with the concentration meter. What are all the ways you can change the concentration of your solution? Switch solutes to compare different chemicals and find out how concentrated you can go before you hit saturation!

Learning Goals
- Describe the relationships between volume and amount of solute to solution concentration
- Explain how solution color and concentration are related
- Predict how solution concentration will change for any action (or combination of actions)

that adds or removes water, solute, or solution, and explain why.
- Design a procedure for creating a solution of a given concentration
- Design and justify a procedure for changing a solution from one concentration to another
- Identify when a solution is saturated and predict how concentration will change for any action or combination of actions where water or solute change.

Teacher's Guide and FAQs
(attach when ready)

Related Sims
Salts & Solubility, Molarity

Teaching Ideas
(upload activity when ready)

Sim completion checklist - Concentration

1) Post 1.0 to website (done)
a. Make sure screenshot is ready (done)
b. Make sure credits are correct (done)

2) Add blog entry

3) ADA and other compliance
a. Check for colorblind and other issues (done, ON - ticket #3265) ON to re-test purple & green

4) Accessories
a. Main topics
b. Keywords
c. Categories (put under "New Sims" category and grade levels)
d. Credits (done)
e. Description (done)
f. Learning goals (done)
g. Related sims (done)
h. NSDL Strand maps (ask TL)

5) Teacher's guide
a. Create editable version (Word doc), check in to SVN
b. Upload PDF to website

6) Teaching ideas
a. Put a model lesson on the website

7) Interviews (done)
a. Back up interviews and related files to phetbackup (done)
b. Send notes to group or put in Google doc (done)

8) Design doc
a. Is it up-to-date? If not, should we make it so?
b. Export a snapshot of Google doc in PDF, check in to SVN
c. Scan hand-written items and put in SVN (nothing for design, but for interviews could be something to add to server when it is set up)

9) Model description
a. Developer leads this with team leader

10) Code review (KP says no code review for Concentration; will review for BLL 2/22/12)
a. Hold 3rd party code review
b. Make recommended changes

11) Unfuddle
a. If this is a new project, add an Unfuddle component with the same name as the project

12) Licensing
Sources and compatible licensing has been verified and documented for:
- images
- sounds (n/a)
- source code

13) Assets
For all images, audio, etc. created by PhET, do we have the original files used to create them checked into the projects "assets" folder?

14) Hold postmortem meeting

15) (Optional) Send email to translators if this is a "flavor" of an existing sim.
- send to translators that have translated original flavor
- wait a month and then send a reminder

16) Identify other sims that should be "related to" the new sim, and update their web information.
Molarity
Sugar and Salt Solutions

Website for Beer's Law Lab

Main Topics
solution, concentration, Molarity, Beer's law, light, absorbance, transmittance, concentration, spectrophotometry

Keywords
solute, solvent, solution, concentration, mole, liter, compound, dilution, molarity, moles, volume, solubility, saturation, beer's law, light, absorbance, transmittance, concentration, spectrophotometry, cuvette, photons, wavelength

Categories
new sims, chemistry, general chemistry, high school, university

Credits

- design team
Julia Chamberlain (lead)
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Kelly Lancaster
Emily Moore
Kathy Perkins

- thanks to - (names confirmed - JC)
Jeffrey Bodwin
Molly Larsen

- (somewhere should also say) - No permission from Kraft yet. Omit for now.
Kool-Aid (R) is a registered trademark of Kraft Foods Inc.

Description
"The thicker the glass, the darker the brew, the less the light that passes through." Make colorful concentrated and dilute solutions and explore how much light they absorb and transmit using a virtual spectrophotometer!

Learning Goals
- Describe the relationships between volume and amount of solute to solution concentration
- Explain qualitatively the relationship between solution color and concentration
- Predict and explain how solution concentration will change for adding or removing: water, solute, and/or solution
- Calculate the concentration of solutions in units of molarity (mol/L)
- Design a procedure for creating a solution of a given concentration
- Identify when a solution is saturated and predict how concentration will change for adding or removing: water, solute, and/or solution
- Describe the relationship between the solution concentration and the intensity of light that is absorbed/transmitted
- Describe the relationship between absorbance, molar absorptivity, path length, and concentration in Beer's Law

- Predict how the intensity of light absorbed/transmitted will change with changes in solution type, solution concentration, container width, or light source, and explain why

Teacher's Guide
(attach when ready - JC working on this)

Related Sims
Molarity, Salts & Solubility, Molecules and Light, Sugar and Salt Solutions, Bending Light

Teaching Ideas
(upload activity when ready)

Sim completion checklist - BLL

1) Post 1.0 to website
a. Make sure screenshot is ready (done - CM)
b. Make sure credits are correct (done, JC)

2) Add blog entry

3) ADA and other compliance
a. Check for colorblind and other issues (Ask ON) - JC will confirm with ON.

4) Accessories
a. Main topics
b. Keywords
c. Categories (put under "New Sims" category and grade levels)
d. Credits
e. Description
f. Learning goals
g. Related sims
h. NSDL Strand maps (ask TL)

5) Teacher's guide - JC to do
a. Create editable version (Word doc), check in to SVN
b. Upload PDF to website

6) Teaching ideas - JC to do
a. Put a model lesson on the website

7) Interviews
a. Back up interviews and related files to phetbackup - JC to do
b. Send notes to group or put in Google doc (done - JC)

8) Design doc
a. Is it up-to-date? If not, should we make it so?
b. Export a snapshot of Google doc in PDF, check in to SVN - JC to do

c. Scan hand-written items and put in SVN (nothing for design, but for interviews could be something to add to server when it is set up)

9) Model description - CM to do
a. Developer leads this with team leader

10) Code review (JB doing this)
a. Hold 3rd party code review
b. Make recommended changes

11) Unfuddle - CM done
a. If this is a new project, add an Unfuddle component with the same name as the project

12) Licensing (done, CM)
Sources and compatible licensing has been verified and documented for:
- images
- sounds (n/a)
- source code

13) Assets (done)
For all images, audio, etc. created by PhET, do we have the original files used to create them checked into the projects "assets" folder?

14) Hold postmortem meeting - JC to schedule

15) (Optional) Send email to translators if this is a "flavor" of an existing sim. - Ask ON
- send to translators that have translated original flavor
- wait a month and then send a reminder

16) Identify other sims that should be "related to" the new sim, and update their web information.
Molarity
Sugar and Salt Solutions
Molecules and Light
Salts and Solubility
Bending Light